WELDING SERVICES, INC.

WELDING PROCEDURE NO.
WPS — A03174-N432
REVISION 1

WELDING CODE: ASME B & PV SECTION IX

WELDING PROCEDURE SPECIFICATION

SUPPORTING PQR(S): A03N432

WELDING PROCESS(ES) 1. Gas Tungsten Arc Welding TYPE Automatic (Machine)
2. Code case N 432 TYPE Temper Bead

BASE METALS (QW—403)
P No. 3 Gr. No. 3 to P No. 3 Gr. No. 3
Thichness Range Maximum 3" IN.
Pipe Dia. Range none IN.
Range for Fillet. Thk. none Dia. none IN.
Max Deposited thickness 3"

POSTWELD HEAT TREATMENT (QW—407)
Type Electrical Resistance
Temperature 450°F to 550°F °F
Time Range 2 hours

FILLER METALS (QW—404)
F No. 1. 6 2. N/A
A No. 1. See Chemical Analysis N/A
SFA Spec. No. 1. 5.28 2. N/A
AWS Class. No. 1. ER80S-D2 2. N/A
Size of Electrode 1. N/A 2. N/A IN.
Size of Filler 1. .035" 2. N/A IN.
Electrode — Flux Class none
Consumable insert none
Pass thickness less than 0.50"

GAS (QW—408)
Shielding Gas 1. Argon
Percent Comp. 99.995%
Shielding Gas Flow Rate 40 to 50 CFH (min.)
Purge Gas none Flow Rate none CFH (min.)
Trailing Shielding Gas Composition none

ELECTRICAL CHARACTERISTICS (QW—409)
Current 1. DCEN 2. N/A
Amps Range 1. * 2. N/A
Volts Range 1. * 2. N/A
Tungsten Elec. Size/Type .125" EWTH 2%

POSITION (QW—405)
Welding Position 2G
Welding Progression Horizontal; See parameter sheets.

PREHEAT (QW—406)
Preheat Temp. 300°F °F (Min.)
Interpass - Temp. Range 450°F Max °F
Preheat Maint. 300°F Min; Preheat 30 minutes prior to start welding.

JOINT DESIGN (QE—402)
Groove Design Weld Repair Code Case N432
Joint Type OB none CI none BS none
Backing Matl Type none

TECHNIQUE (QW—410)
Stringer or Weave Bead 1. Stringer 2. N/A
Bead Width See Page 2
Orifice or Gas Cup Size #4 (.250") IN. (min.)
Initial and interpass cleaning: Welding surfaces shall be wire brushed or ground as required to remove slag, scale or other contaminants.
Method of back gouging none
Oscillation 1. Not allowed 2. N/A IN. (max.)
Contact Tube to work distance N/A IN.
Mutiple or Single Layer 1. Multiple Layer
(Per Side) 2. N/A
Multiple or single electrodes Single
Travel Speed (Range) 1. * 2. N/A IPM

REMARKS

* Parameters are restricted for layers 1 thru 6, see attachments QW-409 and QW-410, for each layer parameters. Range is given for all layers beyond the sixth.

8911220164 891117
PDR ADOCK 05000247
Q PDR

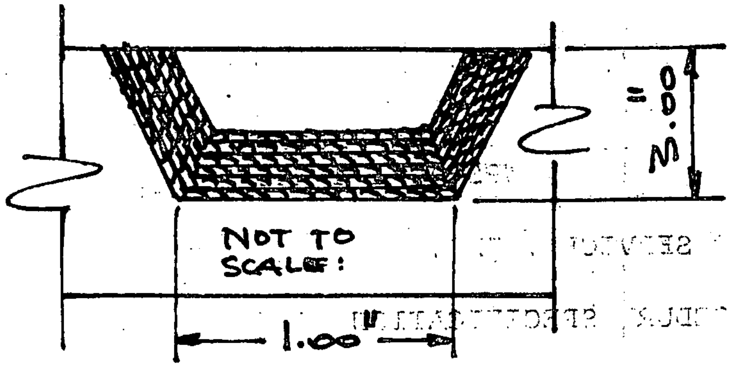
PREPARATION APPROVAL	DATE
[signature] Welding Engineering	6/22/89
Materials Engineering	
[signature] Quality Assurance	6-22-89

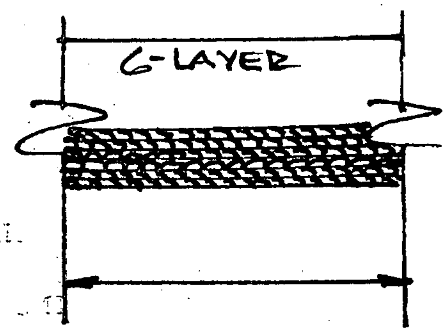
Fab. Codes: ASME B&PV Codes 1981 Edition, Sections III & IX
Project: Indian Point II - Con Edison
Job No.

WELDING TECHNIQUE SHEET		WELDING PROCEDURE NO.
P NO. 3 GROUP 3 TO P NO. 3 GROUP 3 THK. RANGE Maximum 3" IN.		WPS - A03174-N432 REVISION 1 PAGE 2 OF 2

TYPICAL JOINT DESIGNS PERMITTED Plate Dimensions 12"x30", 7 1/4" thick.

ROOT OPENINGS O.B. ______ IN.
B.S. ______ IN.





WELDING PARAMETERS *SINGLE VALUES ARE MINIMUM

LAYER	WELDING PROCESS	FILLER METAL SIZE (IN.)	FILLER METAL AWS CLASS	GAS TYPE	GAS FLOW RATE (CFH) SHIELD	GAS FLOW RATE (CFH) PURGE	ELECTRICAL DATA TYPE/ POLAR.	ELECTRICAL DATA AMPERAGE RANGE	ELECTRICAL DATA VOLTS RANGE	TRAVEL SPEED (IPM)	MAX. BEAD WIDTH (IN.)
1	GTAW	.035	ER80S-D2	Argon	30 to	none	DCEN	P180 B220	P9.7 B8.9	3.2	.375"
2	GTAW	.035	ER80S-D2	Argon	50	none	DCEN	P194 B125	P9.6 B9.1	3.2	↓
3	GTAW	↓	↓	↓	↓	↓	↓	P200 B130	P9.8 B9.2	3.2	↓
4 to 6	GTAW	↓	↓	↓	↓	↓	↓	P220 B140	P9.9 B9.4	3.4	↓
7 to		↓	↓	↓	↓	↓	↓	85 to 250		2.7-5.0	↓

PREHEAT TEMP. 300 °F (Min.)
INTERPASS TEMP. 450 Max °F
PREHEAT MAINT. 300° 30 min. prior to welding
TUNGSTEN ELECT. SIZE & TYPE .125" IN.
EWTh 2%

Bead overlap 40-60%
BACK GOUGING METHOD none
CONTACT TUBE TO WORK DIST. N/A IN. (min.)
ORIFICE OR CUP SIZE #4 (.250") IN. (min.)
WELDING PROGRESSION See technique sheets
Wire Feed See technique sheets

INSTRUCTIONS

1. Preheat to 300°F 30 minutes prior to start of welding, 10" around area to be welded.
2. Thermocouples and recording instruments shall be used to monitor preheat, interpass and post weld heat treatment procedures.
3. No oscillation is to be used on layers 1 through 6.
4. Peening is not permitted.
5. Parameters for layers 1 through 6 as stated in QW409 and QW410 shall be strictly adhered to.
6. Weld heat input for layers 1 through 6 shall be ±10% of QW409 and QW410.
7. Travel speed shall be measured at the work surface.
8. Welding power supply shall be Gold Track II or equivalent.
9. When welding is done remotely, optics for weld puddle shall begin working order.
10. After welding, no non-destructive examination shall be performed for 48 hours.
11. The finished surface of the repair shall be substantially flush with the surface of the component surrounding the repair.

Welding Procedure No.
WPS-A03174-N432

WELDING SERVICES, INC.

WELDING PROCEDURE SPECIFICATION

SPECIAL INSTRUCTIONS

Welding of the repair area shall be in accordance with the following instructions and guidelines:

1. The area to be repaired by welding, and a band around the area, shall be preheated to 300 degrees F minimum. This temperature shall be maintained for at least 30 minutes before welding is started, during welding, and until starting the postweld heating as described below.

2. The width of the preheat band shall be at least three times the thickness of the component to be welded and as needed to accommodate thermocouple attachment and insulation application, but need not exceed ten (10) inches.

3. The interpass temperature shall not exceed 450 degrees F.

4. Thermocouples and recording instruments shall be used to monitor preheat, interpass, and postheat temperatures. Thermocouples may be attached by mechanical methods or capacitor discharge.

5. The first six (6) layers of weld deposit shall be applied as shown on the attached sketches.

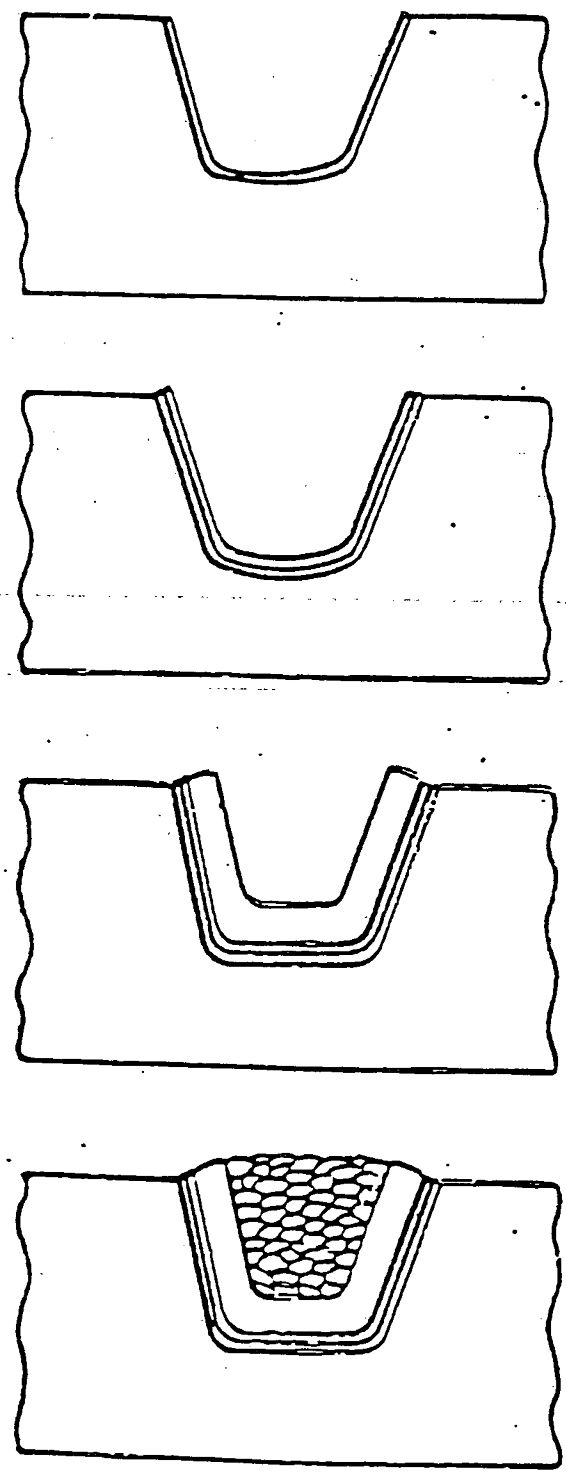
6. The weld heat input for each of the first six (6) layers shall be controlled to within +/- 10% of that used in the procedure qualification test.

7. The remainder of the weld deposit shall be completed with the heat input equal to or less than that used for layers beyond the sixth in procedure qualification.

8. At the completion of welding, the heated band described in #1 and #2 above, shall be maintained in the range of 500 degrees F +/- 50 degrees for two (2) hours minimum.

WELDING SERVICES, INC.
WELDING PROCEDURE SPECIFICATION

Welding Procedure No. WPS-A03174-N432



STEP 1: Deposit layer one with first layer weld parameters used in qualifications.

STEP 2: Deposit layer two with second layer weld parameters used in qualifications.

STEP 3: Deposit next four layers with layer three through six weld parameters used in qualifications.

STEP 4: Subsequent layers to be deposited as qualified.

AUTOMATIC OR MACHINE (GTAW) TEMPERBEAD TECHNIQUE

Temper Bead GTAW
Ref. Code Case N-432

Attachment 1

Electrical Charecteristics (QW-409)

Layer 1

Current: DCEN

Pulsing Current

Low Pulse Frequency 2.0

Low Pulse Width 66

Machine Mode Pulse Arc

Amperage:	Primary 180	Wire Feed: Primary	35
	Background 120	Background	30
Voltage	Primary 9.7		
	Background 8.9		
Tungsten	Size .125"		
	Type EWTh 2%		

Technique (QW-410)

Layer 1

Stringer Beads Only

Gas Cup Size #4 (.250") Min.

Multiple Layer

Single Electrode

Travel Speed 3.2 IPM

HEAT INPUT SHALL NOT EXCEED ± 10% OF THE ABOVE PARAMETERS

Temper Bead GTAW
Ref. Code Case N-432

Attachment 2

Electrical Charecteristics (QW-409)

Layer 2

Current: DCEN

Pulsing Current

Low Pulse Frequency 2.0

Low Pulse Width 66

Machine Mode Pulse Arc

Amperage: Primary 194

Background 125

Wire Feed: Primary 40

Background 30

Voltage Primary 9.6

Background 9.1

Tungsten Size .125"

Type EWTh 2%

Technique (QW-410)

Layer 2

Stringer Beads Only

Gas Cup Size #4 (.250") Min.

Multiple Layer

Single Electrode

Travel Speed 3.2 IPM

HEAT INPUT SHALL NOT EXCEED ± 10% OF THE ABOVE PARAMETERS

Temper Bead GTAW
Ref. Code Case N-432

Attachment 3

Electrical Charecteristics (QW-409)

Layer 3

Current: DCEN

Pulsing Current

Low Pulse Frequency 2.0

Low Pulse Width 66

Machine Mode Pulse Arc

Amperage: Primary 200 Wire Feed: Primary 50

Background 130 Background 40

Voltage Primary 9.8

Background 9.2

Tungsten Size .125"

Type EWTh 2%

Technique (QW-410)

Layer 3

Stringer Beads Only

Gas Cup Size #4 (.250") Min.

Multiple Layer

Single Electrode

Travel Speed 3.2 IPM

HEAT INPUT SHALL NOT EXCEED ± 10% OF THE ABOVE PARAMETERS

Temper Bead GTAW
Ref. Code Case N-432

Attachment 4

Electrical Charecteristics (QW-409)

Layer 4 thru 6

Current: DCEN

Pulsing Current

Low Pulse Frequency 2.0

Low Pulse Width 66

Machine Mode Pulse Arc

Amperage:

Primary 220

Background 140

Wire Feed: Primary 60

Background 50

Voltage

Primary 220

Background 140

Tungsten

Size .125"

Type EWTh 2%

Technique (QW-410)

Layer 4 thru 6

Stringer Beads Only

Gas Cup Size #4 (.250") Min.

Multiple Layer

Single Electrode

Travel Speed 3.4 IPM

HEAT INPUT SHALL NOT EXCEED ± 10% OF THE ABOVE PARAMETERS

Temper Bead GTAW
Ref. Code Case N-432

Attachment 5

Electrical Charecteristics (QW-409)

Layer 7 thru Remainder

Current: DCEN

Pulsing Current

Low Pulse Frequency 2.3 to 2.6

Low Pulse Width 50 to 60

Machine Mode Pulse Arc

Amperage:

Primary 200 to 260

Background 130 to 170

Wire Feed: Primary 10-90

Background 10-90

Voltage

Primary 9.0-11.5

Background 8.7-11.0

Tungsten

Size .125"

Type EWTh 2%

Technique (QW-410)

Layer ______

Stringer Beads Only

Gas Cup Size #4 (.250") Min.

Multiple Layer

Single Electrode

Travel Speed 2.7-5.0

HEAT INPUT SHALL NOT EXCEED ± 10% OF THE ABOVE PARAMETERS

A

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORD (PQR)

(See QW-201.2, Section IX, ASME Boiler and Pressure Vessel Code)

Record Actual Conditions Used to Weld Test Coupon.

Company Name: Welding Services Inc.

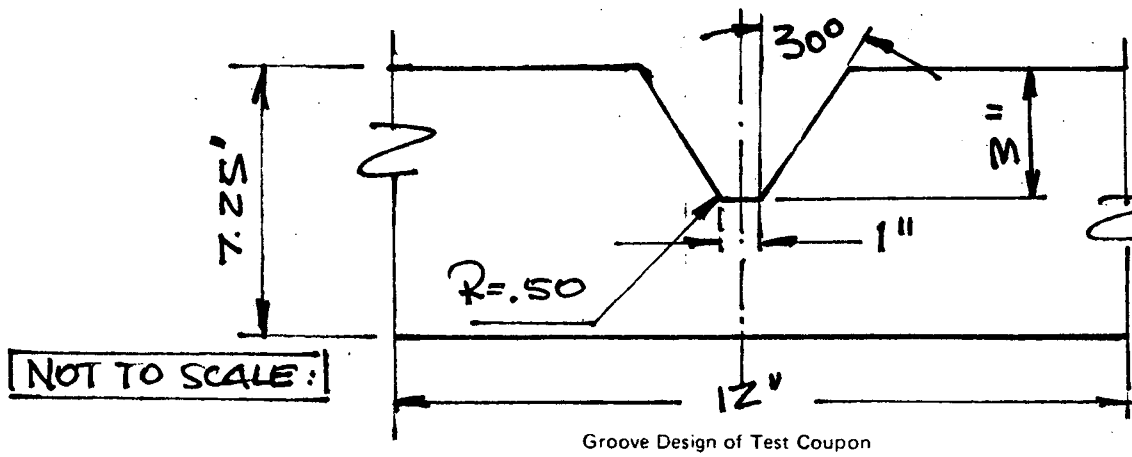
Procedure Qualification Record No.: A03N432 Revision 1 Date: 6-22-89

WPS No.: A03174-N432

Welding Process(es): Gas Tungesten Arc Welding

Types (Manual, Automatic, Semi-Auto.): Automatic (Machine)

JOINTS (QW-402)



Groove Design of Test Coupon

(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal or process weld.)

BASE METALS (QW-403)

Material Spec.: SA 302

Type or Grade: B

P-No.: 3 to P.No.: 3

Thickness of Test Coupon: 7.25"

Diameter of Test Coupon: none

Other:

POSTWELD HEAT TREATMENT (QW-407)

Temperature: 500°F

Time: 2 Hours

Other: Cool to ambient temperature for 48 hours prior to any testing.

GAS (QW-408)

Type of Gas or Gases: Argon

Composition of Gas Mixture: 99.995%

Other:

FILLER METALS (QW-404)

Weld Metal Analysis A-No.: See Chemical Anyalsis

Size of Filler Metal: .035" Dia

Filler Metal F-No.: 6

SFA Specification: 5.28

AWS Classification: ER80S-D2

Other: Max Deposited thickness 3"

ELECTRICAL CHARACTERISTICS (QW-409)

Current: Direct

Polarity: Straight

Amps.: * Volts: *

Tungsten Electrode Size: .125"

Other: * See Attachments for QW409 Parameters are restricted for layers 1 through 6.

POSITION (QW-405)

Position of Groove: 2G

Weld Progression (Uphill, Downhill): Horizontal

Other: Weld bead placement is restricted for layers 1 thru6. See attachments

TECHNIQUE (QW-410)

Travel Speed: *

String or Weave Bead: Stringer

Oscillation: Not allowed

Multipass or Single Pass (per side): Multipass

Single or Multiple Electrodes: Single Electrode

Other: * See attachments for QW-410 Parameters are restricted for layers 1 thru 6

PREHEAT (QW-406)

Preheat Temp.: 300°F 30 minutes prior to welding

Interpass Temp.: 450°F max

Other: Temperatures to be monitored by a strip chart recorder.

NOTE: This PQR was revised for editorial reasons.

QW-483 (Back)

A03 N432
PQR No. Rev 1

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load lb.	Ultimate Unit Stress psi	Type of Failure & Location
2M	0.2477	–	0.0482	4530	94000	BMD
3B	0.2510	–	0.0491	4780	97500	BMD
5M	0.2488	–	0.0486	4770	98000	BMD
6B	0.2496	–	0.0489	4800	98000	BMD

Guided Bend Tests (QW-160)

Type and Figure No.	Result
Side Bend QW462.2 (8)	Acceptable

Toughness Tests (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 ATTACHMENT A --						

Fillet Weld Test (QW-180)

Result — Satisfactory: Yes ______ No ______ Penetration into Parent Metal: Yes ______ No ______

Macro—Results ______

Other Tests

Type of Test MT, UT, RT - Acceptable

Deposit Analysis ______

Other ______

Welder's Name K. Bubash/R.D. Stillwell S. Harmon Clock No. ______ Stamp No. KJE-7575 JDS-8311/SCH-6517

Tests conducted by: APPLIED TECHNICAL SERVICES Laboratory Test No. AO-0394&HO 0516

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

Manufacturer WELDING SERVICES INC.

Date 6-22-89 By [signature]

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)

(6/82)

ATTACHMENT A

PQR No. A03N432

Toughness Tests

~~(QW-170)~~

Drop Weight Tests

	Base Metal	
ASTM E208 Specimens	Type P3 Specimens -40 degrees F: Break	Weld Metal Specimens -10 degrees F: No Break
	-10 degrees F: Break	-10 degrees F: No break
	+20 Degrees F: Break	
	+30 degrees F: Break	Nil Ductility
	+40 degrees F: No Break	Temperature = -20 degrees F
	+40 degrees F: No Break	
	Nil Ductility Temperature = +30 degrees F	

CV Tests

Weld Metal

3	1: 63 ft-lb 63 mils lat. exp. 40% shear	Tcv: 40 degrees F
	2: 105 ft-lb 69 mils lat exp. 70% shear	RT NDT = Tcv -60 degrees F
	3: 80 ft-lb 62 mils lat. exp. 60% shear	RT NDT: -20 degrees F

ATTACHMENT A
PQR No. A03N432
Toughness Tests
(QW-170)

Heat Affected Zone 3	1: 46 ft-lb 39 mils lat. exp. 20% shear	Tcv = 90 degrees F T NDT = 30 degrees F (base metal-drop test)
	2: 51 ft-lb 46 mils lat. exp. 20% shear	29 mils lateral expansion and 28 ft-lb. average for base metal at T vc = 90 degrees F
	3. 35 ft-lb 32 mils lat. exp. 20% shear	
Base Metal 3	C1:27 ft-lb 28 mils lat. exp. 10% shear	Tcv: 90 degrees F
	C2:31 ft-lb 28 mils lat. exp. 10% shear	T NDT: 30 degrees F
	C3:39 ft-lb 37 mils lat. exp. 10% shear	

ATTACHMENT A
PQR No. A03N432
Toughness Tests
(QW-170)

Base Metal
3

D1:39 ft-lb
36 mils lat. exp.
20% shear

Tcv: 120 degrees F

D2:27 ft-lb
27 mils lat. exp.
30% shear

D3:34 ft-lb
34 mils lat. exp.
30% shear

Heat Affected Zone
3

1: 61 ft-lb
45 mils lat. exp.
50% shear

Tcv = 120 degrees F

2: 52 ft-lb
47 mils lat exp.
50% shear

3: 49 ft-lb
45 mils lat. exp.
50% shear

Temper Bead GTAW
Ref. Code Case N-432

Attachment 1

Electrical Charecteristics (QW-409)

Layer 1

Current: DCEN

Pulsing Current

Low Pulse Frequency 2.0

Low Pulse Width 66

Machine Mode Pulse Arc

Amperage:

Primary 180

Background 120

Voltage

Primary 9.7

Background 8.9

Tungsten

Size .125"

Type EWTh 2%

Technique (QW-410)

Layer 1

Stringer Beads Only

Gas Cup Size #4 (.250") Min.

Multiple Layer

Single Electrode

Travel Speed 3.2 IPM

HEAT INPUT SHALL NOT EXCEED ± 10% OF THE ABOVE PARAMETERS

Temper Bead GTAW
Ref. Code Case N-432

Attachment 2

Electrical Charecteristics (QW-409)

Layer 2

Current: DCEN

Pulsing Current

Low Pulse Frequency 2.0

Low Pulse Width 66

Machine Mode Pulse Arc

Amperage:

Primary 194

Background 125

Voltage

Primary 9.6

Background 9.1

Tungsten

Size .125"

Type EWTh 2%

Technique (QW-410)

Layer 2

Stringer Beads Only

Gas Cup Size #4 (.250") Min.

Multiple Layer

Single Electrode

Travel Speed 3.2 IPM

HEAT INPUT SHALL NOT EXCEED ± 10% OF THE ABOVE PARAMETERS

Temper Bead GTAW
Ref. Code Case N-432

Attachment 3

Electrical Charecteristics (QW-409)

Layer 3

Current: DCEN

Pulsing Current

Low Pulse Frequency 2.0

Low Pulse Width 66

Machine Mode Pulse Arc

Amperage:

Primary 200

Background 130

Voltage

Primary 9.8

Background 9.2

Tungsten

Size .125"

Type EWTh 2%

Technique (QW-410)

Layer 3

Stringer Beads Only

Gas Cup Size #4 (.250") Min.

Multiple Layer

Single Electrode

Travel Speed 3.2 IPM

HEAT INPUT SHALL NOT EXCEED ± 10% OF THE ABOVE PARAMETERS

Temper Bead GTAW
Ref. Code Case N-432

Attachment 4

Electrical Charecteristics (QW-409)

Layer 4 thru 6

Current: DCEN

Pulsing Current

Low Pulse Frequency 2.0

Low Pulse Width 66

Machine Mode Pulse Arc

Amperage:

Primary 220

Background 140

Voltage

Primary 220

Background 140

Tungsten

Size .125"

Type EWTh 2%

Technique (QW-410)

Layer 4 thru 6

Stringer Beads Only

Gas Cup Size #4 (.250") Min.

Multiple Layer

Single Electrode

Travel Speed 3.4 IPM

HEAT INPUT SHALL NOT EXCEED ± 10% OF THE ABOVE PARAMETERS

Temper Bead GTAW
Ref. Code Case N-432

Attachment 5

Electrical Charecteristics (QW-409)

Layer 7 thru Remainder

Current: DCEN — Pulsing Current

Low Pulse Frequency 2.3 to 2.6

Low Pulse Width 50 to 60

Machine Mode Pulse Arc

Amperage: Primary 200 to 260

Background 130 to 170

Voltage Primary ____

Background ____

Tungsten Size .125"

Type EWTh 2%

Technique (QW-410)

Layer ____

Stringer Beads Only

Gas Cup Size #4 (.250") Min.

Multiple Layer

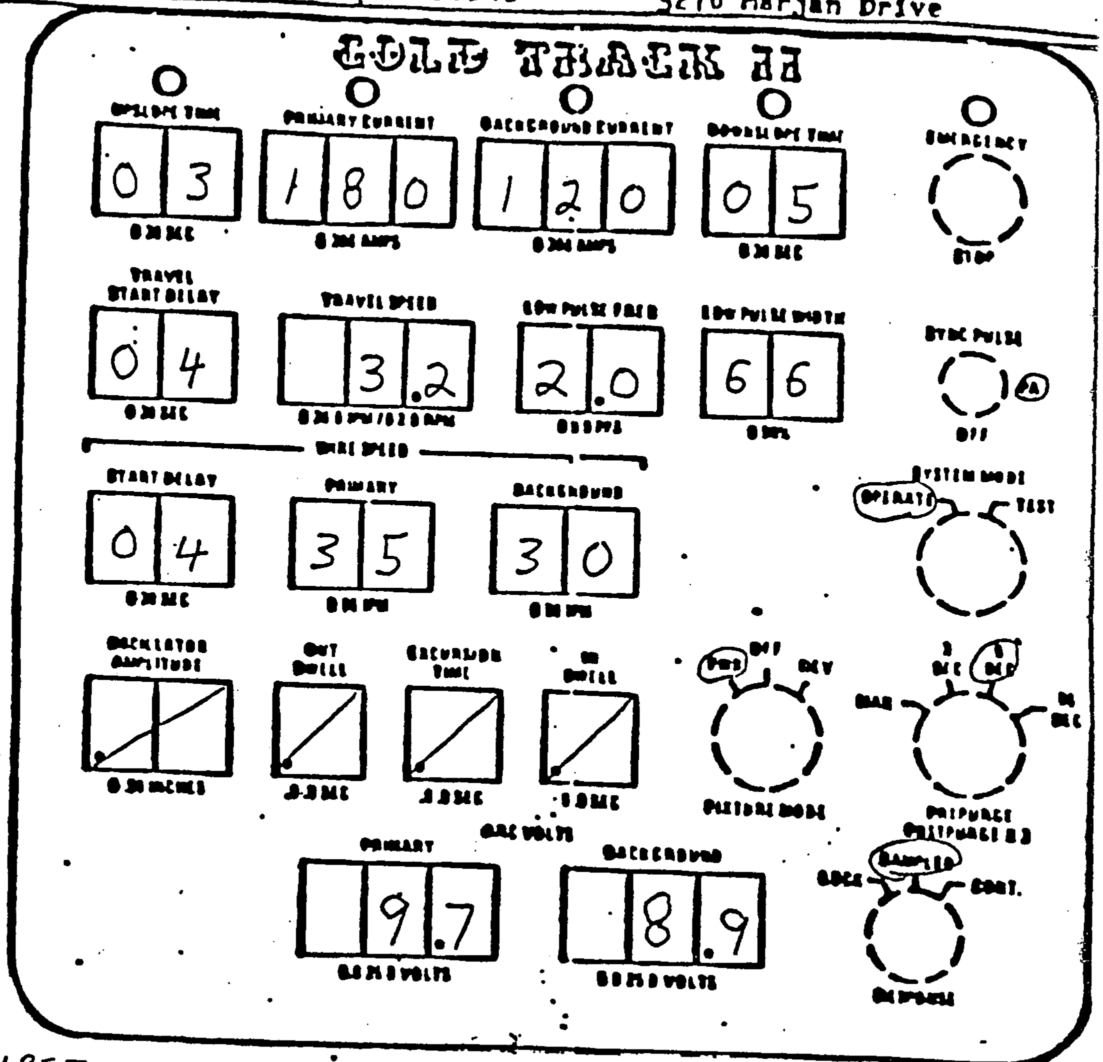
Single Electrode

Travel Speed ____

HEAT INPUT SHALL NOT EXCEED ± 10% OF THE ABOVE PARAMETERS

Specializing in Automated Welding

TELEPHONE (404) 432-0003 ATLANTA, GEORGIA 30340 3276 Marjan Drive



WELDING CODE ______

MATERIAL
SA302 GrB

DIA. & WALL THICKNESS ______

PREHEAT 300 F°

INTERPASS 450 F°

POSITION FIXED Horz.

FILLER MATERIAL
TYPE ER80SD2 SIZE .035

DIRECTION OF TRAVEL Horz. INLINE
CW CCW DBL-UP

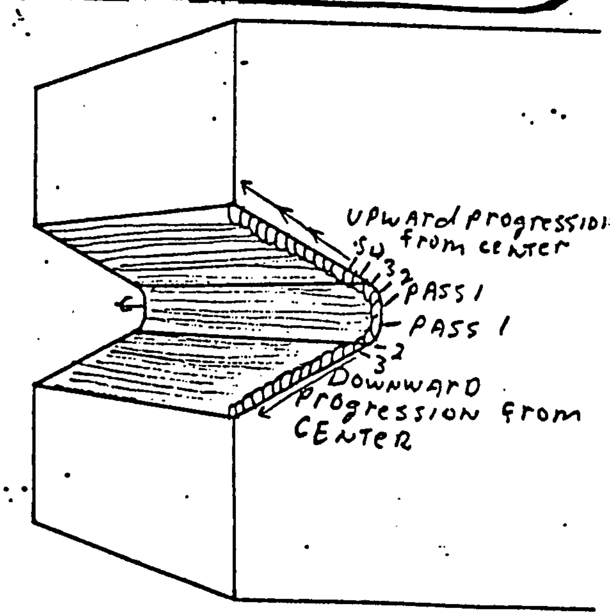
TYPE OF FRONT END
REMOTE

LENS NO. 5

CUP NO. 10

TUNGSTEN SIZE 1/8

FIRST LAYER -O- OSC.
65° BEAD OVERLAP
PROGRESS DOWNWARD + UPWARD FROM CENTER



COMMENTS:

Specializing in Automated Welding

TELEPHONE (404) 452-0005 ATLANTA, GEORGIA 30340 3276 Marjan Drive

WELDING CODE ____________

MATERIAL SA302 GrB

DIA. & WALL THICKNESS ____________

PREHEAT 300 F°

INTERPASS 450 F°

POSITION FIXED Horz.

FILLER MATERIAL
TYPE ER80S02 SIZE .035

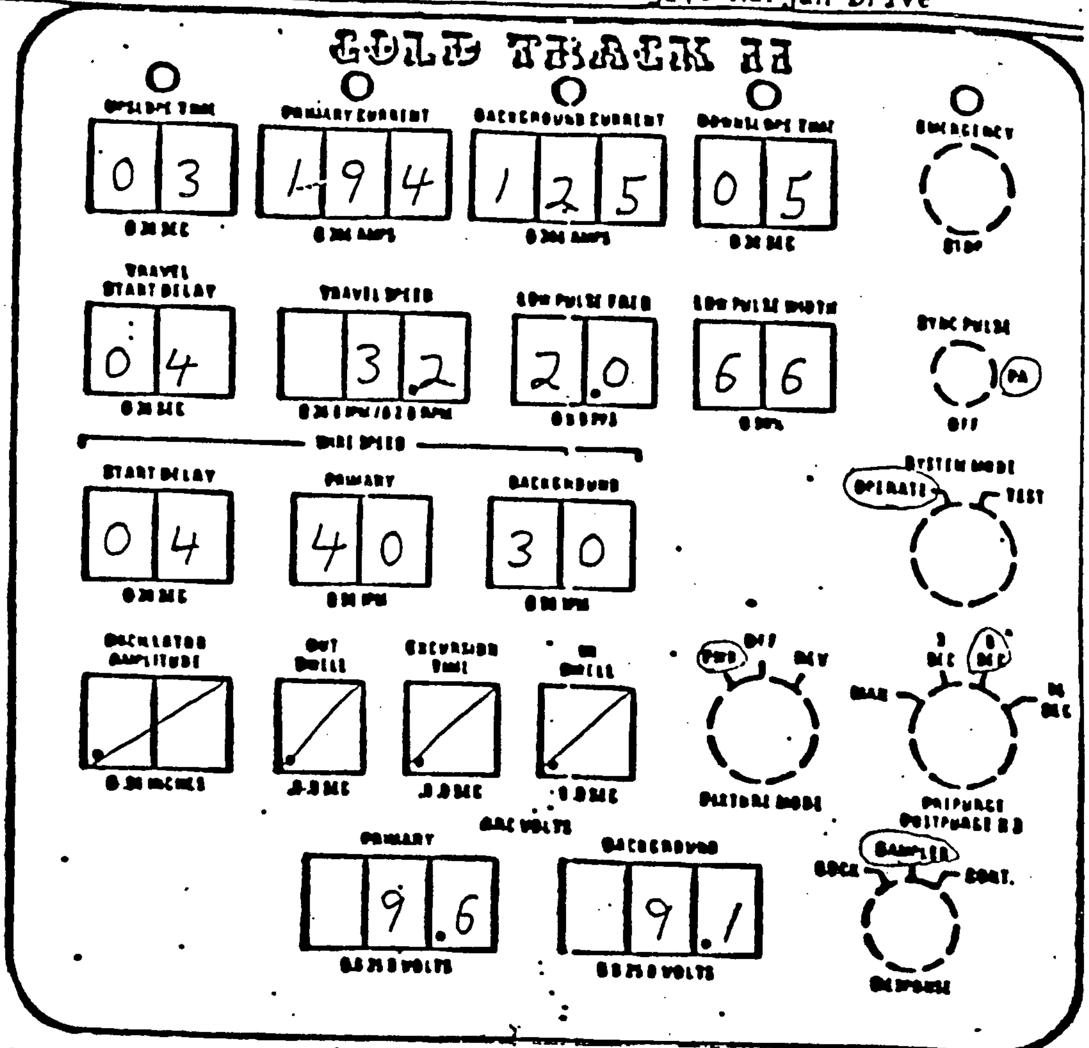
DIRECTION OF TRAVEL Horz. INLINE
CW CCW DBL-UP

TYPE OF FRONT END REMOTE

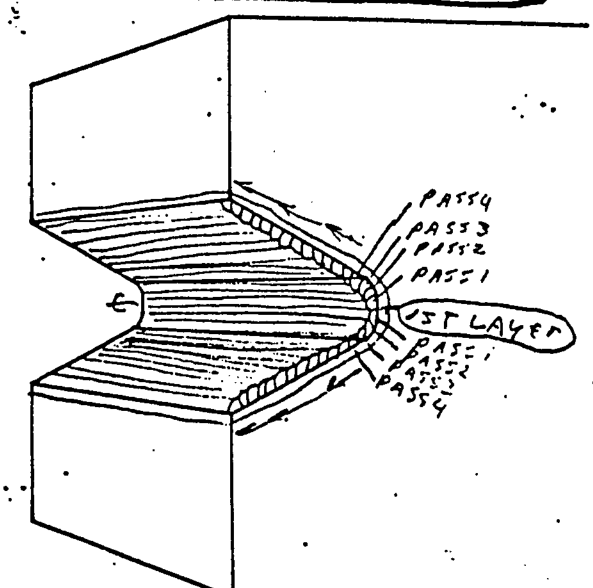
LENS NO. 5

CUP NO. 10

TUNGSTEN SIZE 1/8

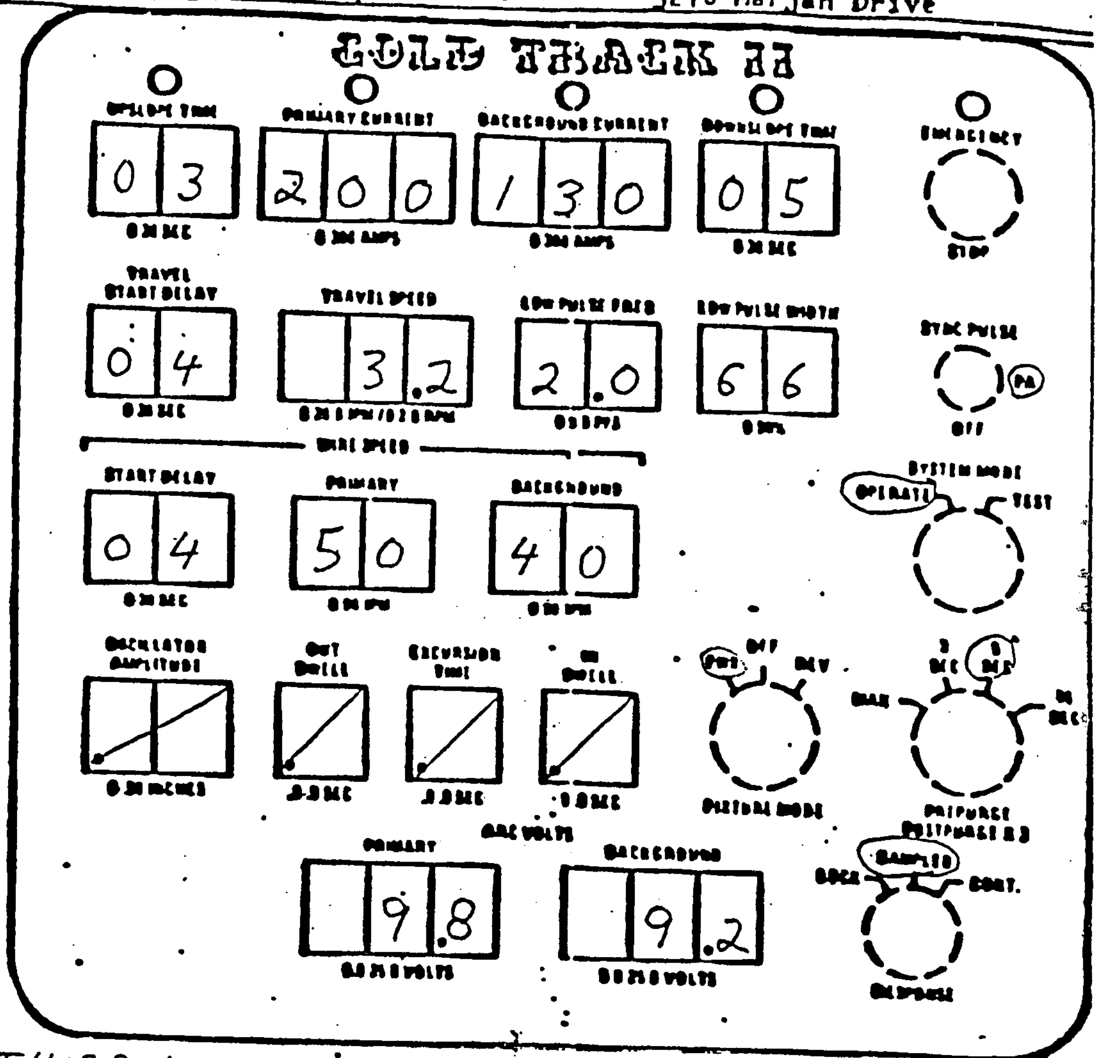


SECOND LAYER
65° BEAD OVERLAP
Progression Downward from CENTER
Upward from CENTER



COMMENTS:

Specializing in Automated Welding
TELEPHONE (404) 452-0005 ATLANTA, GEORGIA 30340 3276 Marjan Drive



WELDING CODE ____

MATERIAL
SA302 Gr B

DIA. & WALL THICKNESS ____

PREHEAT 300 F°

INTERPASS 450 F°

POSITION FIXED HORZ.

FILLER MATERIAL

TYPE ER80SD2 SIZE .035

DIRECTION OF TRAVEL HORZ. INLINE

CW CCW DBL-UP

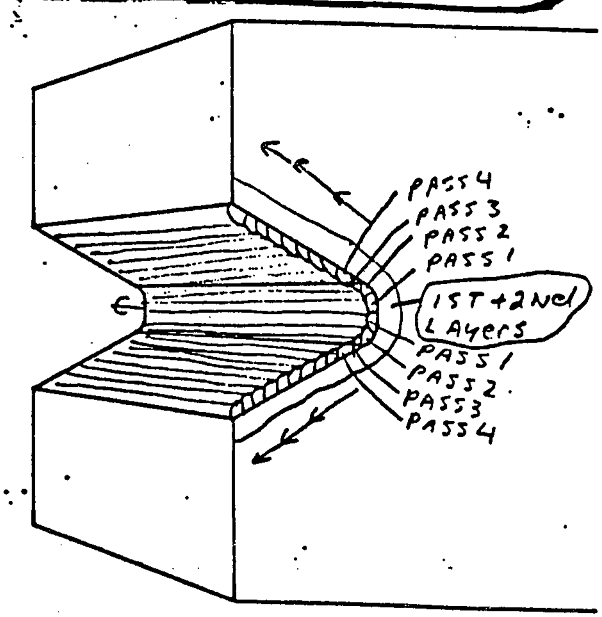
TYPE OF FRONT END REMOTE

LENS NO. 5

CUP NO. 10

TUNGSTEN SIZE 1/8

THIRD LAYER
65° BEAD OVERLAP
PROGRESSION DOWNWARD
From CENTER + UPWARD
From CENTER



COMMENTS:

Specializing in Automated Welding

TELEPHONE (404) 432-0005

ATLANTA, GEORGIA 30340 3276 Marjan Drive

WELDING CODE ____________

MATERIAL
SA302 Gr B

DIA. & WALL THICKNESS ____________

PREHEAT 300 F°

INTERPASS 450 F°

POSITION FIXED Horz

FILLER MATERIAL

TYPE ER80S02 SIZE .035

DIRECTION OF TRAVEL Horz INLINE

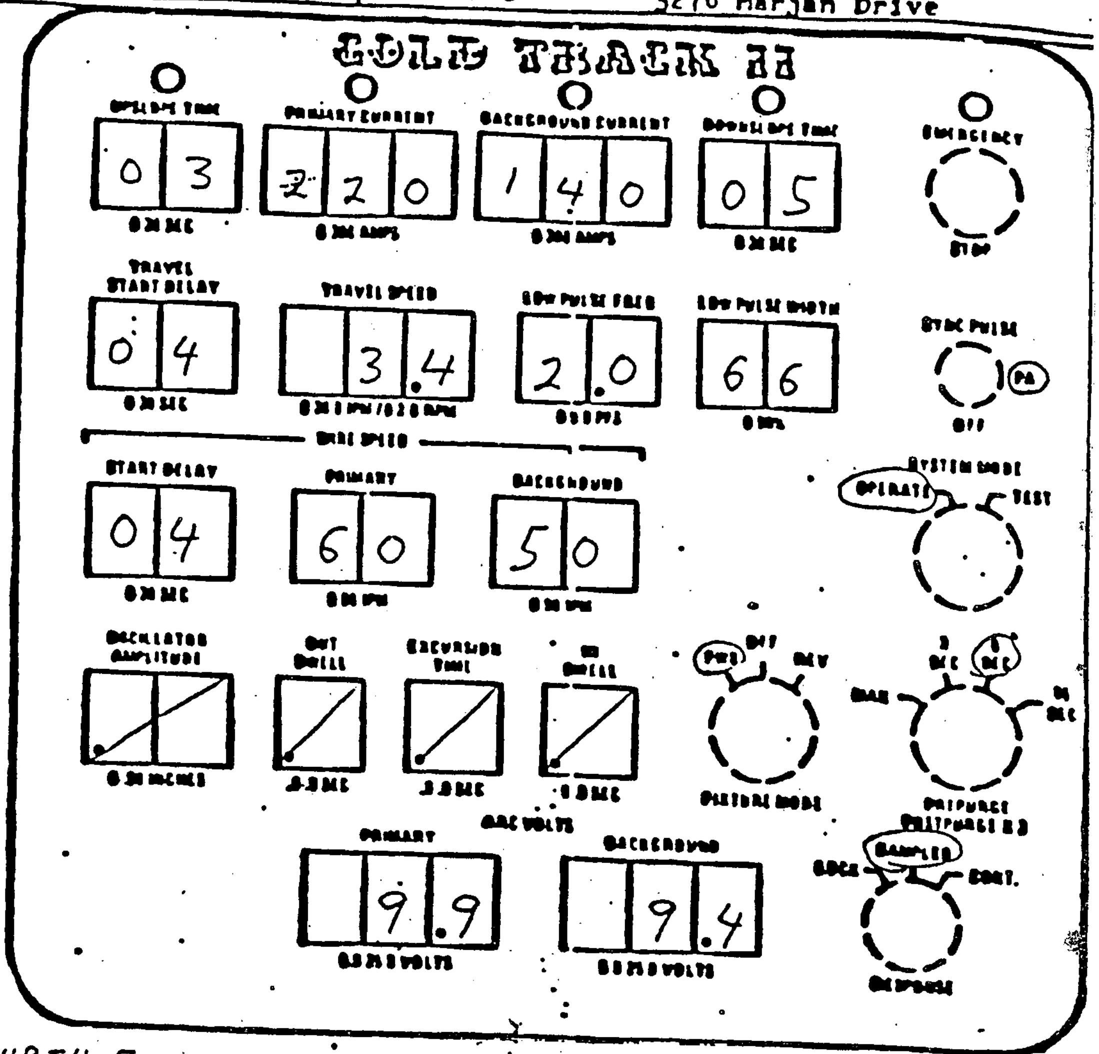
CW CCW DBL-UP

TYPE OF FRONT END REMOTE

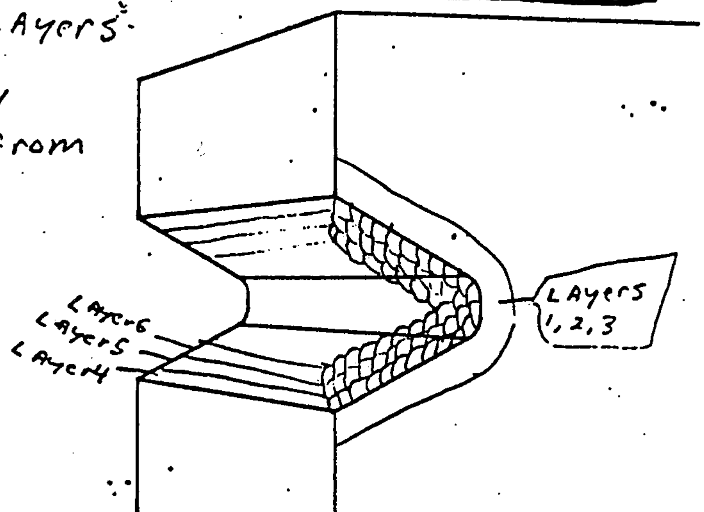
LENS NO. 5

CUP NO. 10

TUNGSTEN SIZE 1/8



FOURTH, FIFTH, SIXTH LAYERS
65° BEAD OVERLAP
Progression DOWNWARD from center + UPWARD from CENTER, BY LAYER.



COMMENTS:

Specializing in Automated Welding

TELEPHONE (404) 432-0005 ATLANTA, GEORGIA 30340 3276 Marian Drive

WELDING CODE ________

MATERIAL SA302 GrB

DIA. & WALL THICKNESS ________

PREHEAT 300 F°

INTERPASS 450 F°

POSITION Fixed Horz.

FILLER MATERIAL
TYPE ER80SD2 SIZE .035

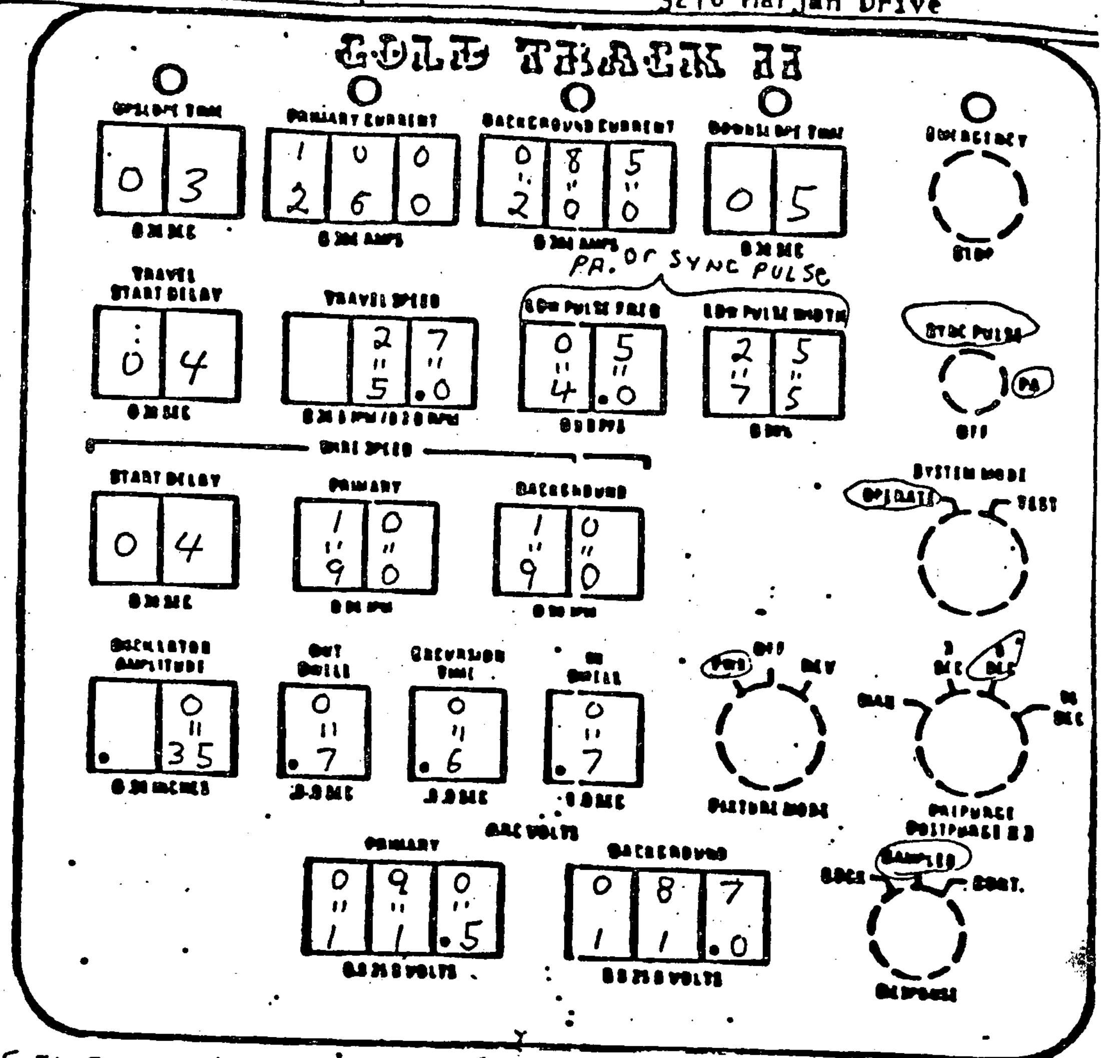
DIRECTION OF TRAVEL Horz. INLINE
CW CCW DBL-UP

TYPE OF FRONT END REMOTE

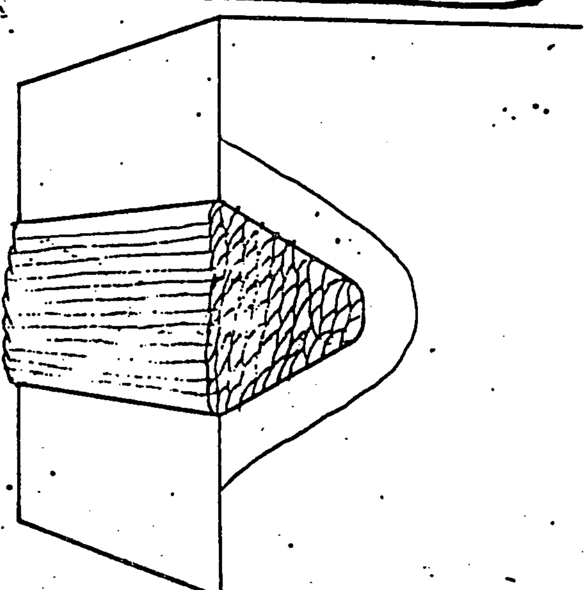
LENS NO. 5

CUP NO. 10

TUNGSTEN SIZE 1/8



. SEVENTH Layer THRU COMPLETION OF WELD
BEAD PLACEMENT AS NEEDED TO COMPLETE WELD
P.A. or SYNC. PULSE
WELD PARAMETERS TO SUIT CONFIGURATION



COMMENTS:

Approval Date: February 20, 1986

See Numeric Index for expiration
and any reaffirmation dates.

Case N-432
Repair Welding Using Automatic or Machine Gas Tungsten-Arc Welding (GTAW) Temperbead Technique
Section XI, Division 1

Inquiry: May the automatic or machine GTAW process be used as an alternative to the SMAW process for performing the temperbead technique on Class 1 components?

Reply: It is the opinion of the Committee that repair to P-Nos. 1, 3, 12A, 12B, and 12C[1] base material and associated welds may be made by the automatic or machine GTAW temperbead technique without the specified postweld heat treatment requirements of Section III, provided the requirements of 1.0 through 5.0 below are met. The depth of repair is not limited provided the test assembly meets the requirements of 2.1.

1.0 GENERAL REQUIREMENTS

(*a*) The requirements of IWA-4000, as applicable, shall be met.

(*b*) Only the automatic or machine GTAW process using cold wire feed shall be used. No arc oscillation shall be used.

(*c*) Welding materials shall be controlled during repair so that they are identified as acceptable material until consumed.

(*d*) The neutron fluence in the repair areas shall be taken into account when establishing the weld metal composition limits.

(*e*) Peening shall not be permitted.

2.0 WELDING QUALIFICATIONS

The Welding Procedure Specification and the welding operators shall be qualified in accordance with Section IX and additional requirements of Section III, as modified by 2.1, 2.2, and 3.0(c) and (d).

2.1 Procedure Qualifications

(*a*) The test assembly materials for the welding procedure qualification shall be of the same specification type, grade, and class as the materials being repaired. The test assembly shall receive a postweld heat treatment that is at least equivalent to the time and temperature applied to the materials being repaired. The procedure and performance qualification tests may be combined, provided Section IX requirements are met. The test assembly dimensions, including joint details, shall be documented on the PQR.

(*b*) The test assembly thickness shall be at least five times the depth of repair, but need not exceed the thickness of the material to be repaired provided the required test specimens can be removed. When the thickness of the base metal to be repaired is greater than 2 in., the depth of the cavity in the test assembly shall be the greater of 1 in. or the depth of the cavity to be repaired. However, in no case shall the procedure qualification test assembly be less than 2 in. thick, nor shall the depth of the cavity in the test assembly be less than 1 in.

(*c*) The test assembly dimensions surrounding the cavity shall be at least the thickness of the component at the location of the repair or 6 in., whichever is greater. If the repair weld is to be performed remotely, the procedure qualification test assembly shall be completed with the same or duplicate sensing and control equipment to be used for the repair. The test assembly shall simulate the position and obstructions of the actual repair.

(*d*) The root width and the included angle of the cavity in the test assembly shall be no greater than the minimum specified to be used in the repair.

(*e*) This test assembly may be used to qualify procedures for weld buildup of pressure retaining materials. For this application, the depth of the cavity shall not be less than the thickness of the weld buildup or 1 in., whichever is greater. In addition, the area of the cavity

[1] P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III, and subsequently reclassified in a later edition of Section XI.

shall not be less than the area of the weld buildup to be applied or 54 sq in., whichever is less.

(*f*) For all applications, the test assembly and cavity shall be of sufficient size to obtain the required test specimens.

(*g*) Welding material shall meet the requirements of Sections IX and III, and the Edition and Addenda shall be stated in the repair program. The appropriate toughness testing requirements of NB-2000 shall be completed for the weld materials used.

(*h*) Welding procedure qualification destructive tests shall be performed in accordance with Sections IX and III for groove welds, and the Edition and Addenda shall be stated in the repair program. Dropweight tests, impact tests, side bend tests, and all weld metal tension tests of the weld deposit are required. A reference nil-ductility transition temperature (RT_{NDT}) of the weld metal ~~and base~~ metal shall be established in accordance with NB-2000. If RT_{NDT} is less than or equal to 60°F, the qualification test shall be considered acceptable. If RT_{NDT} is greater than 60°F, the qualification test shall be rejected and a requalification of the procedure shall be performed. Test specimens shall be obtained from the completed test assembly at the maximum practical depth of repair.

(*i*) Impact testing of the procedure qualification test assembly HAZ shall be conducted as follows.

The T_{NDT} of the unaffected based material shall be determined by dropweight test to establish the test temperature for the C_v tests. The C_v specimens representing the HAZ material and the unaffected base material shall be tested at the (T_{NDT} + 60°F) temperature of the unaffected base material. The HAZ C_v absorbed energy and lateral expansion shall be equal to or greater than the unaffected base material at the (T_{NDT} + 60°F) temperature of the base material.

2.2 Performance Qualification

The welding operator shall be qualified in accordance with Section IX and the following additional requirements. If the repair weld is to be performed where physical obstructions impair the welding operator's ability to perform, the welding operator shall also demonstrate the ability to deposit sound weld metal in the positions required, using the same parameters and simulated physical obstructions that are involved in the repair. Also, if the repair weld is to be performed remotely, the performance qualification test shall be completed with the same or duplicate sensing and control equipment to be used for the repair. For these applications, only nondestructive examination of the weld is required. The procedure and welding operator performance qualification tests may be combined, provided Section IX requirements are met.

3.0 REPAIR WELDING

Welding of the cavity or area being repaired shall be in accordance with the following.

(*a*) The cavity or area to be repaired by welding and a band around the cavity or area shall be preheated to 300°F minimum. This temperature shall be maintained for at least 30 min before welding is started, during welding, and until starting the postweld heat treatment of 450°F to 550°F described in (*e*) below. The width of the band shall be at least three times the thickness ($3T$) of the component to be welded, but need not exceed 10 in. The component thickness (T) shall be determined for the area to be welded prior to formation of the cavity. The interpass temperature shall not exceed 450°F.

(*b*) Thermocouples and recording instruments shall be used to monitor the preheat, interpass, and postweld heat treatment temperatures. Thermocouples shall be attached by welding or mechanical methods.

(*c*) The first six layers of the cavity shall be buttered as shown in Fig. 1, Steps 1 through 3.

(*d*) The essential welding variables shall be controlled as follows.

(*1*) The weld heat input for each of the first six layers shall be controlled to within ±10% of that used in the procedure qualification test.

(*2*) The remainder of the weld deposit shall be completed (see Fig. 1, Step 4) with the heat input equal to or less than that used for layers beyond the sixth in the procedure qualification.

(*3*) The finished surface of the repair shall be substantially flush with the surface of the component surrounding the repair.

(*4*) The technique described in this paragraph shall be performed in the procedure qualification test.

(*e*) At the completion of welding, the $3T$ band as defined in (*a*) above shall be maintained in the range of 450°F to 550°F for at least 2 hr.

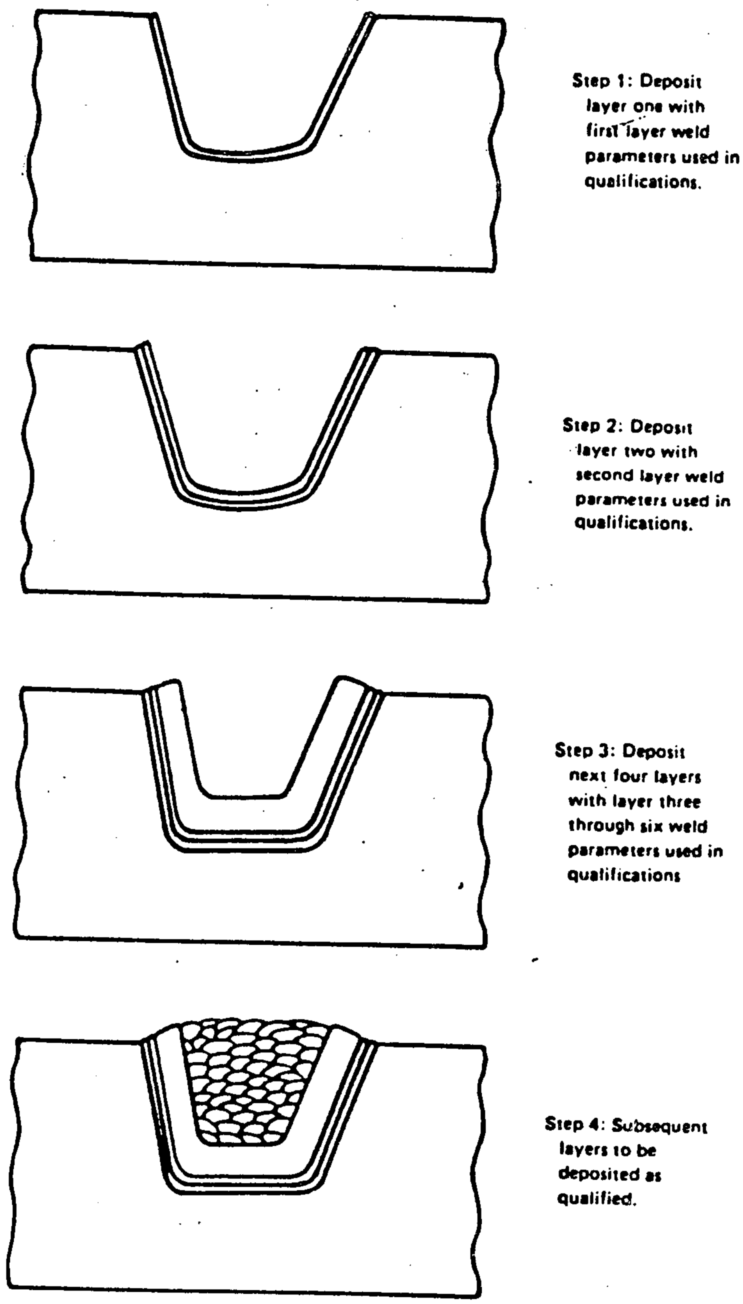


FIG. 1 AUTOMATIC OR MACHINE (GTAW) TEMPERBEAD TECHNIQUE

4.0 EXAMINATION

(*a*) The repair area and the 3*T* band as defined in 3(a) shall be nondestructively examined after the completed weld has been at ambient temperature for at least 48 hr. The nondestructive examination of the repair welded region shall include radiography (if practical), ultrasonic examination, and surface examination.

(*b*) Areas from which weld-attached thermocouples have been removed shall be ground and examined using a surface examination method.

5.0 DOCUMENTATION

The use of this Code Case shall be recorded on Form NIS-2 or other applicable documents.

STRUCTURAL INTEGRITY ASSOCIATES, INC.

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FAX: (408) 978-8964

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

May 31, 1989
AJG-89-035

Mr. S. Burkhalter
Welding Services Incorporated
3276 Marjan Drive
Atlanta, GA 30340

Subject: Revision to Letter AJG-89-031, dated May 19, 1989, "Consulting Support for Qualification of Welding Technique for Temperbead Welding on Indian Point Unit 2 Steam Generator Shell"

Dear Steve:

The purpose of this letter report is to document my review of the results of the subject temperbead welding qualification test program conducted by Welding Services Incorporated (WSI) for Consolidated Edison Company. The temperbead qualification was performed for the Indian point Unit 2 (IP-2) steam generator shell. The shell material is SA302 Grade B low alloy steel, designated by the ASME Code as P-3 Group 3 material. The purpose of the temperbead qualification was to be prepared to perform a cavity weld repair to one or more of the IP-2 steam generator shells using this welding approach, such that an elevated temperature (1150°F) post weld heat treatment would not be required. ASME Code Case N-432, issued in February, 1986 [1], provided guidance for the temperbead qualification activity at WSI. Both weld parameter trial tests (on a thinner plate of SA302 B material) and procedure qualification tests (on a thicker plate) were performed in order to select a weld procedure and then to qualify it. Although a dilemma arose wherein the thicker plate was not entirely representative in terms of toughness, the results on the thinner and thicker plates, taken together, demonstrate that the procedure should be technically acceptable for use on the 3.5 inch thick steam generator shell at IP-2, as discussed in the following sections of this report.

Weld Trials

In the technical program undertaken for the qualification, WSI performed a technical evaluation of eight (8) different automatic gas tungsten arc welding (GTAW) approaches for welding the SA302 B cavity. The welding approaches included a welding technique which reproduced the Babcock and Wilcox approach which formed the basis for ASME Code Case N-432 [2], as well as modifications to that approach to improve the ease of welding in the field.

Following the welding of eight test coupons of SA302 B plate using these eight different welding techniques, metallurgical and microhardness measurements were performed on the test coupons [3]. The microhardness measurements revealed that three of the welding techniques produced a weld heat affected zone (HAZ) hardness well below Rockwell C hardness 37, an upper bound reference hardness used for selecting a welding process as suitable for use in the temperbead procedure qualification. These three welding techniques included the Reference 1 approach and two approaches where the travel speed was adjusted to provide for greater ease of welding. WSI selected technique P-6, one of the two travel speed adjusted welding techniques, for procedure qualification in accordance with Code Case N-432. The microhardness results for the P-6 welding approach are presented in Table 1 [3]. One notes from Table 1 that the maximum hardness in the HAZ in the technique P-6 plate is Rc 33.5, well below the Rc 37 target value. Thus, this procedure appears quite capable of meeting the HAZ requirements of this representative base material.

One additional weld trial was conducted using the P-6 weld parameters. A single bead weld was deposited on the SA302 B plate and the hardness measured in the HAZ of the plate. This test would compare the untempered hardness with the tempering anticipated using the P-6 welding technique. The results of that single bead weld are presented in Table 2, from Reference 3. One observes from Table 2 that the untempered weld HAZ contains a maximum hardness of Rc 49, more than 15 hardness points higher than the tempered P-6 process HAZ. These results confirmed the fact that the temperbead process developed using the P-6 welding technique is representative of a welding process which should produce a base metal weld HAZ which is substantially softer than an untempered structure. Based upon these results and the ease of application of this welding process, the P-6 welding approach was selected as the preferred approach for the temperbead weld procedure qualification.

Weld Procedure Qualification

The Weld Procedure Qualification Record [4] specifies welding a 3 inch deep groove weld into a 7.125 inch thick plate of SA302 B material. The material type and minimum thickness of the plate and the groove for procedure qualification were specified by Code Case N-432 and by Section XI of the ASME Code [5]. The required tensile, side bend, drop weight and Charpy v-notch specimens were removed from the plate following welding and tested at Applied Technical Services, Inc. The tensile test results and the side bend test results were certified to be acceptable as presented in the Applied Technical Services, Inc. certified test reports [6].

The base metal drop weight specimens produced a no break condition in duplicate specimens at +40°F whereas the weld metal produced a no break condition at -10°F. The Code Case requires the reference nil ductility transition temperature of the weld metal and the base metal to be no greater than +60°F, and the weld HAZ to have Charpy v-notch absorbed energy and lateral expansion equal to or greater than the unaffected base metal at the nil ductility transition temperature plus 60°F.

Since the reference temperature from the all weld metal drop weight specimens was -20°F, the Charpy tests were conducted at +40°F and the requirements of the Code Case and the Code were met. Since the reference temperature from the base metal drop weight tests was +30°F, the Charpy v-notch tests for the base metal and the HAZ were performed initially at 90°F. The base metal specimens did not meet the 1980 ASME Section III values for determining reference NDT at +90°F. However the HAZ energy absorbed and lateral expansion were far superior to the base metal properties, thereby meeting that requirement of the Code Case. The Charpy v-notch results for these tests are presented in Attachment 1 [6].

A second series of base metal and HAZ impact tests were performed at +120°F in an attempt to meet the Code of repair requirements at the maximum temperature allowed by the Code Case for the base metal. The results of these tests are presented in Attachment 1. The base metal tests again failed to meet the Code toughness requirements at the maximum temperature allowed by the Code Case. However, note that the HAZ impact toughness is still superior to the base metal toughness at 120°F, attesting to the adequacy of the weld procedure.

Conclusions

The properties of the base metal used in the temperbead qualification program did not meet all of the requirements of Code Case N-432 and the Code of repair. However, application of these requirements in this case is overly restrictive. The plant was constructed to ASME Section III, 1965 with addenda through 1966, a Code which prescribed less in the way of toughness requirements for this material than either the Code of repair, or Code Case N-432. The intent of Code Case N-432 is to assure that the weld procedure which is qualified, qualifies a process on representative material which provides assurance that the welding process has not degraded the base metal. The HAZ Charpy v-notch energy absorbed and lateral expansion were clearly greater than those of the unaffected base metal in this test program. The 7.125 inch thick SA302B plate used in this test program is representative material in that section thickness. One characteristic of this material is its poor through thickness hardenability, thereby resulting in plate which in this thickness, may have poor notch toughness in the 1/4t to 3/4t region. In reduced section thicknesses, this material is expected to have better toughness.

The steam generator shell at IP-2 is significantly thinner, 3.5 inches thick, and has superior Charpy v-notch impact properties compared to the test plate as would be expected for this grade of material. The steam generator shell impact strength exceeds the minimum construction code requirements of 30 ft-lbs at +10°F as contrasted to approximately 30 ft-lbs at 120°F for the 7.125 inch thick test plate. Were the test plate a more representative thickness, I believe that the notch impact properties would have been significantly improved. This observation is substantiated by the weld trial tests in the thinner plate (2.25 inches thick), where hardness measurements revealed a softened HAZ consistent with increased toughness for a representative material. The restrictions of Code Case N-432 required a thicker plate than is to be welded to in the field thereby restricting the qualification program to use of a base metal which could not be reasonably expected to meet the notch toughness requirements in the Code Case. Consequently, while all requirements of Code Case N-432 cannot be literally adhered to, I believe that, when considering both the trial weld tests and the procedure qualification tests taken together, a clear demonstration has been made that the HAZ properties have not been degraded in the SA302 B plate and that the temperbead process is technically qualified for use at IP-2.

I trust that this document meets your requirements regarding the qualification of this process. If you have additional questions, or require additional information, please do not hesitate to call.

Very truly yours,

A. J. Giannuzzi, Ph.D, P.E.
Associate

/mc
enclosures

<u>References</u>

1. Cases of the ASME Boiler and Pressure Vessel Code, Case N-432, Repair Welding Using Automatic or Machine Gas Tungsten Welding (GTAW) Temperbead Technique, Section XI, Division 1, February 20, 1986.

2. EPRI Report NP-3614, Repair Welding of Heavy-Section Steel Components in LWRs, Babcock & Wilcox Company, July, 1984.

3. Report CMS 405-89, Subject: Microhardness Testing of Various Welds Involved in Temper Bead Pass Welding, Consulting Metallurgical Services, Inc., April 27, 1989.

4. Procedure Qualification Record AO3N432, Welding Services Inc.

5. ASME Boiler and Pressure Vessel Code, Section XI, 1980 Edition Including All Addenda Through Winter, 1981.

6. Report AO-0394, Applied Technical Services, Inc., Inspection and Metallurgical Test Reports, Purchase Order No. 207593, May 9, 1989.

Attachment to AJG-89-035

TABLE 1

P-6 Weld Process Microhardness Results

Distance Inches	A Filars	A KHN_{500}	B Filars	B KHN_{500}	C Filars	C KHN_{500}	D Filars	D KHN_{500}
.002	347	268	338	282	336	286	338	282
.004	335	287	321	313	323	309	333	291
.012	345	271	331	294	323	309	322	312
.020	329	297	330	296	321	313	322	312
.028	333	291	322	312	313	330	334	289
.036	336	286	329	298	309	338	348	266
.044	338	282	327	302	318	319	350	263
.052	335	287	337	284	322	312	342	276
.060	346	269	338	282	320	315	342	276
.076	350	263	340	279	329	298	338	282
.084	356	254	318	319	335	287		
.108	352	260	354	257	330	296		

Highest KHN_{500}	Rc (conv.)
A-297	28.9
B-319	31.1
C-338	33.5
D-312	30.0

Attachment to AJG-89-035

TABLE 2

Microhardness Results on Single Bead Weld
Using P-6 Welding Process

Distance from fusion	Filars	A KHN_{500}	Filars	KHN_{500}	Filars	KHN_{500}
0.005"	255	495				
0.015"	257	486				
0.025"	255	495				
0.045"	248	525				
0.065"	252	508				
0.085"	254	500				
0.105"	254	500				

High Hardness

A - $\frac{KHN}{525}$500 $\frac{Rc(conv.)}{49.0}$

ATTACHMENT 1

SUMMARY OF WELD METAL, HAZ AND BASE METAL CHARPY V-NOTCH TOUGHNESS TEST RESULTS

APPLIED TECHNICAL SERVICES, INC.	MARIETTA, GA.

METALLURGICAL TEST REPORT

Ref. H0-0516 **Date** May 11, 1989

PURCHASE ORDER # 207953

Welding Services, Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

Attention: Steve Burkhalter

MATERIAL: SA 302
Grade B
PQR No: A03N432

Metallurgical Test Procedure

Hardness	☐	**Specifications:** Tested in accordance with ASME BPVC Section III; NB-2331 and ASME BPVC Section IX; QW-171 35 mils lateral expansion and 50 ft-lb minimum. Ref. Case Code N-432
Case Depth	☐	
Impact Charpy, V-Notch	☒	
Coating Thickness	☐	
Coating Weight	☐	
Bend Test	☐	
Other_________	☐	

Metallurgical Test Results

PART IDENTIFICATION	QUANTITY	RESULTS	REMARKS
Weld Metal	3	1: 63 ft-lb 63 mils lat. exp. 40% shear	T_{cv}: 40°F
		2: 105 ft-lb 69 mils lat. exp. 70% shear	$RT_{NDT} = T_{cv} -60°F$
		3: 80 ft-lb 62 mils lat. exp. 60% shear	RT_{NDT}: - 20°F

A-11-88

Patricia C. DuBose
Notary Public Cobb County, Georgia
My Commission Expires [illegible]

Witnessed by ____________________

Prepared by: M. Wayne Armistead M. W. Armistead
Test Engineer

Approved by: RWD R. W. Dunning
Manager

APPLIED TECHNICAL SERVICES, INC. MARIETTA, GA.

METALLURGICAL TEST REPORT

Ref. H0-0516 **Date** May 11, 1989

PURCHASE ORDER # 207953

Welding Services, Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

Attention: Steve Burkhalter

MATERIAL: SA 302
Grade B
PQR No: A03N432

Metallurgical Test Procedure

- Hardness ☐
- Case Depth ☐
- Impact Charpy, V-Notch ☒
- Coating Thickness ☐
- Coating Weight ☐
- Bend Test ☐
- Other________ ☐

Specifications: Tested in accordance with ASME BPVC Section III; NB-2331 and ASME BPVC Section IX; QW-171
Ref. Case Code N-432
Absorbed energy and lateral expansion equal to or greater than base metal at T_{NDT} + 60°F of base metal

Metallurgical Test Results

PART IDENTIFICATION	QUANTITY	RESULTS	REMARKS
Heat Affected Zone	3	1. 46 ft-lb 39 mils lat. exp. 20% shear 2. 51 ft-lb 46 mils lat. exp. 20% shear 3. 35 ft-lb 32 mils lat. exp. 20% shear	T_{cv} = 90°F T_{NDT} = 30°F (base metal-drop test) 29 mils lateral expansion and 28 ft-lb average for base metal at T_{vc}=90°F

A-11-88

Witnessed by ____________

Prepared by: M. Wayne Armistead M. W. Armistead
Test Engineer

Approved by: RWD R. W. Dunning
Manager

Patricia L. DuBose
Notary Public, ... County, Georgia
My Commission Expires ...

APPLIED TECHNICAL SERVICES, INC.

APPLIED TECHNICAL SERVICES, INC.	MARIETTA, GA.

METALLURGICAL TEST REPORT

Ref. HO-0516 **Date** May 11, 1989

PURCHASE ORDER # 207953

Welding Services, Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

Attention: Steve Burkhalter

MATERIAL: SA 302
Grade B
PQR No: A03N432

Metallurgical Test Procedure

- Hardness ☐
- Case Depth ☐
- Impact Charpy, V-Notch ☒
- Coating Thickness ☐
- Coating Weight ☐
- Bend Test ☐
- Other_____ ☐

Specifications: Tested in accordance with ASME BPVC Section III; NB-2331 and ASME BPVC Section IX; QW-171 35 mils lateral expansion and 50 ft-lb minimum Ref. Case Code N-432

Metallurgical Test Results

PART IDENTIFICATION	QUANTITY	RESULTS	REMARKS
Base Metal	3	C1: 27 ft-lb 28 mils lat. exp. 10% shear	T_{cv}: 90°F
		C2: 31 ft-lb 28 mils lat. exp. 10% shear	T_{NDT}: 30°F
		C3: 39 ft-lb 37 mils lat. exp. 10% shear	

A-11-88

Patricia T. DuBose
Notary Public, Cobb County, Georgia
My Commission Expires Jan 29 1992

Witnessed by ____

Prepared by: M. Wayne Armistead M. W. Armistead
Test Engineer

Approved by: RWD R. W. Dunning
Manager

APPLIED TECHNICAL SERVICES, INC.

APPLIED TECHNICAL SERVICES, INC. **MARIETTA, GA.**

METALLURGICAL TEST REPORT

Ref. HO-0516-2 **Date** May 15, 1989 **Page** 1 **of** 1

PURCHASE ORDER # 207953

Welding Services, Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

Attention: Steve Burkhalter

MATERIAL SA 302
Grade B
PQR No: A03N432

Metallurgical Test Procedure

- Hardness ☐
- Case Depth ☐
- Impact Charpy, V-Notch ☒
- Coating Thickness ☐
- Coating Weight ☐
- Bend Test ☐
- Other ☐

Specifications: Tested in accordance with ASME BPVC Section III; NB-2331 and ASME BPVC Section IX; QW-171
Ref. Case Code N-432
Absorbed energy and lateral expansion equal to or greater than base metal at T_{NDT} + 60°F of base metal

Metallurgical Test Results

PART IDENTIFICATION	QUANTITY	RESULTS	REMARKS
Heat Affected Zone	3	1: 61 ft-lb 45 mils lat. exp. 50% shear 2: 52 ft-lb 47 mils lat. exp. 50% shear 3: 49 ft-lb 45 mils lat. exp. 50% Shear	T_{cv} = 120°F

A-11-58

Witnessed by ______________________

Prepared by: M. Wayne Armistead — M. W. Armistead, Test Engineer

Patricia T. DuBose

APPLIED TECHNICAL SERVICES, INC. **MARIETTA, GA.**

METALLURGICAL TEST REPORT

Ref. H0-0516 **Date** May 11, 1989

PURCHASE ORDER # 207953

Welding Services, Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

Attention: Steve Burkhalter

MATERIAL: SA 302
Grade B
PQR No: A03N432

Metallurgical Test Procedure

- **Hardness** ☐
- **Case Depth** ☐
- **Impact** ☐
- **Coating Thickness** ☐
- **Coating Weight** ☐
- **Bend Test** ☐
- **Other_____** ☐

Specifications: Tested in accordance with ASME BPVC Section III; NB-2331 and ASME BPVC Section IX; QW-171 35 mils lateral expansion and 50 ft-lb minimum. Ref. Case Code N-432

Metallurgical Test Results

PART IDENTIFICATION	QUANTITY	RESULTS	REMARKS
Base Metal	3	D1: 39 ft-lb 36 mils lat. exp. 20% shear D2: 27 ft-lb 27 mils lat. exp. 30% shear D3: 34 ft-lb 34 mils lat. exp. 30% shear	T_{cv}: 120°F

A-11-88

Patricia T. DuBose
Notary Public, [illegible] County, Georgia
My Commission Expires [illegible]

Witnessed by ________________

Prepared by: M. Wayne Armistead M. W. Armistead
Test Engineer

Approved by: RWD R. W. Dunning
Manager

APPLIED TECHNICAL SERVICES, INC.

Dr. Anthony J. Giannuzzi, P. E.
Associate

Education

BS, Physics, LeMoyne College (1964)
MS, Solid State Science and Technology, Syracuse University (1967)
PhD, Solid State Science and Technology, Syracuse University (1969)

Professional Associations

Professional Corrosion Engineer, State of California

Professional Experience

1983 to present	Structural Integrity Associates, San Jose, CA Vice President
1979 to 1983	Electric Power Research Institute, Palo Alto, CA Project Manager
1978 to 1979	NUTECH, San Jose, CA Project Manager
1972 to 1978	General Electric Company, San Jose, CA Principal Engineer
1969 to 1972	Aerojet Nuclear Systems Company, Sacramento, CA

Summary

Dr. Giannuzzi has been involved in solving materials and corrosion problems for the nuclear industry since 1969. One of the world's leading authorities on intergranular stress corrosion cracking of stainless steel in aqueous systems, Dr. Giannuzzi was employed by the Electric Power Research Institute in the Nuclear Systems and Materials Department for three and one–half years prior to joining Structural Integrity Associates in 1983. At EPRI, Dr. Giannuzzi was task leader and principal investigator involved in development and qualification of all the Boiling Water Reactor IGSCC piping remedies. This activity included primary responsibility for qualifying and producing material specification for the alternative materials (Types 316NG and 304NG stainless steels), qualifying the induction heating stress improvement (IHSI) remedy, qualifying heat sink welding, last pass heat sink welding and the weld overlay and performing the investigations to determine the causes of and remedies to IGSCC in Type 304 stainless steel pipe.

In addition to his BWR IGSCC responsibility at EPRI, Dr. Giannuzzi has had the lead responsibility for investigating the causes of low pressure large steam turbine stress corrosion cracking in nuclear and fossil steam turbines and has been involved in projects associated with bolt and fastener reliability, steam and water piping erosion–corrosion and has been active in projects related to primary and secondary side corrosion of steam generators. Dr. Giannuzzi has also been the lead project manager responsible for all materials related failure analysis activities in the Nuclear Systems and Materials Department and was a member of the EPRI Three Mile Island Unit 2 task force.

Prior to his employment at EPRI, Dr. Giannuzzi was employed as a senior consultant at NUTECH. While at NUTECH, he formed the stress corrosion cracking group and developed the methodology used to estimate likely locations of IGSCC in stainless steel piping systems. He also was involved in the earliest investigations involving PWR boric acid corrosion and assisted in the final formulation of the NRC I–E Bulletin 79–02 which established criteria for inspection of the boric acid system piping.

From 1972 to 1978, Dr. Giannuzzi worked as a principal development engineer at the General Electric Company Nuclear Energy Division. His responsibilities while at GE involved investigation of alternative materials and processes to alleviate the IGSCC problem in stainless steel piping. He managed the initial weld residual stress measurement and analyses activities which lead to the development of the residual stress remedies to IGSCC.

From 1969 to 1972, Dr. Giannuzzi worked for the Aerojet Nuclear Systems Company developing materials for use in the nuclear rocket engine (NERVA).

In 1983, Dr. Giannuzzi founded Structural Integrity Associates with Dr. P. C. Riccardella and Dr. T. L. Gerber. His activities at Structural Integrity have included nuclear plant life extension studies, temper bead welding development on low alloy steels and selecting of remedies to IGSCC in BWRs.

Bob Spring - Please get a copy of the Code Case. If its a Section XI Code case we should identify in this letter that ① we are incorporating it into our Section XI ISI program

July 20, 1989

Re: Indian Point Unit No. 2
Docket No. 50.247

② and we are providing an alternative interpretation of the Code Case as described herein

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUBJECT: Relief Request Regarding Temperbead Welding on Indian Point Unit No. 2 Steam Generator Shell

S. Wasilenko

As a contingency measure for the 1990 mid-cycle outage for Indian Point Unit No. 2, Consolidated Edison has been planning the development and qualification of an automatic gas tungsten arc welding (GTAW) temperbead process to be available for steam generator girth weld repair. The automatic GTAW temperbead process is a welding process which produces a tempered, as deposited, heat-affected zone microstructure and weldment properties which are similar to that of GTAW weld deposits which have been post weld heat treated. The qualification requirements for the GTAW procedure cannot be met to the letter of the applicable ASME code case due to the unavailability of the test material required as stated.

Attachment A contains a brief discussion and basis upon which Consolidated Edison hereby requests that the NRC grant relief, per 10 CFR 50.55a subparagraph(6)(i), from strict interpretation of Code Case N-432 for this repair procedure.

Attachment B contains the detailed weld procedure qualification package for your review.

Should the staff have any questions on this matter, please contact Mr. Jude Del Percio, Manager of Regulatory Affairs and Safety Assessment.

Attachment

If its a Section III Code Case I've got to think further.

Also this requires revision to standard relief request format.

ATTACHMENT A

Regulatory Input Related to Relief Request
Regarding Temperbead Welding of
Low Alloy Steel Vessel Materials
Using GTAW

Consolidated Edison Company of New York, Inc.
Indian Point Unit No. 2
Docket No. 50-247
July, 1989

In anticipation of need, Consolidated Edison has developed a temperbead weld qualification program for the Indian Point Unit No. 2 steam generator shell. The shell material is SA302 Grade B low alloy steel, designated by the ASME Code as P-3 Group 3 material. The purpose of the temperbead qualification was to be prepared to perform a cavity weld repair to one or more of the IP-2 steam generator shells using this welding approach, such that an elevated temperature (1150°F) post weld heat treatment would not be required. ASME Code Case N-432, issued in February 1986, provided guidance for the temperbead qualification activity. Both weld parameter trial tests (on a thinner plate of SA302 Grade B material) and procedure qualification tests (on a thicker plate) were performed in order to select a weld procedure and then to qualify it. Although a dilemma arose wherein the thicker plate was not entirely representative in terms of toughness, the results on the thinner and thicker plates, taken together, demonstrate that the procedure should be technically acceptable for use on the 3.5 inch thick steam generator shell at IP-2, as discussed below.

The properties of the base metal used in the temperbead qualification program did not meet all of the requirements of Code Case N-432 and the Code of repair. However, application of these requirements in this case is overly restrictive. The plant was constructed to ASME Section III, 1965 with addenda through 1966, a Code which prescribed less in the way of toughness requirements for this material than either the Code of repair, or Code Case N-432. The intent of Code Case N-432 is to assure that the weld procedure which is qualified, qualifies a process on representative material which provides assurance that the welding process has not degraded the base metal. The HAZ Charpy v-notch energy absorbed and lateral expansion were clearly greater than those of the unaffected base metal in this test program. The 7.125 inch thick SA302B plate use in this test program is representative material in that section thickness. One characteristic of this material is its poor through thickness hardenability, thereby resulting in plate which, in this thickness, may have poor notch toughness in the 1/4t to 3/4t region. In reduced section thicknesses, this material is expected to have better toughness.

The steam generator shell at IP-2 is significantly thinner, 3.5 inches thick, and has a superior Charpy v-notch impact properties compared to the test plate as would be expected for this grade of material. The steam generator shell impact strength exceeds the minimum construction code requirements of 30 ft-lbs at +10°F as constrasted to approximately 30 ft-lbs at 120°F for the 7.125 inch thick test plate. Were the test plate a more representative thickness, we believe that the notch impact properties would have been significantly improved. This observation is substantiated by the weld trial tests in the thinner plate (2.25 inches thick), where hardness measurements revealed a softened HAZ consistent with increased toughness for a representative material. The restrictions of Code Case N-432 required a thicker plate than is to be welded to in the field thereby restricting the qualification program to use of a base metal which could not be reasonably expected to meet the notch toughness requirements in the Code Case. Consequently, while all requirements of

Code Case N-432 cannot be literally adhered to, we believe that, when considering both the trial weld tests and the procedure qualification tests taken together, a clear demonstration has been made that the HAZ properties have not been degraded in the SA302 Grade B plate and that the temperbead process is technically qualified for use at IP-2.

In addition, the ASME Section XI Special Working Group on Repair by Welding will formally include the use of automatic GTAW temperbead in the code. This will be addressed during the summer 1989 meeting. Additionally, the ASME has realized that the present N-432 code case for automatic GTAW temperbead, as it now exists, is unworkable, specifically for thick section plate qualification. As a result, the committee is recommending the following changes to the weld qualification requirements:

- The test assembly shall be of the same "P" number and Group number as the component being repaired.

- The base metal impact properties shall meet the design specification.

- The average of the three charpy V-notch HAZ results shall be equal or greater than the average of the three base metal impact values.

In conclusion, Consolidated Edison believes that the strict interpretation of Code Case N-432 for this temperbead repair of SA302 Grade B steam generator shell material is clearly impractical and that the weld procedure, as prepared, is technically adequate.

Consolidated Edison, therefore, requests relief from the full requirements of Code Case N-432 such that the weld procedure already developed is acceptable and qualified.

STRUCTURAL INTEGRITY ASSOCIATES, INC.

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May 31, 1989
AJG-89-034

Mr. S. Burkhalter
Welding Services Incorporated
3276 Marjan Drive
Atlanta, GA 30340

Subject: Additional Information Regarding Through Thickness Properties of A302 B in Thick Sections

Dear Steve:

As a result of our telephone conversation of May 25, 1989, and your request for additional data regarding the through-thickness properties of A302 Grade B pressure vessel steels in thick sections, I have performed an additional literature review, with the assistance of Fred Copeland, of the properties of this class of low alloy steel. As you know, A302-B is representative of a pressure vessel steel which is not generally used today in thick nuclear vessel applications due to its lack of through-thickness hardenability. Consequently, a literature review involves examination of relatively old data from limited sources. Two reference documents were located from which this letter report was prepared (References 1 & 2). Reference 1 is a background technical report from Lukens Steel entitled "Heavy Gage Plate Steels for Nuclear Service". Reference 2, appended to this letter report, is entitled "Utilization of Quenching and Tempering for Improvement of Low Alloy Steels in Heavy Thickness for Welded Construction".

One of the characteristics of most steels is the fact that in the solid state, minor changes in composition and/or in heat treatment can produce dramatic changes in properties of the steel. For example, in a carbon or low alloy steel, a rapid cooling from above the austenitizing temperature can produce a very strong bainitic or martensitic structure, whereas slower cooling will produce a ferrite-pearlite microstructure. The bainitic or martensitic structure, once properly tempered, will produce a high yield strength, high toughness material, whereas, the ferrite-pearlite structure will have lower toughness and lower yield and ultimate tensile strength. One notes that the only fabrication differences between the high strength, high toughness structure and the low strength, low toughness structure is cooling rate. This cooling rate from austenitizing heat treatment temperature is a function of quench medium, plate thickness and location in the plate through-thickness direction (surface vs. mid-wall, etc.) However, for a given cooling rate (defined by the above parameters), the tendency of a steel to transform to bainite and/or martensite can be enhanced by further increasing the alloying or carbon content to increase the hardenability of the steel. Hardenability, therefore, can be defined as an index of the depth to which martensite or bainite can be formed in a given steel as the result of a given hardening treatment and cooling rate.

The A302 Grade B low alloy steel pressure vessel material has somewhat limited hardenability in thick sections as illustrated in Figures 1 through 3, from Reference 1. One notes from Figure 1 for A302-B plate with additional nickel, that the Charpy-v-notch toughness decreases dramatically as plate thickness is increased. Figures 2 and 3 illustrate that the yield and ultimate tensile strengths are also dramatically decreased as plate thickness increases. Even in the quenched and tempered condition, the notch toughness of the A302-B steel is degraded in thicker sections as illustrated in Figure 4 (Reference 2).

As a result of the toughness and hardenability problem in thick sections, steel producers developed a second generation of reactor steels (Reference 1), steels which included the A543, A542 and A533 designation of low alloy steels. The A533 Grade B became the modern generation replacement material to A302 Grade B. The basic difference between A533-B steel and A302-B is the fact that the second generation material contains some nickel which lowers the nil ductility transition (NDT) temperature and improves notch toughness of the A533-B material (Reference 1). Although some through-thickness problems do indeed still exist in the second generation A533-B materials, the dramatic reduction in the NDT temperature (typically to less than 0°F), and the large improvement in notch toughness due to the nickel addition, more than compensate for the through-thickness hardening deficiency in thick sections.

In summary, the through-thickness hardenability problem which exists in A302 Grade B low alloy steel pressure vessel material also exists to a lesser degree in the modern generation replacement material, A533 Grade B. However, the nickel addition produces such a dramatic increase in upper shelf notch toughness and dramatic decrease in NDT temperature that the hardenability problem can be tolerated in this modern material. For applications involving thick section plates, the residual elements, such as Cr, and other elements are also typically mainatined near the top end of permitted limits, in order to get an additional "boost" in hardenability and, thus, in through-thickness strength and toughness. The lower toughness A302-B material does not provide the toughness margin provided in the A533-B. It is for that reason that we had difficulty meeting the base metal toughness requirements in thick sections in the A302-B material.

May 31, 1989
AJG-89-034

I trust that this report and the accompanying paper will meet your needs in the subject area. If you require additional information, or further clarification, please do not hesitate to call.

Very truly yours,

A. J. Giannuzzi
Associate

/mc
enclosures

References

1. "Heavy Gage Plate Steels for Nuclear Service", R. H. Sterne, Jr., Lukens Steel Company, June, 1966.

2. "Utilization of Quenching and Tempering for Improvement in Properties of Low Alloy Steels in Heavy Thicknesses for Welded Construction, R. E. Lorentz, Jr., Welding Research Supplement to the Welding Journal, October, 1962.

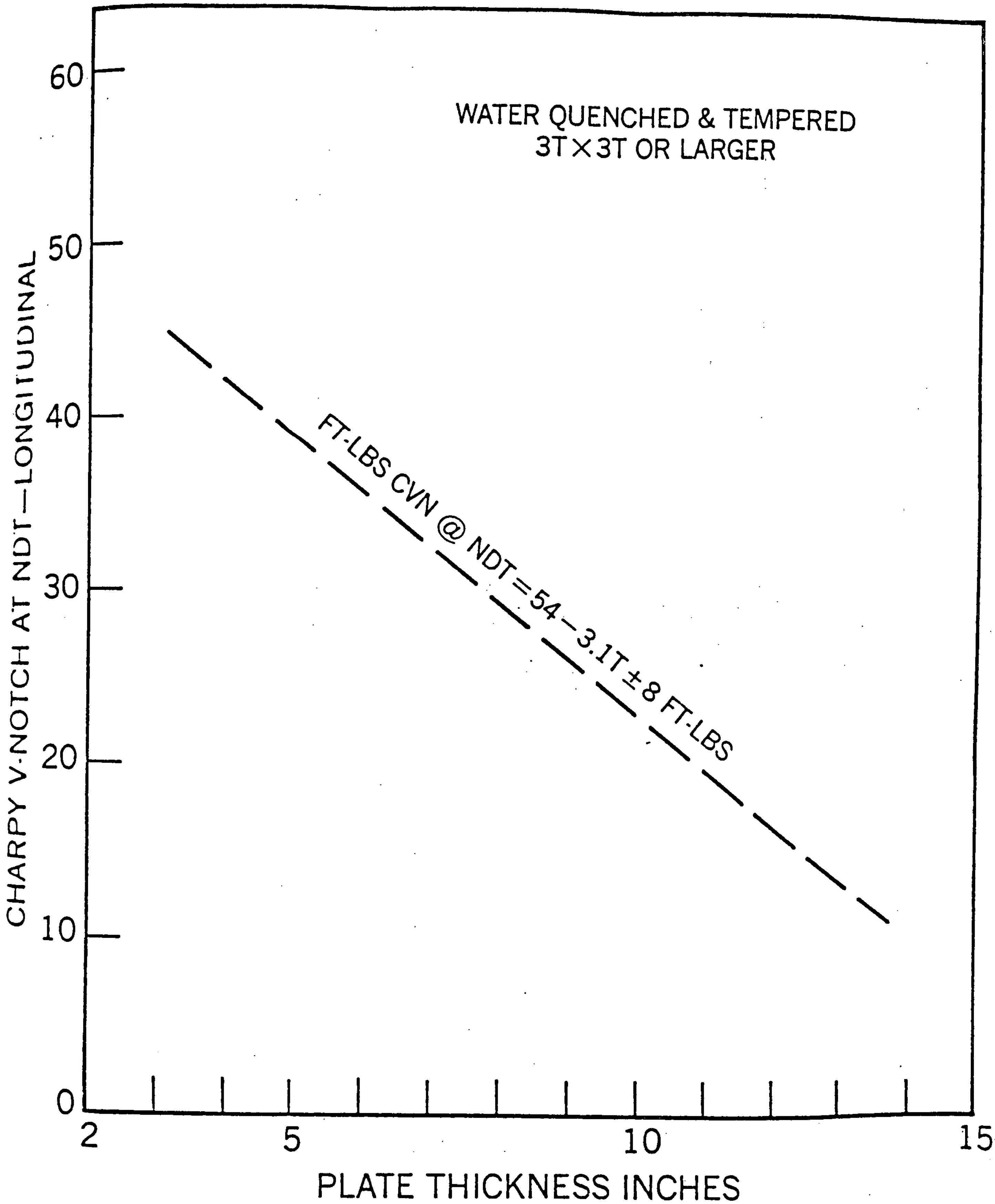

Figure 1. Effect of Plate Thickness on Charpy V-Notch Energy at NDT-ASTM A302 GR. B + 0.50 - 100% Nickel

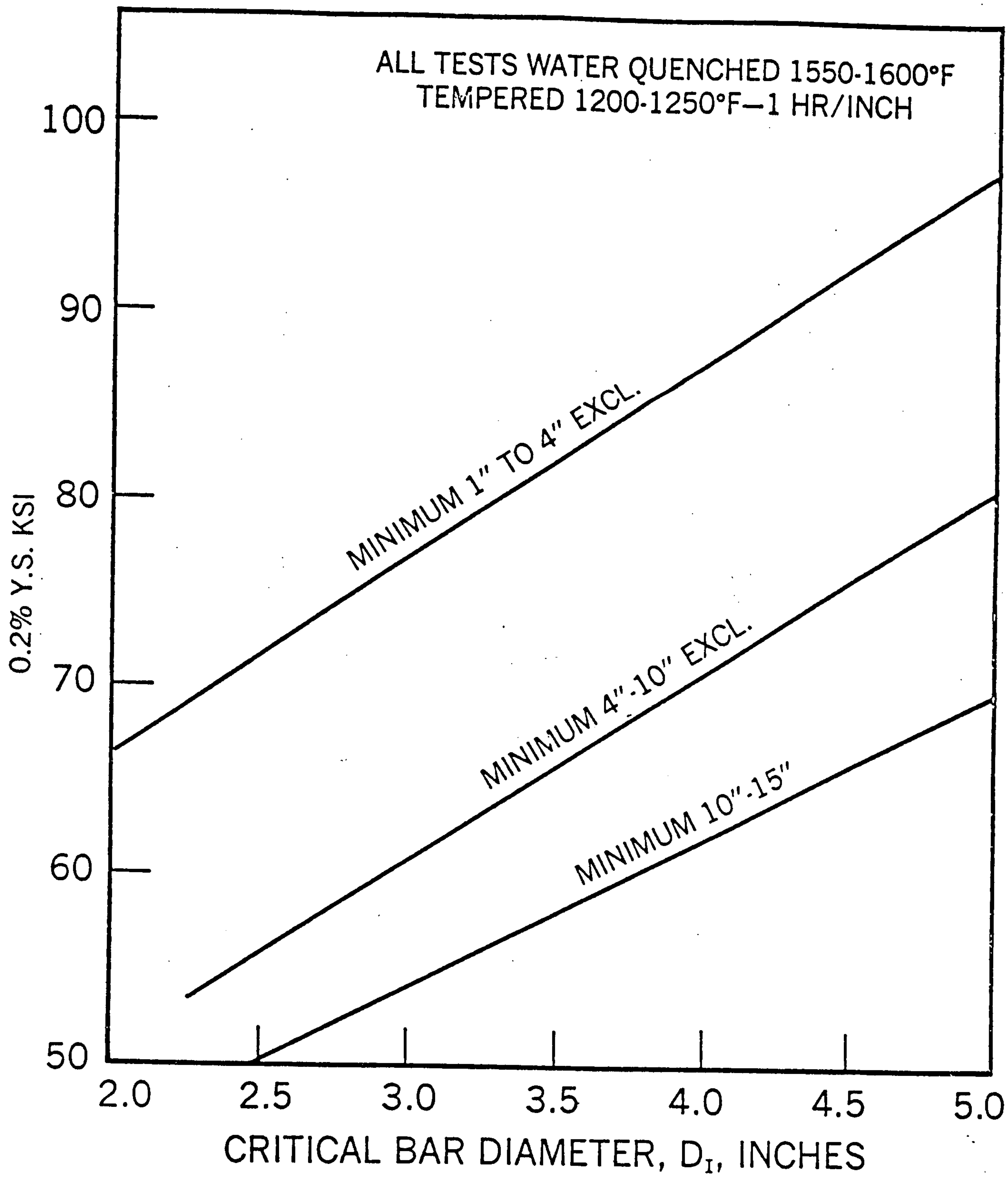

Figure 2. Effect of Hardenability on Yield Strength - ASTM A302 GR. B Steel

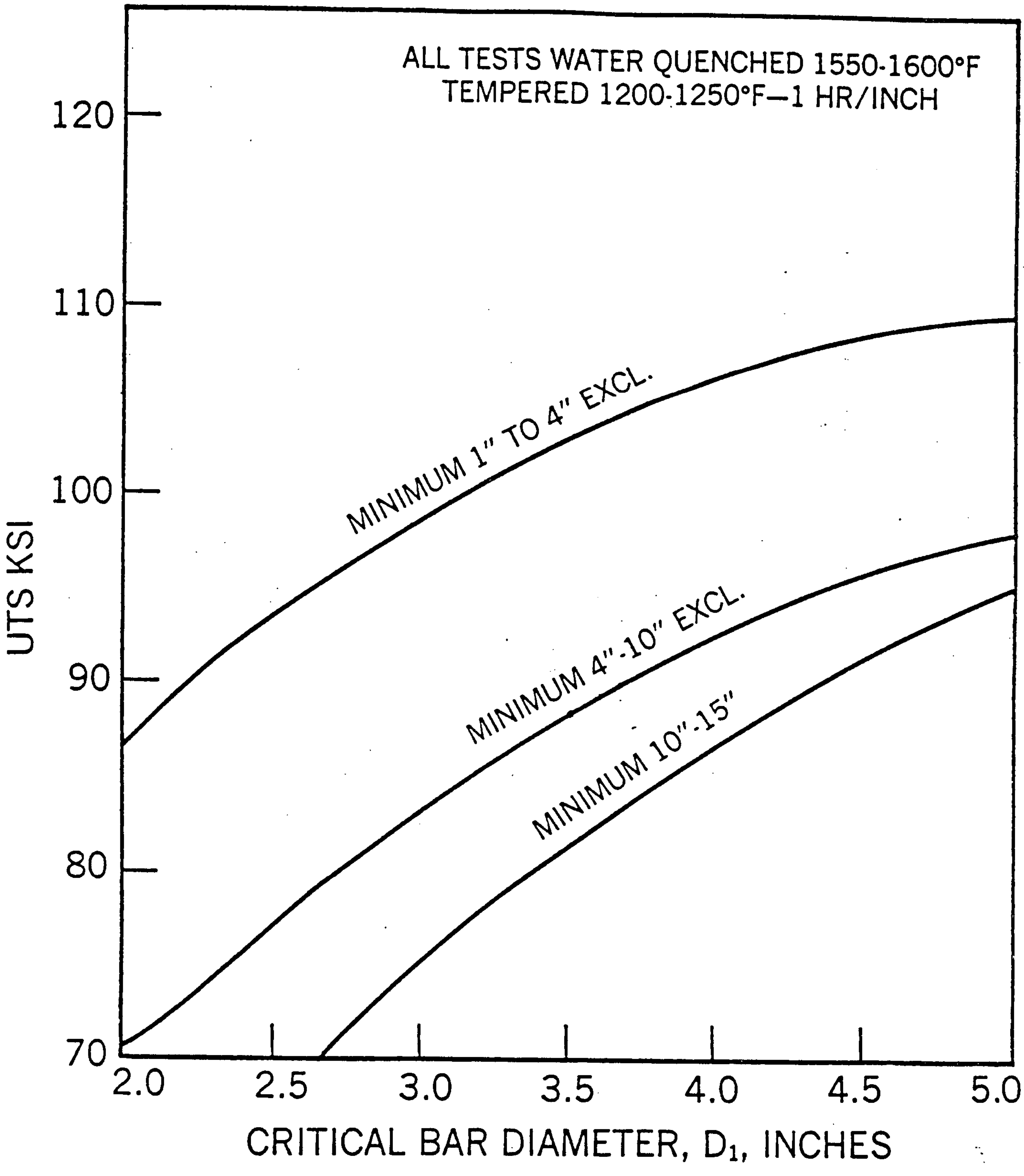

Figure 3. Effect of Hardenability on Tensile Strength - ASTM A302 GR. B Steel

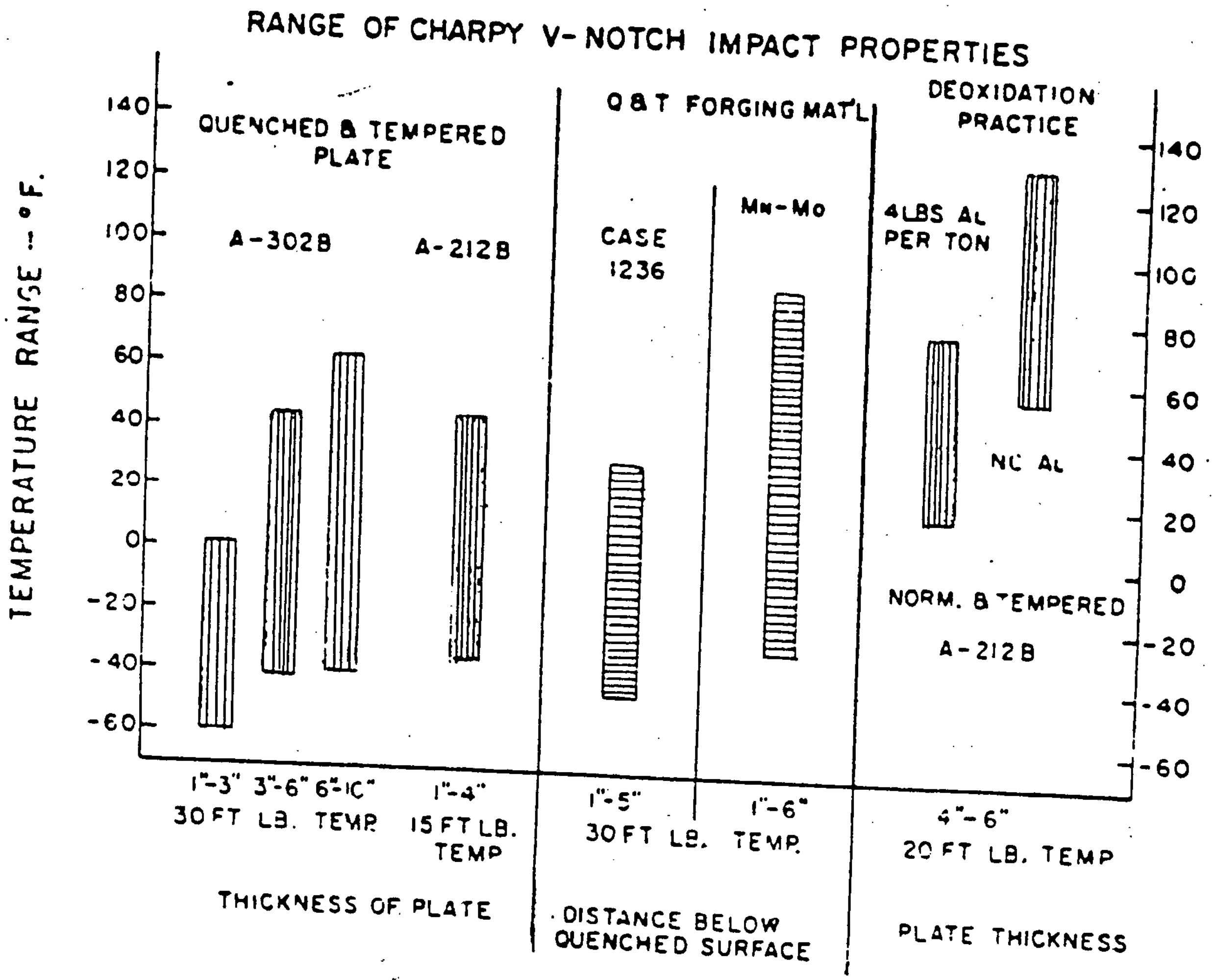

Figure 4. Charpy V-Notch Impact Data for Different Quenched and Tempered Plate Metals

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May 19, 1989
AJG-89-031

Mr. S. Burkhalter
Welding Services Incorporated
3276 Marjan Drive
Atlanta, GA 30340

Subject: Consulting Support for Qualification of Welding Technique for Temperbead Welding on Indian Point Unit 2 Steam Generator Shell

Dear Steve:

The purpose of this letter report is to document my review of the results of the subject temperbead welding qualification test program conducted by Welding Services Incorporated (WSI) for Consolidated Edison Company. The temperbead qualification was performed for the Indian point Unit 2 (IP-2) steam generator shell. The shell material is SA302 Grade B low alloy steel, designated by the ASME Code as P-3 Group 3 material. The purpose of the temperbead qualification was to be prepared to perform a cavity weld repair to one or more of the IP-2 steam generator shells using this welding approach, such that an elevated temperature (1150°F) post weld heat treatment would not be required. ASME Code Case N-432, issued in February, 1986 [1], provided guidance for the temperbead qualification activity at WSI. Both weld parameter trial tests (on a thinner plate of SA302 B material) and procedure qualification tests (on a thicker plate) were performed in order to select a weld procedure and then to qualify it. Although a dilemma arose wherein the thicker plate was not entirely representative in terms of toughness, the results on the thinner and thicker plates, taken together, demonstrate that the procedure should be technically acceptable for use on the 3.5 inch thick steam generator shell at IP-2, as discussed in the following sections of this report.

Weld Trials

In the technical program undertaken for the qualification, WSI performed a technical evaluation of eight (8) different automatic gas tungsten arc welding (GTAW) approaches for welding the SA302 B cavity. The welding approaches included a welding technique which reproduced the Babcock and Wilcox approach which formed the basis for ASME Code Case N-432 [2], as well as modifications to that approach to improve the ease of welding in the field.

Following the welding of eight test coupons of SA302 B plate using these eight different welding techniques, metallurgical and microhardness measurements were performed on the test coupons [3]. The microhardness measurements revealed that three of the welding techniques produced a weld heat affected zone (HAZ) hardness well below Rockwell C hardness 37, an upper bound reference hardness used for selecting a welding process as suitable for use in the temperbead procedure qualification. These three welding techniques included the Reference 1 approach and two approaches where the travel speed was adjusted to provide for greater ease of welding. WSI selected technique P-6, one of the two travel speed adjusted welding techniques, for procedure qualification in accordance with Code Case N-432. The microhardness results for the P-6 welding approach are presented in Table 1 [3]. One notes from Table 1 that the maximum hardness in the HAZ in the technique P-6 plate is Rc 33.5, well below the Rc 37 target value. Thus, this procedure appears quite capable of meeting the HAZ requirements of this representative base material.

One additional weld trial was conducted using the P-6 weld parameters. A single bead weld was deposited on the SA302 B plate and the hardness measured in the HAZ of the plate. This test would compare the untempered hardness with the tempering anticipated using the P-6 welding technique. The results of that single bead weld are presented in Table 2, from Reference 3. One observes from Table 2 that the untempered weld HAZ contains a maximum hardness of Rc 49, more than 15 hardness points higher than the tempered P-6 process HAZ. These results confirmed the fact that the temperbead process developed using the P-6 welding technique is representative of a welding process which should produce a base metal weld HAZ which is substantially softer than an untempered structure. Based upon these results and the ease of application of this welding process, the P-6 welding approach was selected as the preferred approach for the temperbead weld procedure qualification.

Weld Procedure Qualification

The Weld Procedure Qualification Record [4] specifies welding a 3 inch deep groove weld into a 7.125 inch thick plate of SA302 B material. The material type and minimum thickness of the plate and the groove for procedure qualification were specified by Code Case N-432 and by Section XI of the ASME Code [5]. The required tensile, side bend, drop weight and Charpy v-notch specimens were removed from the plate following welding and tested at Applied Technical Services, Inc. The tensile test results and the side bend test results were certified to be acceptable as presented in the Applied Technical Services, Inc. certified test reports [6]. The base metal drop weight specimens produced a no break condition in duplicate specimens at +40°F whereas the weld metal produced a no break condition at -10°F. The Code Case requires the reference nil ductility transition temperature of the weld metal and the base metal to be no greater than +60°F, and the weld HAZ to have Charpy v-notch absorbed energy and lateral expansion equal to or greater than the unaffected base metal at the nil ductility transition temperature plus 60°F.

Since the reference temperature from the all weld metal drop weight specimens was -20°F, the Charpy tests were conducted at +40°F and the requirements of the Code Case and the Code were met. Since the reference temperature from the base metal drop weight tests was +30°F, the Charpy v-notch tests for the base metal and the HAZ were performed initially at 90°F. The base metal specimens did not meet the 1980 ASME Section III values for determining reference NDT at +90°F. However the HAZ energy absorbed and lateral expansion were far superior to the base metal properties, thereby meeting that requirement of the Code Case. The Charpy v-notch results for these tests are presented in Attachment 1 [6].

A second series of base metal and HAZ impact tests were performed at +120°F in an attempt to meet the Code of repair requirements at the maximum temperature allowed by the Code Case for the base metal. The results of these tests are presented in Attachment 1. The base metal tests again failed to meet the Code toughness requirements at the maximum temperature allowed by the Code Case. However, note that the HAZ impact toughness is still superior to the base metal toughness at 120°F, attesting to the adequacy of the weld procedure.

Conclusions

The properties of the base metal used in the temperbead qualification program did not meet all of the requirements of Code Case N-432 and the Code of repair. However, application of these requirements in this case is overly restrictive. The plant was constructed to ANSI Code B31.1 which prescribed much less in the way of notch toughness requirements for this material. The intent of Code Case N-432 is to assure that the weld procedure which is qualified, qualifies a process on representative material which provides assurance that the welding process has not degraded the base metal. The HAZ Charpy v-notch energy absorbed and lateral expansion were clearly greater than those of the unaffected base metal in this test program. The 7.125 inch thick SA302B plate used in this test program is representative material in that section thickness. One characteristic of this material is its poor through thickness hardenability, thereby resulting in plate which in this thickness, may have poor notch toughness in the 1/4t to 3/4t region. In reduced section thicknesses, this material is expected to have better toughness.

The steam generator shell at IP-2 is significantly thinner, 3.5 inches thick, and has superior Charpy v-notch impact properties compared to the test plate as would be expected for this grade of material. The steam generator shell impact strength exceeds the minimum construction code requirements of 30 ft-lbs at +10°F as contrasted to approximately 30 ft-lbs at 120°F for the 7.125 inch thick test plate. Were the test plate a more representative thickness, I believe that the notch impact properties would have been significantly improved. This observation is substantiated by the weld trial tests in the thinner plate (2.25 inches thick), where hardness measurements revealed a softened HAZ consistent with increased toughness for a representative material. The restrictions of Code Case N-432 required a thicker plate than is to be welded to in the field thereby restricting the qualification program to use of a base metal which could not be reasonably expected to meet the notch toughness requirements in the Code Case. Consequently, while all requirements of Code Case N-432 cannot be literally adhered to, I believe that, when considering both the trial weld tests and the procedure qualification tests taken together, a clear demonstration has been made that the HAZ properties have not been degraded in the SA302 B plate and that the temperbead process is technically qualified for use at IP-2.

I trust that this document meets your requirements regarding the qualification of this process. If you have additional questions, or require additional information, please do not hesitate to call.

Very truly yours,

A. J. Giannuzzi, Ph.D, P.E.
Associate

/mc
enclosures

References

1. Cases of the ASME Boiler and Pressure Vessel Code, Case N-432, Repair Welding Using Automatic or Machine Gas Tungsten Welding (GTAW) Temperbead Technique, Section XI, Division 1, February 20, 1986.

2. EPRI Report NP-3614, Repair Welding of Heavy-Section Steel Components in LWRs, Babcock & Wilcox Company, July, 1984.

3. Report CMS 405-89, Subject: Microhardness Testing of Various Welds Involved in Temper Bead Pass Welding, Consulting Metallurgical Services, Inc., April 27, 1989.

4. Procedure Qualification Record AO3N432, Welding Services Inc.

5. ASME Boiler and Pressure Vessel Code, Section XI, 1980 Edition Including All Addenda Through Winter, 1981.

6. Report AO-0394, Applied Technical Services, Inc., Inspection and Metallurgical Test Reports, Purchase Order No. 207593, May 9, 1989.

Attachment to AJG-89-031

TABLE 1

P-6 Weld Process Microhardness Results

Distance Inches	A		B		C		D	
	Filars	KHN_{500}	Filars	KHN_{500}	Filars	KHN_{500}	Filars	KHN_{500}
.002	347	268	338	282	336	286	338	282
.004	335	287	321	313	323	309	333	291
.012	345	271	331	294	323	309	322	312
.020	329	297	330	296	321	313	322	312
.028	333	291	322	312	313	330	334	289
.036	336	286	329	298	309	338	348	266
.044	338	282	327	302	318	319	350	263
.052	335	287	337	284	322	312	342	276
.060	346	269	338	282	320	315	342	276
.076	350	263	340	279	329	298	338	282
.084	356	254	318	319	335	287		
.108	352	260	354	257	330	296		

Highest KHN_{500}	Rc(conv.)
A-297	28.9
B-319	31.1
C-338	33.5
D-312	30.0

Attachment to AJG-89-031

TABLE 2

Microhardness Results on Single Bead Weld
Using P-6 Welding Process

Distance from fusion	A Filars	KHN_{500}	Filars	KHN_{500}	Filars	KHN_{500}
0.005"	255	495				
0.015"	257	486				
0.025"	255	495				
0.045"	248	525				
0.065"	252	508				
0.085"	254	500				
0.105"	254	500				

High Hardness

A - $\frac{KHN}{525}$ 500 $\frac{Rc(conv.)}{49.0}$

ATTACHMENT 1

SUMMARY OF WELD METAL, HAZ
AND BASE METAL CHARPY V-NOTCH
TOUGHNESS TEST RESULTS

APPLIED TECHNICAL SERVICES, INC. MARIETTA, GA.

METALLURGICAL TEST REPORT

Ref. H0-0516 **Date** May 11, 1989

PURCHASE ORDER # 207953

Welding Services, Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

Attention: Steve Burkhalter

MATERIAL: SA 302
Grade B
PQR No: A03N432

Metallurgical Test Procedure

- Hardness ☐
- Case Depth ☐
- Impact Charpy, V-Notch ☒
- Coating Thickness ☐
- Coating Weight ☐
- Bend Test ☐
- Other__________ ☐

Specifications: Tested in accordance with ASME BPVC Section III; NB-2331 and ASME BPVC Section IX; QW-171 35 mils lateral expansion and 50 ft-lb minimum.
Ref. Case Code N-432

Metallurgical Test Results

PART IDENTIFICATION	QUANTITY	RESULTS	REMARKS
Weld Metal	3	1: 63 ft-lb 63 mils lat. exp. 40% shear	T_{cv}: 40°F
		2: 105 ft-lb 69 mils lat. exp. 70% shear	$RT_{NDT} = T_{cv} - 60°F$
		3: 80 ft-lb 62 mils lat. exp. 60% shear	RT_{NDT}: - 20°F

A-11-88

Witnessed by________________

Prepared by: [signature] M. W. Armistead
Test Engineer

Approved by: RWD R. W. Dunning
Manager

[signature] Patricia C. DuBose
Notary Public, Cobb County, Georgia
My Commission Expires Jan. 2[illegible]

APPLIED TECHNICAL SERVICES, INC.

APPLIED TECHNICAL SERVICES, INC. **MARIETTA, GA.**

METALLURGICAL TEST REPORT

Ref. H0-0516 **Date** May 11, 1989

PURCHASE ORDER # 207953

Welding Services, Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

Attention: Steve Burkhalter

MATERIAL: SA 302
Grade B
PQR No: A03N432

Metallurgical Test Procedure

- **Hardness** ☐
- **Case Depth** ☐
- **Impact** Charpy, V-Notch ☒
- **Coating Thickness** ☐
- **Coating Weight** ☐
- **Bend Test** ☐
- **Other**____________ ☐

Specifications: Tested in accordance with ASME BPVC Section III; NB-2331 and ASME BPVC Section IX; QW-171
Ref. Case Code N-432
Absorbed energy and lateral expansion equal to or greater than base metal at T_{NDT} + 60°F of base metal

Metallurgical Test Results

PART IDENTIFICATION	QUANTITY	RESULTS	REMARKS
Heat Affected Zone	3	1. 46 ft-lb 39 mils lat. exp. 20% shear 2. 51 ft-lb 46 mils lat. exp. 20% shear 3. 35 ft-lb 32 mils lat. exp. 20% shear	T_{cv} = 90°F T_{NDT} = 30°F (base metal-drop test) 29 mils lateral expansion and 28 ft-lb average for base metal at T_{vc}=90°F

A-11-88

Witnessed by__________

Prepared by: M. Wayne Armistead M. W. Armistead
Test Engineer

Approved by: RWD R. W. Dunning
Manager

Patricia C. DuBose
Notary Public, Cobb County, Georgia
My Commission Expires Jan. 29, 1992

APPLIED TECHNICAL SERVICES, INC.

APPLIED TECHNICAL SERVICES, INC.		MARIETTA, GA.
METALLURGICAL TEST REPORT		
Ref. H0-0516	**Date** May 11, 1989	**Page** 8 **of** 10

PURCHASE ORDER # 207953

Welding Services, Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

Attention: Steve Burkhalter

MATERIAL: SA 302
Grade B
PQR No: A03N432

Metallurgical Test Procedure

- Hardness ☐
- Case Depth ☐
- Impact Charpy, V-Notch ☒
- Coating Thickness ☐
- Coating Weight ☐
- Bend Test ☐
- Other_____ ☐

Specifications: Tested in accordance with ASME BPVC Section III; NB-2331 and ASME BPVC Section IX; QW-171 35 mils lateral expansion and 50 ft-lb minimum Ref. Case Code N-432

Metallurgical Test Results

PART IDENTIFICATION	QUANTITY	RESULTS	REMARKS
Base Metal	3	C1: 27 ft-lb 28 mils lat. exp. 10% shear	T_{cv}: 90°F
		C2: 31 ft-lb 28 mils lat. exp. 10% shear	T_{NDT}: 30°F
		C3: 39 ft-lb 37 mils lat. exp. 10% shear	

A-11-88

Patricia T. DuBose
Notary Public, Cobb County, Georgia
My Commission Expires Jan. 29, 1992

Witnessed by ____________

Prepared by: M. Wayne Armistead M. W. Armistead
Test Engineer

Approved by: RWD R. W. Dunning
Manager

APPLIED TECHNICAL SERVICES, INC. **MARIETTA, GA.**

METALLURGICAL TEST REPORT

Ref. H0-0516-2 **Date** May 15, 1989 **Page** 1 **of** 1

PURCHASE ORDER # 207953

Welding Services, Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

Attention: Steve Burkhalter

MATERIAL SA 302
Grade B
PQR No: A03N432

Metallurgical Test Procedure

- Hardness ☐
- Case Depth ☐
- Impact Charpy, V-Notch ☒
- Coating Thickness ☐
- Coating Weight ☐
- Bend Test ☐
- Other ☐

Specifications: Tested in accordance with ASME BPVC Section III; NB-2331 and ASME BPVC Section IX; QW-171
Ref. Case Code N-432
Absorbed energy and lateral expansion equal to or greater than base metal at T_{NDT} + 60°F of base metal

Metallurgical Test Results

PART IDENTIFICATION	QUANTITY	RESULTS	REMARKS
Heat Affected Zone	3	1: 61 ft-lb 45 mils lat. exp. 50% shear 2: 52 ft-lb 47 mils lat. exp. 50% shear 3: 49 ft-lb 45 mils lat. exp. 50% Shear	T_{cv} = 120°F

A-11-88

Witnessed by ____________________

Prepared by: [signature] M. W. Armistead

APPLIED TECHNICAL SERVICES, INC. **MARIETTA, GA.**

METALLURGICAL TEST REPORT

Ref. H0-0516 **Date** May 11, 1989

PURCHASE ORDER # 207953

Welding Services, Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

Attention: Steve Burkhalter

MATERIAL: SA 302
Grade B
PQR No: A03N432

Metallurgical Test Procedure

- Hardness ☐
- Case Depth ☐
- Impact ☐
- Coating Thickness ☐
- Coating Weight ☐
- Bend Test ☐
- Other_____ ☐

Specifications: Tested in accordance with ASME BPVC Section III; NB-2331 and ASME BPVC Section IX; QW-171 35 mils lateral expansion and 50 ft-lb minimum. Ref. Case Code N-432

Metallurgical Test Results

PART IDENTIFICATION	QUANTITY	RESULTS	REMARKS
Base Metal	3	D1: 39 ft-lb 36 mils lat. exp. 20% shear D2: 27 ft-lb 27 mils lat. exp. 30% shear D3: 34 ft-lb 34 mils lat. exp. 30% shear	T_{cv}: 120°F

A-11-88

Patricia T. DuBose
Notary Public, Cobb County, Georgia
My Commission Expires Jan. 28, 1993

Witnessed by ____________

Prepared by: M. Wayne Armistead M. W. Armistead
Test Engineer

Approved by: RWD R. W. Dunning
Manager

APPLIED TECHNICAL SERVICES, INC.

Dr. Anthony J. Giannuzzi, P. E.

Associate

Education

BS, Physics, LeMoyne College (1964)
MS, Solid State Science and Technology, Syracuse University (1967)
PhD, Solid State Science and Technology, Syracuse University (1969)

Professional Associations

Professional Corrosion Engineer, State of California

Professional Experience

1983 to present	Structural Integrity Associates, San Jose, CA Vice President
1979 to 1983	Electric Power Research Institute, Palo Alto, CA Project Manager
1978 to 1979	NUTECH, San Jose, CA Project Manager
1972 to 1978	General Electric Company, San Jose, CA Principal Engineer
1969 to 1972	Aerojet Nuclear Systems Company, Sacramento, CA

Summary

Dr. Giannuzzi has been involved in solving materials and corrosion problems for the nuclear industry since 1969. One of the world's leading authorities on intergranular stress corrosion cracking of stainless steel in aqueous systems, Dr. Giannuzzi was employed by the Electric Power Research Institute in the Nuclear Systems and Materials Department for three and one–half years prior to joining Structural Integrity Associates in 1983. At EPRI, Dr. Giannuzzi was task leader and principal investigator involved in development and qualification of all the Boiling Water Reactor IGSCC piping remedies. This activity included primary responsibility for qualifying and producing material specification for the alternative materials (Types 316NG and 304NG stainless steels), qualifying the induction heating stress improvement (IHSI) remedy, qualifying heat sink welding, last pass heat sink welding and the weld overlay and performing the investigations to determine the causes of and remedies to IGSCC in Type 304 stainless steel pipe.

In addition to his BWR IGSCC responsibility at EPRI, Dr. Giannuzzi has had the lead responsibility for investigating the causes of low pressure large steam turbine stress corrosion cracking in nuclear and fossil steam turbines and has been involved in projects associated with bolt and fastener reliability, steam and water piping erosion–corrosion and has been active in projects related to primary and secondary side corrosion of steam generators. Dr. Giannuzzi has also been the lead project manager responsible for all materials related failure analysis activities in the Nuclear Systems and Materials Department and was a member of the EPRI Three Mile Island Unit 2 task force.

Prior to his employment at EPRI, Dr. Giannuzzi was employed as a senior consultant at NUTECH. While at NUTECH, he formed the stress corrosion cracking group and developed the methodology used to estimate likely locations of IGSCC in stainless steel piping systems. He also was involved in the earliest investigations involving PWR boric acid corrosion and assisted in the final formulation of the NRC I–E Bulletin 79–02 which established criteria for inspection of the boric acid system piping.

From 1972 to 1978, Dr. Giannuzzi worked as a principal development engineer at the General Electric Company Nuclear Energy Division. His responsibilities while at GE involved investigation of alternative materials and processes to alleviate the IGSCC problem in stainless steel piping. He managed the initial weld residual stress measurement and analyses activities which lead to the development of the residual stress remedies to IGSCC.

From 1969 to 1972, Dr. Giannuzzi worked for the Aerojet Nuclear Systems Company developing materials for use in the nuclear rocket engine (NERVA).

In 1983, Dr. Giannuzzi founded Structural Integrity Associates with Dr. P. C. Riccardella and Dr. T. L. Gerber. His activities at Structural Integrity have included nuclear plant life extension studies, temper bead welding development on low alloy steels and selecting of remedies to IGSCC in BWRs.

Research
Sponsored by the Welding Research Council
of the Engineering Foundation
WRC

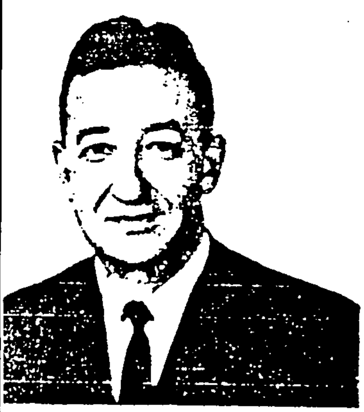
PPLEMENT TO THE WELDING JOURNAL, OCTOBER 1962

1962 ADAMS LECTURE

lization of Quenching and Tempering for provement in Properties of Low Alloy Steels in Heavy cknesses for Welded Construction

Successful welded construction with low alloy steels in heavy thicknesses requires closer control of techniques and procedures than those generally required for annealed and normalized and tempered material

R. E. LORENTZ, JR.



. Lorentz, Jr., was born 46 ago in Champaign, Ill. Fol- g his early schooling in Illinois tended the University of Illi- where he received a Bachelor of e degree in Metallurgical En- ing in 1939. A year later he ed a masters degree in science Metallurgical Engineering— Lehigh University and immedi- joined Combustion Engineer- nc., where he has since been here he is now District Manager—Metallurgical Research and Development.

The affiliations of Mr. Lorentz include membership in the AMERICAN WELDING SOCIETY, the American Society for Metals, the American Society for Testing Materials as well as the Chattanooga Engineers Club. He has held the position of chairman as well as other offices in local sections of AWS and ASM. He is the Past Southeastern District Representative of AWS and was a member of the National Nominating Committee of AWS for 1956–1957 as well as 1961–1962.

Mr. Lorentz is presently a member of several technical committees. These include the ASME Subcommittee on Welding, ASTM Committee-7 on Nondestructive Testing, the WRC High Alloys Committee, the PVRC Pressure Vessel Fabrication Committee, the AWS Committee on Standard Qualification Procedures, and the AWS Committee for Section IV Chapter 75 of the WELDING HANDBOOK (Clad Steels). He has also contributed several significant articles to the technical literature, the last being "The Eddystone Story" which he co-authored with E. C. Chapman and which was in the ASME transactions.

FOREWORD. I wish to express my appreciation to the officers and members of the AMERICAN WELDING SOCIETY in being invited to present this, the 20th Adams Lecture. I appreciated the friendship and high principles of Comfort A. Adams over a period of several years. His enthusiasm and interest in the SOCIETY were attested to by his regular attendance at the technical sessions (usually in the front row and participation in the discussions. In those earlier years, it was possible to attend all of the sessions.

Introduction

This broad subject is one which is receiving increasing attention. The Pressure Vessel Research Committee of the Welding Research Council foresaw the need many years ago for basic study in this field and has sponsored University research which has been the forerunner of industrial

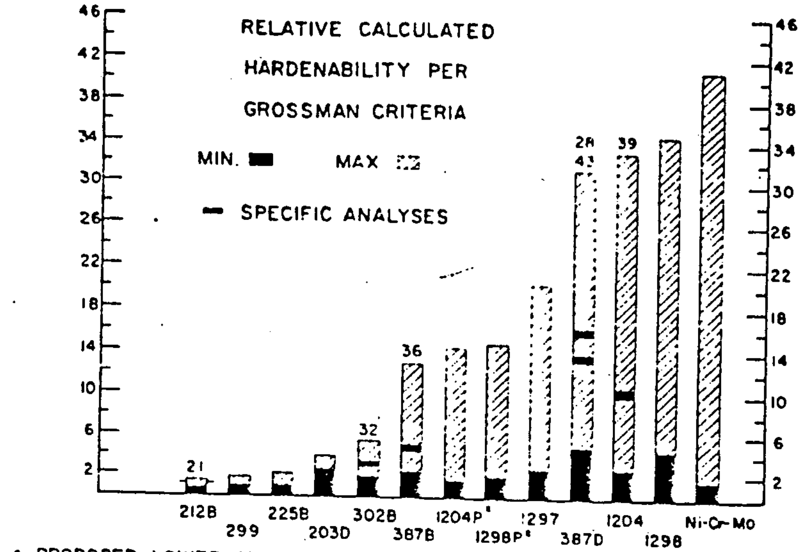


Fig. 1—Hardness ranges calculated from chemical analyses of several pressure vessel steels

development. The work of Professor Stout and his colleagues at Lehigh University has been and is continuing to be particularly progressive.[1-10] The continuing work of W. S. Pellini and his colleagues at the United States Naval Research Laboratory in illuminating conditions affecting brittle fracture and temper embrittlement has been pertinent.[11-16] Pertinent information on the subject has been presented in previous Adams Lectures.[17-21] Many others have also contributed[22-18] to the extent that the subject is now receiving broad study aimed toward the development of base material purchase specifications in the American Society for Testing Materials and development of fabrication saf rules in the American Society Mechanical Engineers. Both gro have set up committees study various aspects.

Present Usage

High strength quenched and te pered plates up to 2½ in. maxim thickness are presently recogni by the ASME Boiler and Press Vessel Code in its Case Nos. 12 1297 and 1298. This recognition limited to particular chemical an yses of material and is predica on the material exhibiting maxim and minimum required tensile pr erties throughout its thickness. is also predicated upon the mate being heat treated by the mate manufacturer. In addition, fabricator is required to limit a forming and stress relieving heat to a temperature below the n tempering temperature. Other li its are also assigned.

The ASME Code also presen recognizes use of "accelerated cc ing" in several case numbers (12 1241, 1243, 1255, etc.) applied

Table 1—Chemical Analysis and Multiplying Factors for Determining Hardenability

	A212B		A299		A225B		A203D		A302B		1204P*		A387B	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
C	0.15	0.35	0.15	0.31	0.10	0.20	0.10	0.20	0.15	0.25	0.10	0.23	[illegible]	0.17
Factor	0.14	0.22	0.15	0.20	0.13	0.17	0.13	0.17	0.15	0.19	0.12	0.18	[illegible]	0.16
Mn	0.60	0.90	0.86	1.45	0.90	1.45	0.60	0.90	1.10	1.55	0.65	1.05	0.36	0.69
Factor	3.5	4.5	4.5	6.8	4.5	7.0	3.5	4.5	5.5	7.3	3.5	5.1	2.5	3.9
P	0.010	0.035	0.01	0.035	0.01	0.035	0.01	0.035	0.01	0.035	0.01	0.035	0.01	0.03
Factor	1.03	1.1	1.03	1.1	1.03	1.1	1.03	1.1	1.03	1.1	1.03	1.1	1.03	1.1
S	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04
Factor	0.96	0.99	0.96	0.99	0.96	0.99	0.96	0.99	0.96	0.99	0.96	0.99	0.96	0.99
Si	0.13	0.33	0.13	0.33	0.13	0.32	0.13	0.32	0.13	0.32	0.18	0.37	0.13	0.32
Factor	1.08	1.25	1.08	1.25	1.08	1.25	1.08	1.25	1.08	1.25	1.12	1.27	1.08	1.25
Ni	...	...	...	...	...	...	3.18	3.82	...	...	...	...	..	..
Factor	...	...	...	...	...	...	2.8	3.8	...	...	...	...	...	..
Cr	...	...	...	...	...	...	...	...	...	...	0.36	0.69	0.74	1.2
Factor	...	...	...	...	...	...	...	...	...	...	2.0	2.95	3.15	4.7
Mo	...	...	...	...	...	...	...	...	0.41	0.64	0.12	0.28	0.40	0.70
Factor	...	...	...	...	...	...	...	...	2.25	2.90	1.38	1.85	2.2	3.2
V	...	...	...	...	0.07	0.16	...	...	...	...	0.02	0.09	...	..
Factor	...	...	...	...	1.35	1.40	...	...	...	...	1.25	1.3	...	..
Ti	...	...	...	...	...	...	...	...	...	...	0.01	0.03	...	..
Factor	...	...	...	...	...	...	...	...	...	...	1.05	1.08	...	..
Zr	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Factor	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Cu	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Factor	...	...	...	...	...	...	...	...	...	...	...	...	...	..
B	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Factor	...	...	...	...	...	...	...	...	...	...	0.0005	0.005	...	..
	...	...	...	...	...	...	...	...	...	...	1.02	1.48	...	..
Hardenability	0.58	1.28	0.74	1.85	0.85	2.27	1.36	3.96	1.98	5.48	1.72	14.4	2.13	12.8

...not for purpose of utilizing any higher tensile properties which may result. This approach is limited to materials of relatively low hardenability.

Quenched and tempered steels of heavier thicknesses than 2½ in. have been used to fabricate "non-Code" type pressure vessels for ambient and low temperature service. Large cylindrical pressure vessels of this type up to approximately 4 in. and heavier thickness, of single thickness material, have been built to allowable stress values of up to ½ the yield strength.

Large tonnages of quenched and tempered steel have been used for pressure vessel and structural applications.[30, 31] Large tonnages have been used for marine applications requiring both high strength and exceptionally high notch toughness. These have been built to Government material and fabrication specifications.[32-34]

Possible Future Usage

The properties available through and large structures exhibiting these properties has awaited developments in procedures for welding and in procedures of control for assurance of required properties. ASME Code approval of the quenched and tempered materials to limited thicknesses was given only after extensive testing was performed, involving not only tests of welded samples but also tests to destruction of relatively large vessels. Service experience of these materials has now been obtained with pressure vessel and structural applications.

Lower alloy modifications of the materials have been proposed for use for the thinner thicknesses, heat treated to the same strength levels, to allow use of more economical materials. Conversely, the original alloy range has been proposed for usage at thicknesses greater than 2½ in. Requests for ASME Code approval of other low alloy steels up to various thickness levels have been made.

Several of the ASME Code materials presently used in the normal-quenched" and tempered condition which would exhibit improved mechanical properties. Some of these materials would exhibit this improvement throughout thicknesses heavier than 2½ in. Most would exhibit variation in properties from center of thickness to surface. What are the maximum thicknesses which would exhibit improved properties throughout their thickness? What variations are exhibited? Is it possible to utilize any improved tensile properties in design?

There is a present need for large diameter vessels of an operating pressure which requires thickness of plates of present ASME Code materials heavier than the capabilities of mills to produce (with sufficient degree of hot working) but which may be produced in usable thicknesses and sizes with quenched and tempered materials. Although satisfying this need is not entirely limited by economics, the wider use of quenched and tempered materials may allow more economical finished products for other needs through

Table 1 (Continued)

	1298P'		1297-2		1204-9		A387D		1298-2		Ni-Cr-Mo	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
	0.11	0.22	0.13	0.22	0.08	0.22	0.08	0.15	0.10	0.22	0.10	0.23
ctor	0.125	0.17	0.14	0.17	0.10	0.17	0.10	0.15	0.12	0.17	0.13	0.175
n	0.36	0.74	0.75	1.15	0.55	1.05	2.07	0.63	0.36	0.74	0.10	0.40
ctor	2.5	4.0	4.0	5.7	3.0	5.1	2.0	3.7	2.5	4.0	1.3	2.3
	0.01	0.035	0.01	0.035	0.01	0.035	0.01	0.035	0.01	0.035	0.01	0.035
ctor	1.03	1.1	1.03	1.1	1.03	1.1	1.03	1.1	1.03	1.1	1.03	1.1
	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.035	0.01	0.04	0.01	0.04
ctor	0.96	0.99	0.96	0.99	0.96	0.99	0.96	0.99	0.96	0.99	0.96	0.99
	0.18	0.37	0.44	0.86	0.13	0.37	0.15	0.50	0.18	0.37	0.15	0.35
ctor	1.12	1.27	1.3	1.6	1.08	1.27	1.1	1.35	1.12	1.27	1.08	1.28
	...	..		...	0.67	1.03	...	...	...	...	2.0	3.25
ctor	...	.		...	1.2	1.35	...	...	...	...	1.8	2.8
	0.79	[illegible]	0.4[illegible]	0.84	0.36	0.69	1.88	2.62	1.34	2.06	0.90	1.85
ctor	3.2	[illegible]	2.[illegible]	3.35	2.0	2.95	6.3	8.4	4.8	6.8	3.5	6.3
	0.12	[illegible]	0.1[illegible]	0.31	0.36	0.64	0.85	1.15	0.36	0.64	0.23	0.60
ctor	1.35	[illegible]	1.4	1.90	2.05	3.0	3.6	4.6	2.05	3.0	1.6	2.8
	...		..	..	0.02	0.09	...	...	...	...	...	0.03
ctor	...		..	.	1.25	1.3	...	...	...	...	...	1.35
	[illegible]03	[illegible]	..		...	...	...	...	0.03	0.11	...	0.02
ctor	1 08	1	...		...	...	...	...	1.08	1.1	...	1.05
	...	.	04	0.16	...	...	...	...	...	...	...	...
ctor	..	.	1	1.[illegible]	...	...	...	...	...	...	...	...
	[illegible]7	0.[illegible]	..	.	0.12	0.53	...	...	0.17	0.43	...	0.25
ctor	[illegible]5	1	.	.	1.03	1.2	...	...	1.05	1.15	...	1.1
	[illegible]015	[illegible]	.	0.00[illegible]	0.002	0.006	...	...	0.0015	0.005	...	...
ctor	[illegible]	[illegible]	.	1.4	1.4	1.48	...	...	1.2	1.48	...	...
rdenability	[illegible]4	1[illegible]	[illegible]4	[illegible].4	2.84	33.2	4.94	31.5	4.47	35.8	1.82	43.2

Proposed modifica[illegible] to A[illegible] C[illegible] Ca[illegible] [illegible] th[illegible]
Proposed modifi[illegible] to A[illegible] C[illegible] Ca[illegible] [illegible] th[illegible]
ASME Code Case [illegible] nal[illegible]

Fig. 2—Location of thermocouples on test plate to determine cooling rates

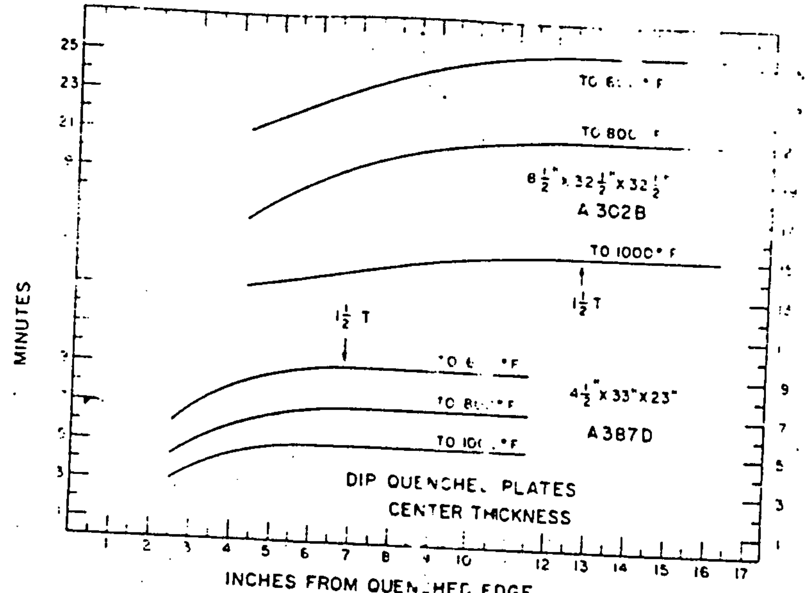


Fig. 3—Time required to reach specific temperatures during dip quenching

use of thinner and lighter materials.

The heavy thickness materials are most economically shaped by hot pressing rather than cold or warm pressing.[42-44] The presently used materials require normalizing, which can be performed either at the mill applied to flat plate or forged shapes or at the fabricator's shop. The fabricators generally find it more economical, with heavy thickness plates, to hot form during cooling from the normalizing temperature and to warm size or cold size following hot forming in order to remove distortions in shape caused by air cooling from normalizing. Application of this procedure to a quenched and tempered product fabricated from thick plate requires that the fabricator apply the quench and temper either to the formed parts prior to welding or to the finished vessel after welding. Both procedures may be applicable dependent upon the finished product.

Both procedures, however, require close control of all the variables of the quenching process to the same extent as those applied by the material producer at his mill. For some designs, it may be advantageous to apply quenching to shapes prior to joining them by welding than to apply quenching to a completed vessel. Distortion due to heat treatment of shapes can be removed by cold or warm shaping. In either case, the weld metal must be specifically tailored for the applicable heat treatment of tempering only or quench and temper. Also in either case, the required properties must also be met in the heat-affected zone.

This sequence of events has resulted in a need for development of material procurement specifications specifically designed for quenched and tempered steels, heat treated either by the material producer or by the material fabricator. Traditionally this has been a function of the American Society for Testing Materials.

It also has resulted in a need for further development of codes regulating safe construction rules and procedures. Traditionally this has been a function of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code and various Government agencies. All of these groups are active in this subject.

Development of high strength weld metal deposits has kept pace with quenched and tempered base metal development.[45] What remains to be done for heavy thicknesses is to determine properties which are available and possible, to determine limits of controls necessary for assurance of these properties, and to police purchase and fabrication such that these are obtained.

Hardenability

An approximation of the depth of hardening capabilities of various materials can be obtained from the work of M. A. Grossmann.[46] The range of minimum and maximum hardenability calculated from the range of chemical analysis of several presently used and proposed type pressure vessel steels is shown in Fig. 1. The chemical analyses and multiplying factors used in these calculations are given in Table 1 of the Appendix.

It appears obvious that utilization of the higher hardenability steels to their heaviest capable thickness requires close control of analysis. This also emphasizes the need for close analysis control in minimization of segregation of analysis.

The ... 1204 and 1298 steels are reported capable of meeting 90,000 to ... psi minimum yield strengths at the center of the thickness of 4 in. or heavier material. The 387D material is capable of meeting 100,000 psi minimum yield strength at the center of the thickness of 6 in. or heavier material.[46]

The relative hardenability data shown in Fig. 1 is useful in estimating depth of hardening capabilities for material sizes which can be cooled rapidly enough to allow transformation of all or a portion of the material to martensite or bainite. Heavy thicknesses of some materials cannot be cooled sufficiently rapidly to allow such transformation. The transformation characteristics of each material and the practical cooling rates possible for the material may regulate the degree of hardenability which can be realized.[47, 48]

Design

Presently approved ASME quenched and tempered materials, as other Code materials, are assigned an allowable maximum design stress of 1/4 of their minimum ultimate tensile strength to a specified temperature limit. Where allowable stresses are assigned above this limit, they are progressively decreased dependent upon criteria based upon yield strength, stress rupture strength or creep strength at each temperature.

The high strength quenched and tempered plate materials approved

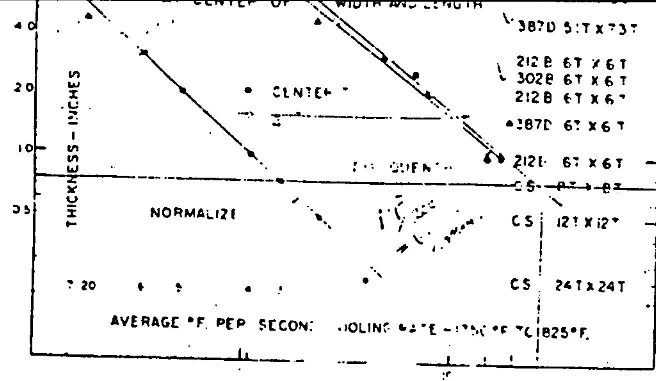


Fig. 4—Cooling rates for dip quench and normalized test pieces

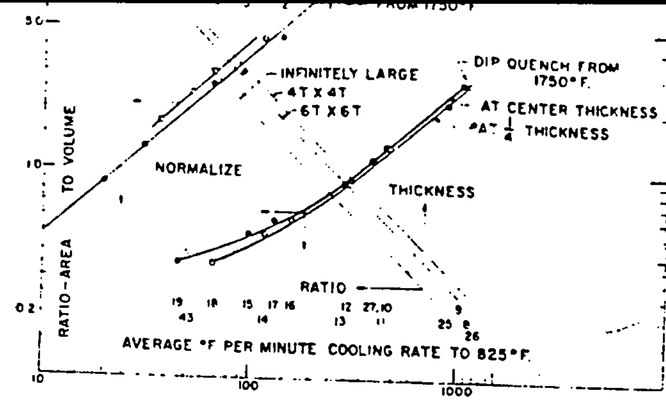


Fig. 5—Cooling rate vs. ratio of surface area to volume

by the ASME Code are presently assigned a maximum allowable stress up to 2 in. thickness of 28,750 psi at minus 20 to plus 150° F and progressively less up to 650° F at which the allowable stress is limited to 25,000 psi. Between 2 and 2½ in. the allowable stress is 26,250 psi at minus 20 to plus 150° F and decreases to 22,800 psi at 650° F.

New design criteria, which consider yield strength as well as tensile strength and which additionally consider superimposed service stresses such as thermal stresses and low cycle fatigue and more rigorously define allowable design details, are about to be presented in a new ASME Code section. This section also more rigorously defines destructive and nondestructive testing. With this approach, higher design stresses are to be allowed for specified materials and temperature limits.

The designer wishes to select the least expensive steel capable of consistently meeting the highest design properties at the maximum thickness required in the design. The maximum individual plate thickness in the design, among other factors, may be dependent upon whether the design is based on use of a single thickness material or a multilayer thickness material. The latter, where it is allowed by the construction code, will allow either the selection of a thin thickness but high strength economical material, the selection of a more expensive higher strength thin thickness material, or the selection of a thick thickness more expensive material usable in fewer layers to obtain the requisite thickness. This approach is regulated by the fabrication cost of assembling the multilayer and by whether operating conditions are such as to allow this type construction. This can be dependent upon heat transfer conditions, vessel connection requirements and practicality of nondestructive testing requirements. For many constructions, a single thickness material is required. This requires a material capable of meeting minimum design strength at the center of the thickness of the quenched and tempered single thickness material.

Cooling Rate

The means available for cooling from the austenitizing temperature consist of air cooling, oil quenching and water or brine quenching. The quenching can be accomplished by either a spray or by dipping in the quenching medium. Dip quenching should be done in a medium which is agitated to avoid vapor blanketing. Agitation can be accomplished by circulation of the medium by pumping or by agitation with air.

Literature data is available concerning cooling rates of various shapes and sizes of samples subjected to cooling in still air and various quenching methods.

The pertinent variables involved in spray and dip quenching are:

1. Austenitizing temperature and time.
2. Time from furnace to start of quench and temperature at start of quench.
3. Surface condition of the metal (degree of scale).
4. Volume of spray per unit time per unit area per side and for dip application the ratio of quenching medium volume to metal volume, the degree of agitation and circulation, and the temperature rise of the quenching medium.
5. Time of application.

Data directly applicable to pressure vessel part thicknesses and sizes is limited. Work most directly pertinent has been performed at Lehigh University[76] on normalizing and spray quenching cooling rates.

Cooling rates obtained by dip quenching of plates in agitated water and comparable cooling rates obtained by normalizing have been investigated. This has been done with various sizes and thicknesses of plates with thermocouples placed at the center of the thickness and at the ¼ thickness level at various locations in the plates. These locations varied from the center of the width and length to near the edges of the plates as indicated in photograph of Fig. 2.

Figure 3 shows the time required to reach a specific temperature during dip quenching at various distances from the quenched edge for two heavy thicknesses of a range of thicknesses tested. This time becomes uniform at a distance from the quenched edge of approximately 1½ times the plate thickness. A test plate size of width and length of three times the plate thickness would exhibit a cooling rate at the center of its width, length and thickness approximating that of a larger production-size plate. A specimen of larger size than 3T x 3T would be required, however, if any appreciable volume of metal is required for representative testing samples. This is also dependent upon the hardenability characteristics of the material.

Figure 4 shows cooling rate data from 1750 to 825° F for both dip quenched and normalized test pieces. The data given are for the ¼ thickness level and at the center of the thickness and at the center of the width and length of the test samples. The majority of the test samples consist of carbon steel material and the lines are drawn specifically to the carbon steel material. The A302 Grade B material and the A387 Grade D material in general are off the curve and are better represented on the dip quench

Table 2—Cooling Data

Point no.	Material	Thickness, in.	Width in.	Length in.	A/V	Cooling	At center of width and length, Average °F/min. to 400	600	825	1000	1200	1400	Start from °F	Location in thickness	S[illegible]
1	C.S.	1/4	6	6	8.7	Air	133	182	238	268	317	428	1750	Center	24T x [illegible]
2	C.S.	1/2	6	6	4.6	Air	91	118	142	156	190	270	1750	Center	12T [illegible]
3	C.S.	3/4	6	6	3.1	Air	59	77	92	104	112	194	1750	Center	8T [illegible]
4	212B	1	6	6	2.7	Air	40	53	66	73	79	160	1750	Center	6T x 6T
5	212B	2	12	12	1.33	Air	18	26	31	32	37	70	1750	Center	6T x 6T
6	212B	3	18	18	0.89	Air	13	17	20	21	23	37	1750	Center	6T x 6T
7	212B	6 3/8	24	24	0.50	Air	6	7.7	9.2	9.6	11	17.5	1750	Center	3.8T x 3.8T
8	212B	1	6	6	2.7	Water	1158	1188	1110	1104	1104	1230	1750	1/4T	6T x 6T
9	212B	1	6	6	2.7	Water	1122	1116	1050	978	1032	1164	1750	Center	6T x 6T
10	212B	2	12	12	1.33	Water	435	467	478	459	486	500	1750	1/4T	6T x 6T
11	212B	2	12	12	1.33	Water	·35	460	474	450	452	477	1750	Center	6T x 6T
12	212B	3	18	18	0.89	Water	284	294	303	302	330	338	1750	1/4T	6T x 6T
13	212B	3	18	18	0.89	Water	272	280	283	266	260	256	1750	Center	6T x 6T
14	212B	6 3/8	24	24	0.50	Water	103	110	118	125	131	116	1750	1/4T	3.8T x 3.8T
15	212B	6 3/8	24	24	0.50	Water	95	101	100	91	79	77	1750	Center	3.8T x 3.8T
16	387D	4 1/2	23	33	0.59	Water	121	139	162	178	184	166	1750	1/4T	5.1T x 7.3T
17	387D	4 1/2	23	33	0.59	Water	113	120	132	143	162	146	1750	Center	5.1T x 7.3T
18	302B	8 1/2	32 1/2	32 1/2	0.36	Water	47	55	67	78	79	77	1750	1/4T	3.8T x 3.8T
19	302B	8 1/2	32 1/2	32 1/2	0.36	Water	42	45	46	50	52	47	1750	Center	3.8T x 3.8T
20	387D	4 1/2	23	33	0.59	Air	6.5	8.1	9.7	15	18	21	1750	Center	5.1T x 7.3T
21	212B	1/2	8	10	4.5	Air	70	91	118	130	150	250	1650	Center	16T x 20T
22	212B	3/4	8	10	3.1	Air	40	54	66	73	75	125	1650	Center	10.7 x 13.3T
23	212B	1	8	10	2.5	Air	31	42	52	56	60	100	1650	Center	8T x 10T
24	212B	1 1/2	8	10	1.8	Air	23	31	41	41	40	71	1650	Center	53T x 6.7T
25	212B	1	30	30	2.13	Water	1122	1080	894	804	798	810	1750	Center	30T x 30T
26	387D	1 1/2	9	9	1.78	Water	900	990	1176	1320	1176	954	1750	Center	6 x 6T
27	302B	2 1/2	15	15	1.16	Water	368	379	388	443	432	408	1750	Center	6 x 6T
28	387D	1/2	8	10	4.45	Air	54	70	83	167	220	232	1750	Center	16 x 20T
29	387D	3/4	8	10	3.12	Air	38	51	59	116	157	175	1750	Center	10.7 x 13.3T
30	387D	1	8	10	2.45	Air	28	34	34	68	85	100	1750	Center	8 x 10T
31	387D	1 1/2	8	10	1.78	Air	22	28	31	53	73	88	1750	Center	5.3 x 6.7T
32	302B	1/2	8	10	4.45	Air	58	75	97	163	225	250	1650	Center	16 x 20T
33	302B	3/4	8	10	3.12	Air	35	48	59	93	150	167	1650	Center	10.7 x 13.3T
34	302B	1	8	10	2.45	Air	28	36	44	65	112	125	1650	Center	8 x 10T
35	302B	1 1/2	8	10	1.78	Air	20	26	32	43	69	83	1650	Center	5.3T x 6.7T
36	387B	1/2	8	10	4.45	Air	59.5	78	103	130	150	250	1650	Center	16 x 20T
37	387B	3/4	8	10	3.12	Air	41.5	54	69	87	98	125	1650	Center	10.7 x 13.3T
38	387B	1	8	10	2.45	Air	31	42	50	63	69	100	1650	Center	8 x 10T
39	1204	1/2	8	10	4.45	Air	57	73	100	188	250	380	1700	Center	16 x 20T
40	1204	3/4	8	10	3.12	Air	44	55	71	118	165	234	1700	Center	10.7 x 13.3T
41	1204	1	8	10	2.45	Air	32	44	53	76	128	146	1700	Center	8 x 10T
42	1204	1 1/2	8	10	1.78	Air	22	29	37	50	81	100	1700	Center	5.3 x 6.7T
43	387D	7 3/16	24 1/4	48 3/8	0.405	Water	47	49	51	54	56		1750	1/4T	3.4 x 6.8T

Table 3—Material Check Analyses, %

Point numbers	Material	Si	S	P	Mn	C	Cr	Ni	Mo	Cu	V	B
1	C.S.	0.05	0.019	0.009	0.40	0.059	...	...	...	...	...	...
2	C.S.	0.06	0.020	0.011	0.47	0.176	...	...	...	...	...	...
3	C.S.	0.07	0.019	0.017	0.47	0.210	...	...	...	...	...	...
4, 8, 9	212B	0.20	0.021	0.016	0.72	0.298	...	...	...	...	...	...
5, 10, 11	212B	0.25	0.019	0.020	0.80	0.290	...	...	...	...	...	...
6, 12, 13	212B	0.24	0.020	0.003	0.79	0.281	...	...	...	...	...	...
7, 14, 15	212B	0.20	0.019	0.009	0.74	0.279	...	...	...	...	...	...
16, 17, 20	387D	0.28	0.029	0.014	0.53	0.13	2.40	...	0.98	...	...	...
18, 19	302B	0.21	0.023	0.017	1.57	0.256	...	...	0.50	...	...	...
21, 22, 23, 24	212B	0.20	0.017	0.012	0.82	0.29	...	...	...	...	...	...
25	212B	0.23	0.017	0.027	0.86	0.26	Nil	...	Nil	...	...	...
26, 28, 29, 30, 31	387D	0.22	0.021	0.011	0.50	0.146	2.29	...	0.98	...	...	...
27	302B	0.20	0.025	0.041	1.20	0.23	...	...	0.50	...	...	...
32, 33, 34, 35	302B	0.19	0.025	0.036	1.21	0.23	...	...	0.52	...	...	...
36, 37, 38	387B	0.25	0.023	0.011	0.50	0.143	0.94	...	0.47	...	...	...
39, 40, 41, 42	1204	0.21	0.023	0.016	0.82	0.18	0.48	0.89	0.48	0.31	0.051	0.002/0.006
43	387D	0.23	0.021	0.009	0.43	0.135	2.12	...	...	...	...	...

a faster average rate than the carbon steel material at the thin thickness and at a slower average rate at the heavy thickness.

The size of the sample with relation to its thickness also may be important with respect to cooling rate. The same data, therefore, were plotted a different way, in which the cooling rate was plotted vs. the ratio of surface area to volume. This is shown in Fig. 5. This figure shows the variation of ratio in area to volume of a 4T x 4T, a 6T x 6T, and an infinitely large plate as it varies with thickness of plate. Point 9 is the center of the thickness of a 6 x 6 x 1 in. test sample having a ratio of area to volume of 2.7. Point 25 is also a 1 in. plate out of 30 x 30 in. having a ratio of area to volume of 2.13. The cooling rate is lesser, and it is believed that the amount less is limited to within the degree shown on the chart.

The data from which the Figs. 4 and 5 were obtained, and further data for cooling to other higher and lower temperatures of the type shown in Figs. 4 and 5 are given in Tables 2 and 3 and Figs. 17 through 31 of the Appendix.

The temperature rise of water obtained on dip quenching of course, is dependent upon the relative volume of steel and water, degree of circulation and many other variables. The data of rise in temperature as actually obtained on the specific test samples are shown in Fig. 6. The actual cooling curves of temperature vs. time obtained with the various test samples are shown in the Appendix, and some are plotted superimposed on continuous cooling or isothermal temperature-time transformation curves for several materials discussed below.

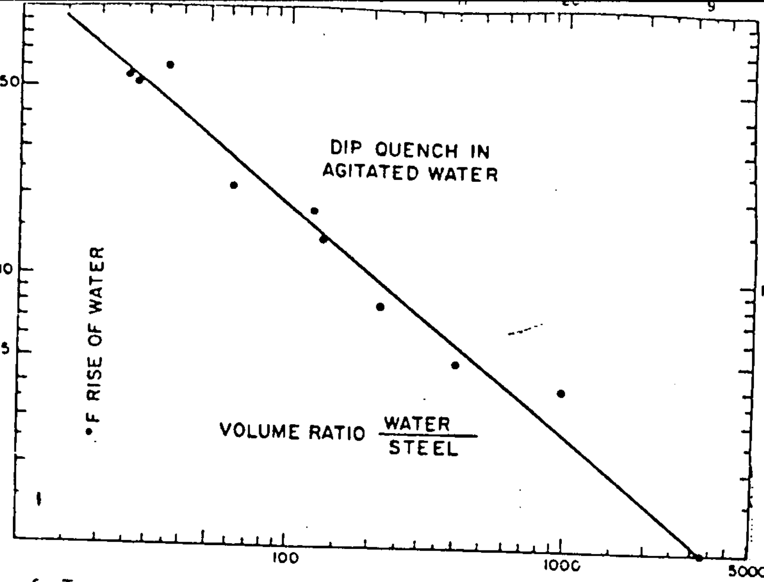


Fig. 6—Temperature rates of water vs. volume rate of water to steel

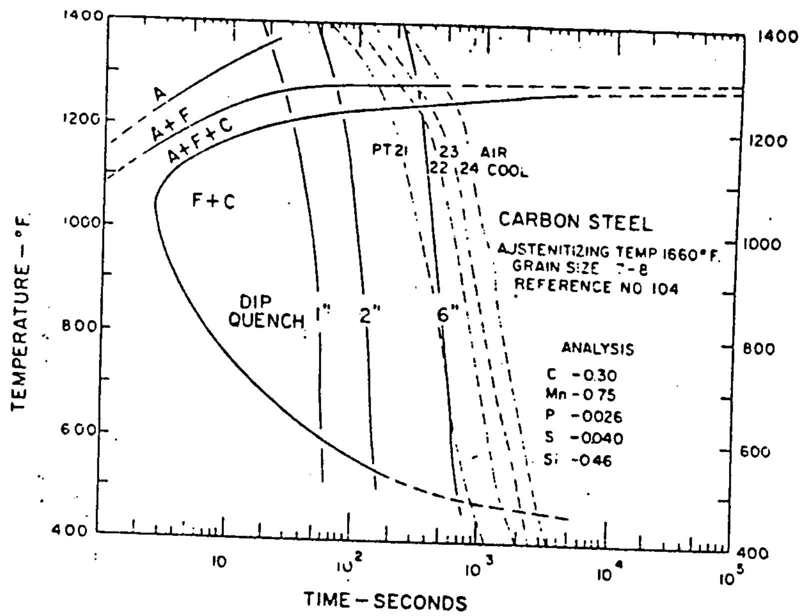


Fig. 7—Cooling rate data superimposed on carbon-steel isothermal transformation data

Temperature-Time Transformation

When the cooling rate of the particular thickness and size of material is known and when isothermal transformation data or continuous cooling transformation are available, a rough estimation can be made of the possibility of realizing improvement in properties by quenching for the combination of thickness and material involved. Considerable continuous cooling and isothermal transformation information are in the literature.[9-13]

Figure 7 shows cooling rate data superimposed on isothermal transformation data of carbon steel similar to A212B material. It is to be noted that transformation takes place only at a high temperature. Little improvement in tensile properties can result from quenching of this material. The dotted cooling curves represent actual cooling rates of air cooled pieces of ½, ¾, 1 and [illegible] in. thickness test pieces which were later tempered at various temperatures and times and resultant tensile strength plotted as subsequently illustrated. Figure 8 shows similar data superimposed on a continuous cooling transformation diagram of A387B material. Here it can be seen that air cooling rates for [illegible] and 1 in. materials are too slow to realize any appreciable improvement in properties, but the dip quenching rates of 1 in. thickness and possibly heavier thickness are sufficiently rapid to realize an improvement.

Figure 9 shows similar data for A387D material superimposed on a continuous cooling transformation diagram. Air-cooled material of ½, ¾, 1 and 1½ in. thickness exhibit cooling rates sufficiently rapid to realize improvement as does water quenched material of 7 in. and possibly heavier thickness.

Figure 10 shows similar data for A302B material superimposed on an isothermal transformation diagram. Here, again, some improvement can

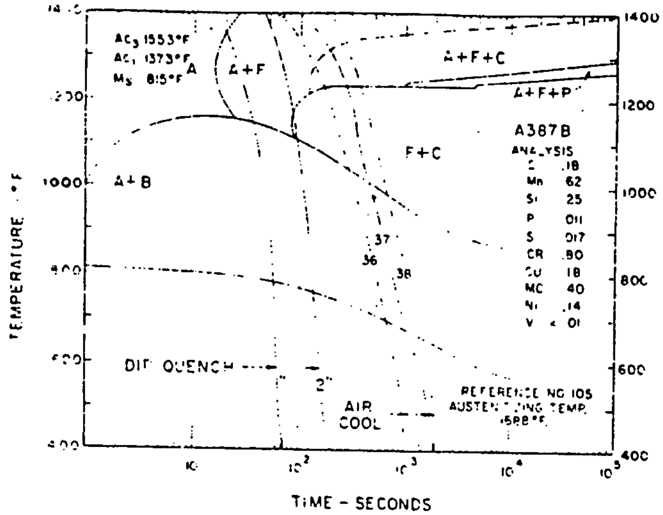


Fig. 8—Cooling rate data superimposed on A387B continuous cooling transformation diagram

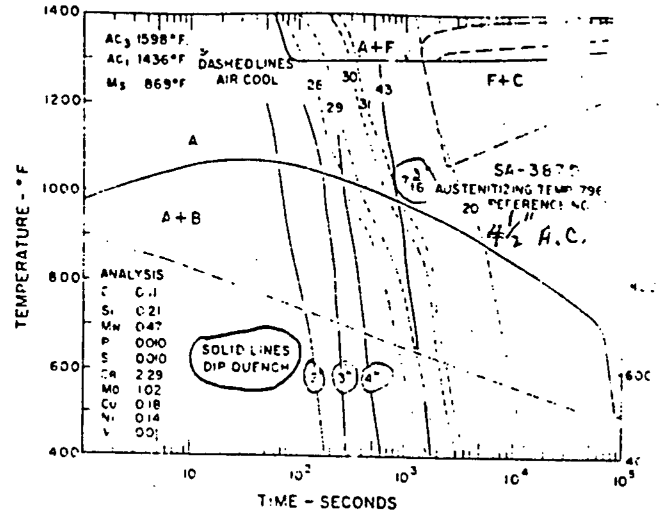


Fig. 9—Cooling rate data superimposed on A387D continuous cooling transformation diagram

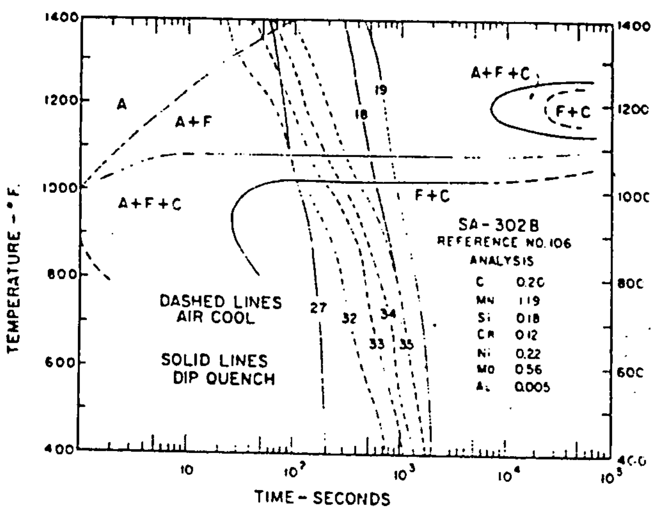


Fig. 10—Cooling rate data superimposed on A302B continuous cooling transformation diagram

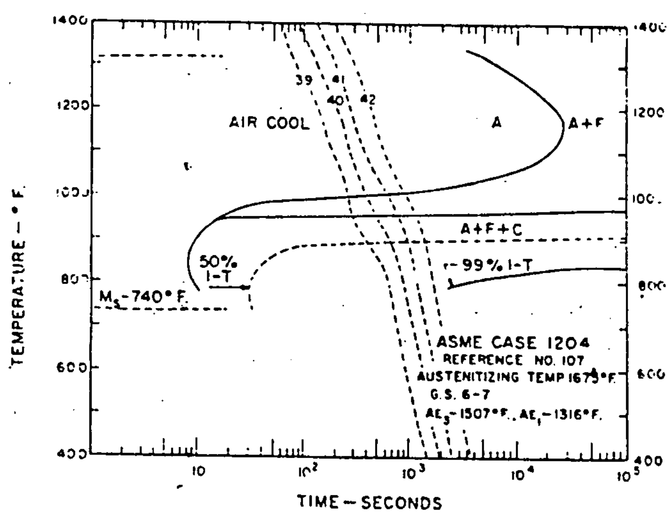


Fig. 11—Cooling rate data superimposed on ASME Code Case 1204 continuous cooling transformation diagram

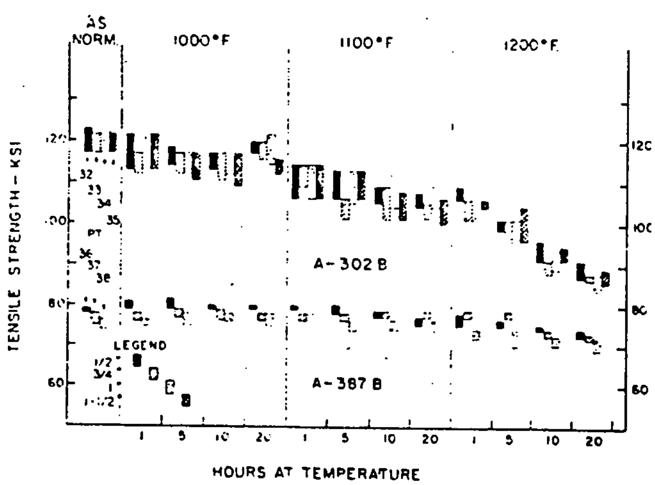


Fig. 12—Effect of tempering temperature on tensile strength of A302B and A387B steels.

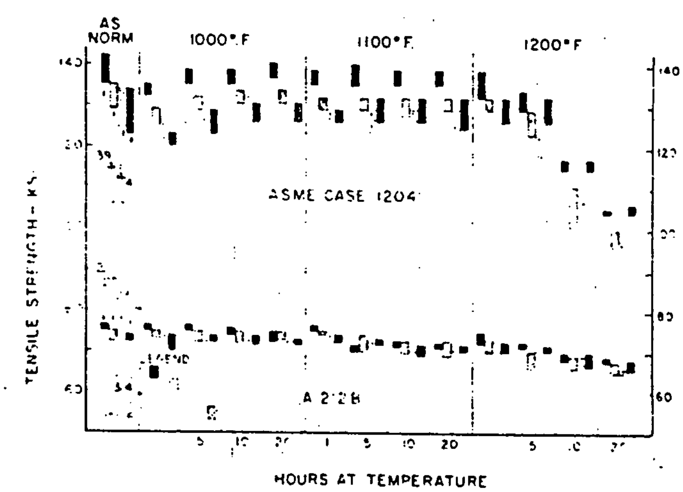


Fig. 13—Effect of tempering temperature on tensile strength of ASME Case 1204 and A212B steels

be realized to a relatively heavy thickness.

Figure 11 shows data for ASME Code Case 1204 material. Improvement in properites can be realized in heavy thicknesses.

It must also be kept in mind that continuous cooling results in shifting the transformations generally to the right and downward. The transformation curves are taken from the literature.[104-106]

Tempering Time and Temperature

Material heat treated by austenitizing and quenching must be tempered prior to cold forming or cold

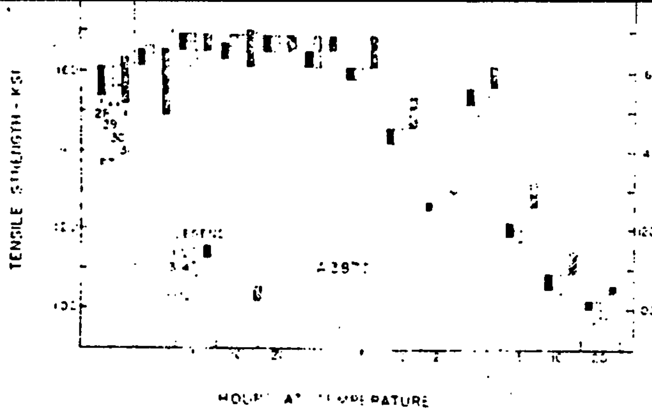


Fig. 14—Effect of tempering temperature on tensile strength of A387D steel

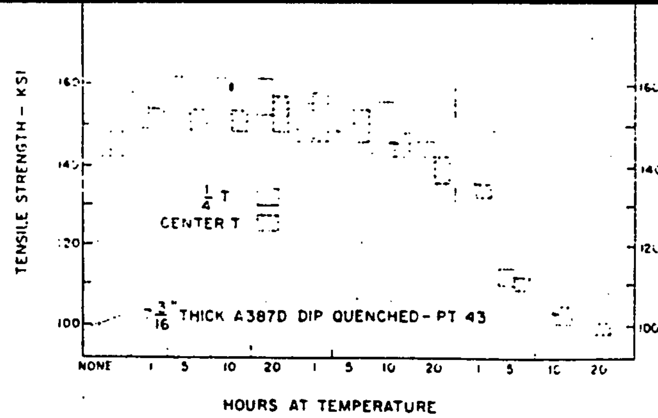


Fig. 15—Effect of tempering temperature on tensile strength of $7^{3}/_{16}$ in. thick A387D dip quenched steel

sizing. After welding the heavy thicknesses, it must also be tempered; in most instances, this must be done prior to cooling from the welding temperature to assure freedom from cracking. Large vessels constructed by successively joining several courses will subject the first course to several tempering heat treatments. Although the time at each tempering heat treatment can be short, the sum total plus that of a final stress relieving heat treatment can be on the order of 10 to 20 hr. Similar but possibly lesser total time at temperature will be required for materials heat treated as flat plates and warm formed or heat treated as finish welded shells or heads and then subjected to welding tempering and stress relieving.

The as-quenched mechanical properties will be affected by these tempering and stress relieving temperatures and time at temperature.[10] The properties may be adversely affected by some form of temper embrittlement. The degree to which the properties are affected must be known so that the finished product will exhibit the desired minimum properties.

The effect of up to 20 hr time at each of several temperatures on the tensile strength of several quenched low alloy steels is given in Figs. 12, 13, 14 and 15. The tensile data has been converted from Rockwell hardness testing using conversion data given in the literature.

Figure 12 shows the strength of A387B and A302B material cooled at rates shown in Figs. 8 and 10 respectively. It can be noted that the A387B material is not appreciably strengthened by these cooling rates but that the A302B material is.

Figure 13 shows similar data for A212B and ASME Code Case 1204 material cooled at rates shown in Figs. 7 and 11 respectively. Here A212B shows no improvement, whereas 1204 material does and it retains its strength after tempering for 20 hr at temperatures of 1000 and 1100° F and for 5 hr at 1200° F but loses appreciable strength at 10 and 20 hr tempering at 1200° F.

Figure 14 shows similar data for A387D material cooled at rates shown in Fig. 9. It exhibits an increase in strength on tempering at 1000° F for up to 20 hr with strength rapidly decreasing after 10 hr or longer at 1100° F and 5 hr or longer at 1200° F. The maximum strength level exhibited, however, is higher than that exhibited by the Case 1204 or A302B material.

Figure 15 shows data for a $7^{3}/_{16}$ in. thick A387D dip quenched plate at the center of the thickness and at the 1/4 thickness level at the cooling rate of point 43 as shown in Fig. 9. Here, also, an increase in strength is exhibited at 1000° F temper for up to 20 hr. This high strength is retained up to 10 hr at 1100° F temper but drops below 140,000 psi tensile strength at the center of the thickness after 20 hr at 1100° F. Further decrease is exhibited after only 1 hr at 1200° F. These properties, however, are quite high for such thick material.

In most applications, the finish fabricated pressure vessel will be ready for service after being tempered or stress relieved for the relatively short time of up to approximately 20 hr. Its subsequent service may be at low or intermediate temperature. The effect of service temperature over long time periods on the material properties must also be known.

Welding

Manual welding electrodes of a wide variety of deposited metal analyses are available and will deposit sound weld metal exhibiting a variety of ranges of high strength tensile and impact properties in the as-welded and as-welded and tempered conditions. These can be chosen of various diameters and resultant operating amperages and used at selected travel speeds to regulate heat input to tolerances required for control of properties of the base metal heat-affected zone.

Multilayer gas metal-arc automatic processes are also available and require similar heat input control for maintenance of heat-affected zone properties. Flux cored wires and strips are also available and usable for alloy additions. Multilayer submerged-arc processes, using bare electrode of the proper alloy content and/or alloy additions to the flux or braided wires for regulation of the alloy content, either as a directly consumable electrode or as an additive to the molten pool, are also available. In all cases, however, the use of these processes for welding on steels previously quenched and tempered must observe proper heat input control to preserve the base metal heat-affected zone properties.[18, 19, 33, 133, 134]

Preheat and interpass temperatures must also be closely controlled—above a minimum to prevent cracking and below a maximum to prevent excessive loss of properties.

Material, which is to be welded in the annealed or normalized and tempered condition followed by quenching and tempering heat treatment of the welded part, requires an analysis of weld metal, different from that above, which will develop properties equal to those of the base metal upon being subjected to quenching and tempering. The high heat input welding processes of gas metal-arc, submerged-

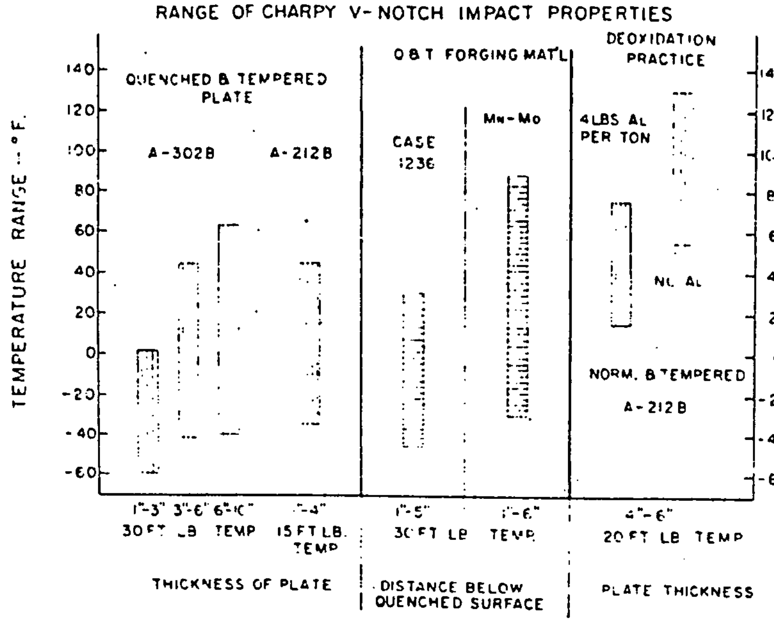


Fig. 16—Charpy V-Notch impact data for different quenched and tempered plate metals

arc and electroslag or electrogas methods are usable for this type application.

Heavy thicknesses subjected to tempering or stress relieving heat treatments must be designed such that no welding is applied after the final heat treatment, or such that welding is applied only to previously prepared attachment areas engineered so that the later applied as-welded attachment will not affect the integrity of the part. This necessitates careful design and selection of weld metal and attachment material with respect to material strength and resistance to brittle fracture.

Service Criteria

Brittle Fracture

Quenched and tempered materials are advantageous not only for utilization of higher tensile properties but also for utilization of improved resistance to brittle fracture.[135-145] Whether such improved resistance to brittle fracture is necessary or not depends upon several factors. It may not be necessary for materials which operate warm, and which have poorer resistance at lower temperatures, if any failure at the lower temperature does not entail excessive risk of life and property. The lower temperature may be at the hydrostatic test or it may be an unforseen impact loading. High resistance to brittle fracture may not be necessary for materials which are stress relieved and are adequately nondestructive tested to assure sufficient freedom from "crack starter" type discontinuities. The carbon steel and low alloy steels, of a low hardenability analysis not appreciably improved in tensile properties by quenching and tempering, are appreciably improved in impact properties in heavy thicknesses by accelerating cooling, only if they are melted to fine grain practice. Such deoxidation practice also minimizes deleterious effects from strain aging and quench aging.[146]

The range of Charpy V-notch properties of quenched and tempered plate of A212B and A302B materials and similar forging material analyses, tested in large production quantities, are shown in Fig. 16.

The more hardenable quenched and tempered materials, however, generally show a greater degree of improvement in impact property values, although they also generally require higher impact values for equivalent degree of resistance to brittle fracture. The work of Pellini and Puzak and their colleagues, and Stout and his colleagues, has been particularly illuminating to this subject.

Temperature Limits

The maximum temperature and times at which quenched and tempered materials will retain their improved tensile properties is not known precisely. Design is generally based upon a factor of the yield strength at temperature, the tensile strength at temperature, the stress rupture strength at temperature and the creep strength at temperature. The temperature at which each criteria becomes controlling must be determined for each material and condition. It is generally believed that, in the absence of such factors as temper embrittlement, the tensile properties are controlling up to possibly 700 or 800° F and that stress rupture and creep properties become controlling at above this temperature. At higher temperatures, the material will revert toward its normalized and tempered or annealed properties. Since most pressure vessels are designed for long life, on the order of 20 years or more, quenching and tempering

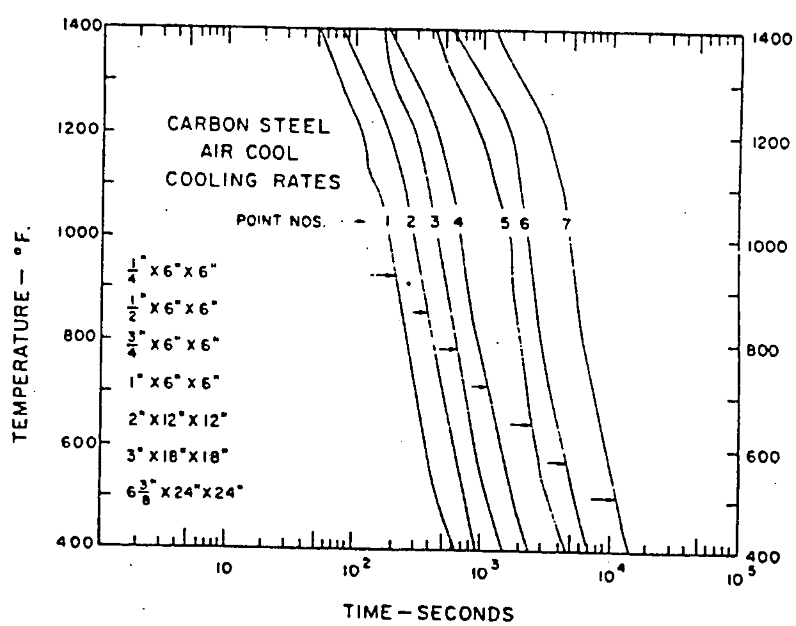


Fig. 17—Cooling rates for Points 1-7

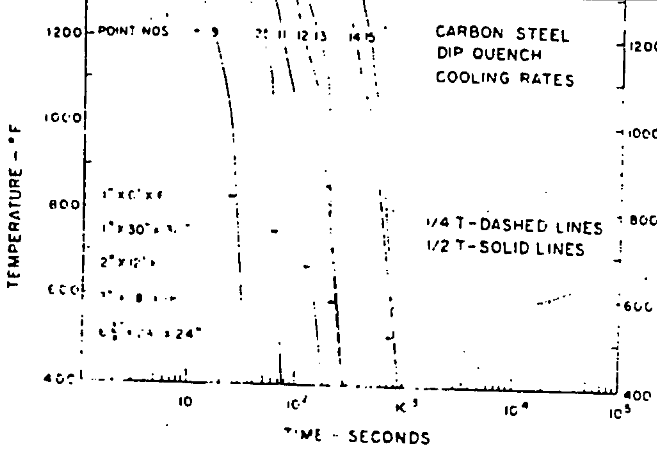


Fig. 18—Cooling rates for Points 9, 11–15 and 25

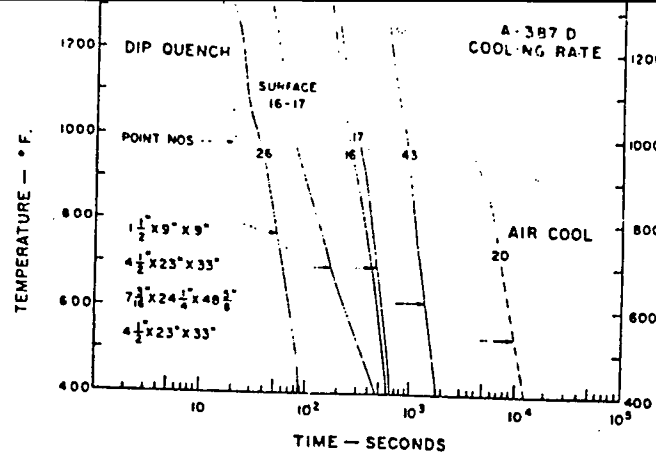


Fig. 19—Cooling rates for Points 16, 17, 20, 26 and 43

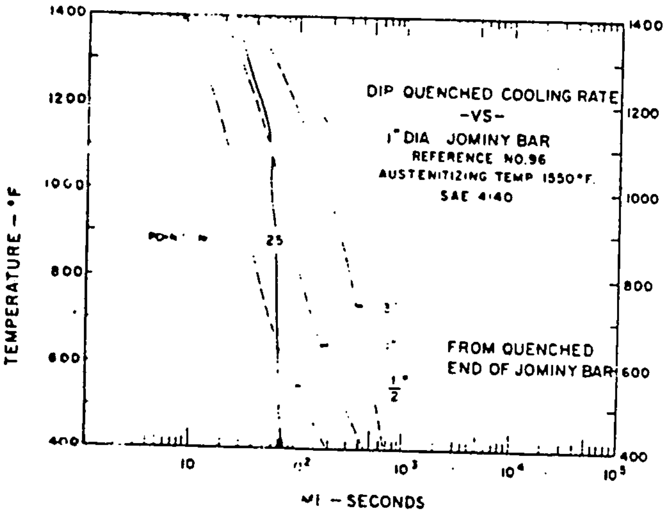


Fig. 20—Cooling rates for Jominy test bar—SAE 4140 steel

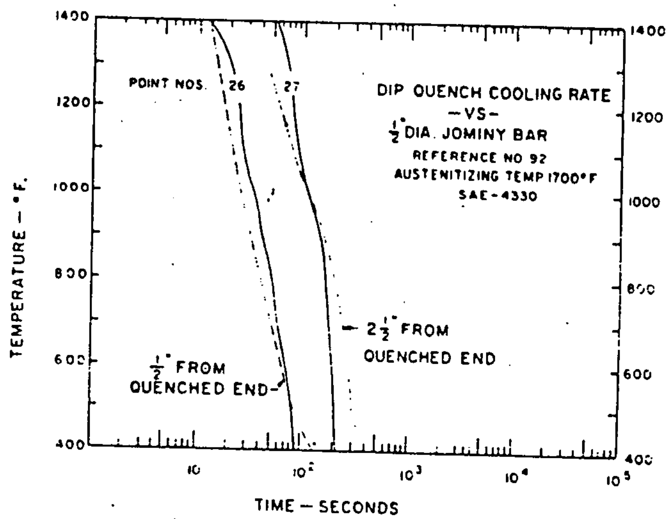


Fig. 21—Cooling rates for Jominy test bar—SAE 4330 steel

applied [illegible] ls to operate at high temperature does not appear to be highly promising.

In addition [illegible] susceptibility of quenched and tempered material to aging embrittlement over long periods of time [illegible] operating temperatures from room temperature up must also be known.[30] Stout and his colleagues [illegible] tested several materials [illegible] this [illegible]

Corrosion

Quenched [illegible] must be considered [illegible] in corrosive service [illegible] generally a function of the [illegible] construction codes but rather is primarily dependent upon knowledge of the [illegible] With some highly corrosive services wherein the thickness is primarily required for corrosion allowance quenched and tempered materials might not be advantageous and might be disadvantageous.

Annealed or normalized and tempered materials presently used because of their resistance to specific corrosion media must be retested for contemplated use in the quenched and tempered condition to assure that they are sufficiently resistant. The weld metal must also be resistant and not be chosen on only the basis of its mechanical characteristics.

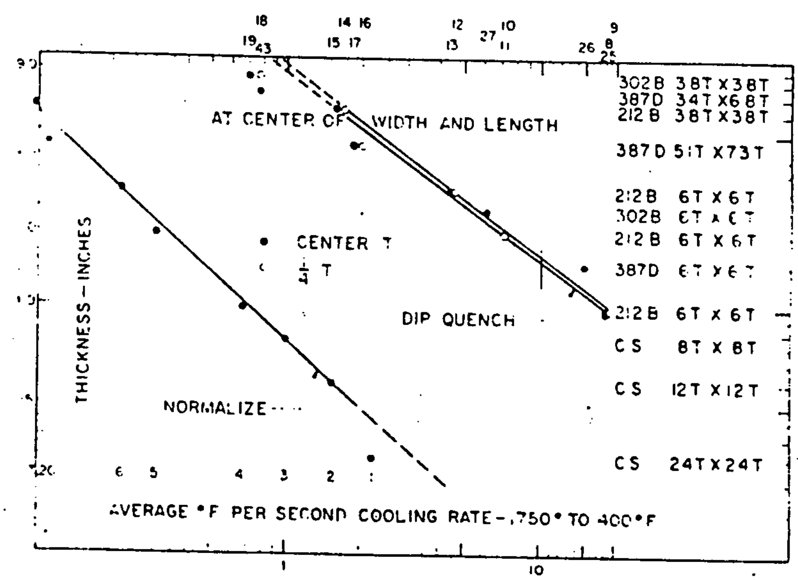


Fig. 22—Thickness vs. cooling rate from 1750 to 400° F

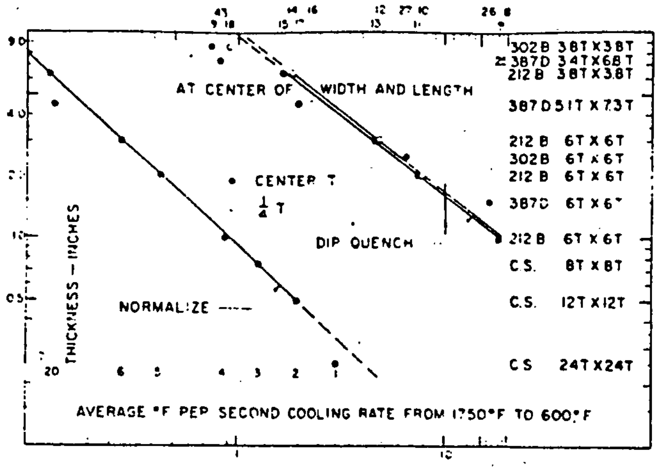


Fig. 23—Thickness vs. cooling rate from 1750 to 600° F

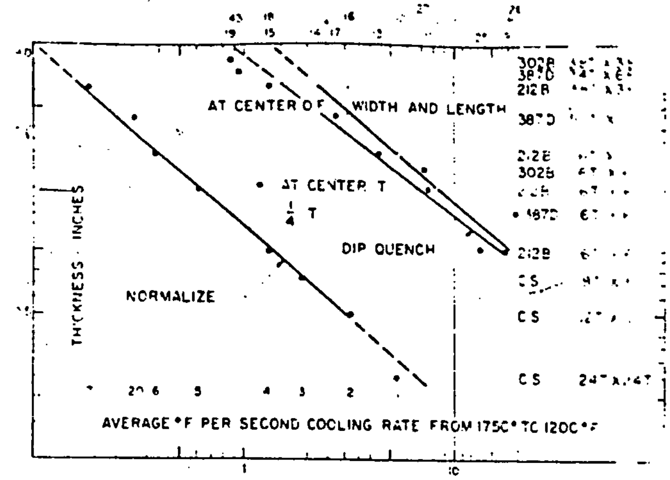


Fig. 24—Thickness vs. cooling rate from 1750 to 1000° F

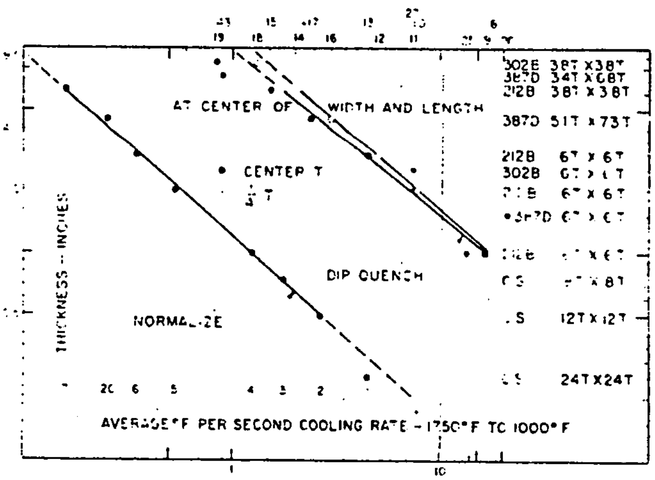


Fig. 25—Thickness vs. cooling rate from 1750 to 1200° F

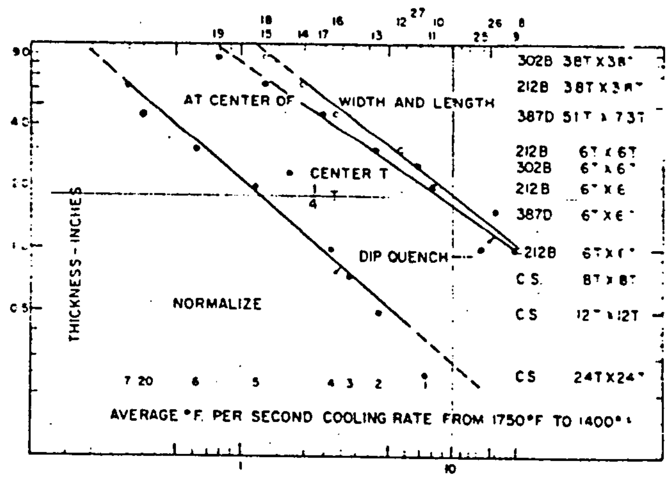


Fig. 26—Thickness vs. cooling rate from 1750 to 1400° F

Summary

Information is presently available to allow construction and use of welded pressure vessels of material quenched and tempered to high strength levels in heavy thicknesses as well as light thicknesses. Wider use of such construction is awaiting the formulation of material purchasing specification criteria to allow a wider selection of possible materials and to allow application of the quenching and tempering at the fabricators shops. It also is awaiting the formulation of Code rules regulating safe construction procedures.

Successful construction is dependent upon maintaining close control of material chemical analysis, heat treatment, welding procedure and all aspects of fabrication forming, heating and cooling. This requires closer control of techniques and procedures than those generally required for annealed and normalized and tempered material. This requires closer control in procedures of obtaining test samples for destructive testing which are representative of the larger mass of the production materials. Information which will be helpful in determining degree of control necessary in some of these aspects is given.

It is believed that the quality control assurances necessary for proper application will consist of specific rules regulating and defining material procurement specifications, design aspects, and fabrica-

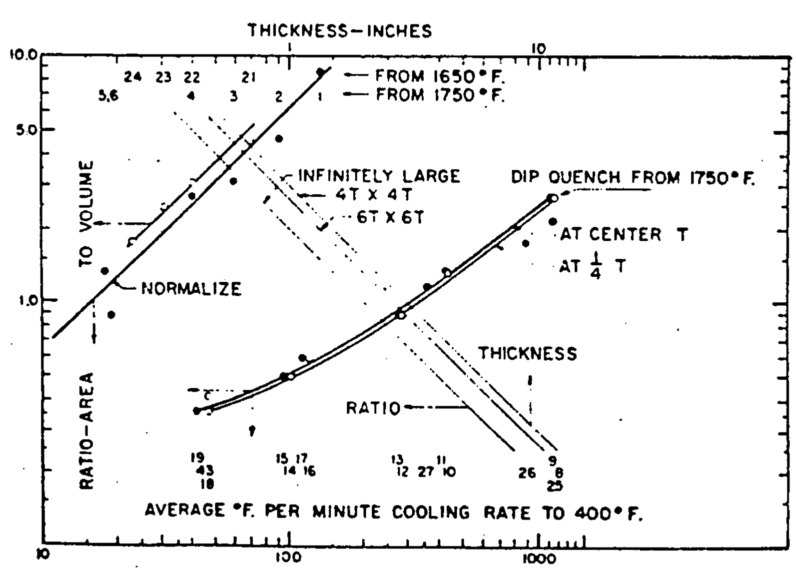


Fig. 27—Ratio of surface area to volume vs. cooling rate to 400° F

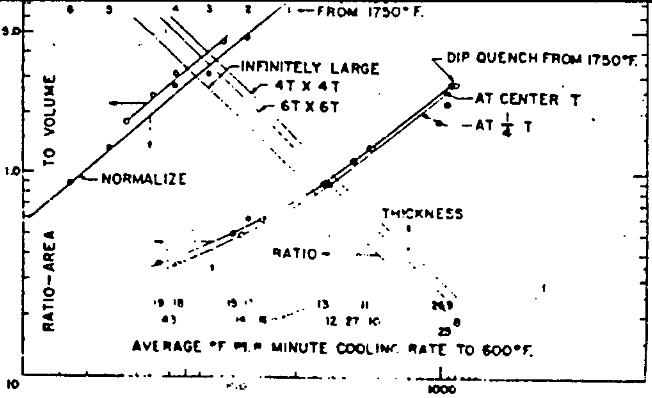


Fig. 28—Ratio of surface area to volume vs. cooling rate to 600° F

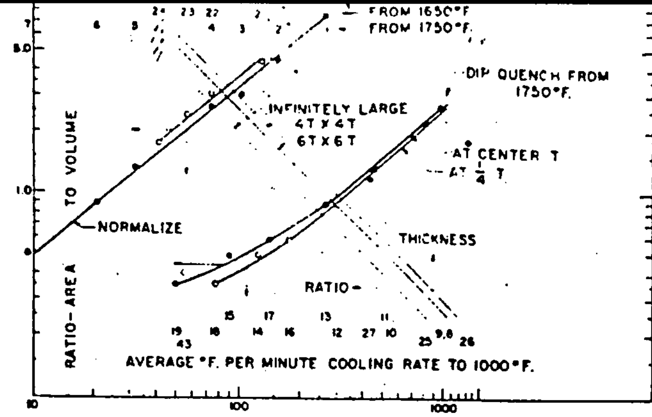


Fig. 29—Ratio of surface area to volume vs. cooling rate to 1000° F

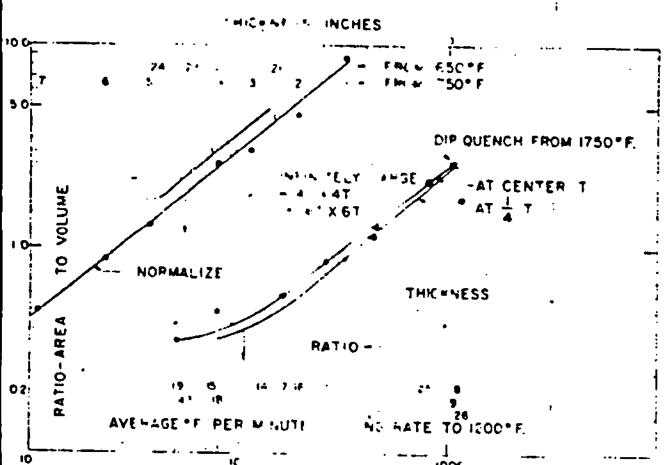


Fig. 30—Ratio of surface area to volume vs. cooling rate to 1200° F

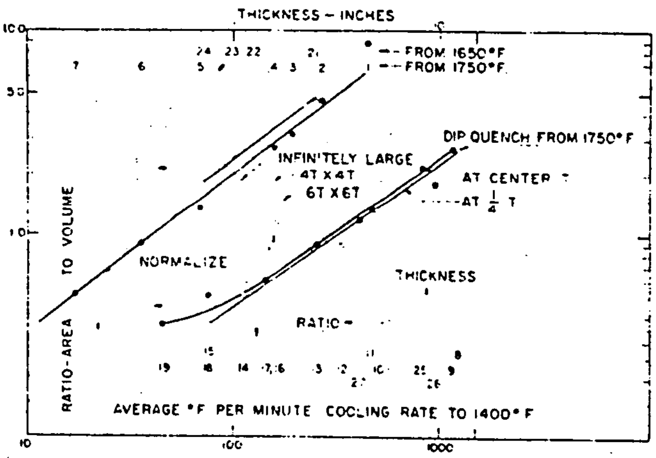


Fig. 31—Ratio of surface area to volume vs. cooling rate to 1400° F

tion procedures involving heating and cooling treatments, welding procedure qualifications, and representative fabrication test plates. Nondestructive testing procedures must also be defined but will vary, depending upon the service usage and specific design.

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142. McGeady, L. J., "Transition Temperature Behavior of Pressure Vessel Steels," *Ibid.*, 340, Research Suppl., 1-s to 11-s (1955).

143. Wessel, E. T., and Pryle, W. H., "Brittle Fracture Characteristics of a Reactor Pressure Vessel Steel," *Ibid.*, 40 (1), Research Suppl., 41-s to 48-s (1961).

144. Puzak, P. P., and Babecki, A. J., "Normalization Procedures for NRL Drop-Weight Test," *Ibid.*, 38 (5), Research Suppl., 209-s to 218-s (1959).

145. Soderbert, C. R., Jr., "Pressure Equipment for Low-Temperature Service," *Ibid.*, 38 (1), Research Suppl., 39-s to 44-s (1959).

146. Thielsch, H., "Strain Aging of Pressure Vessel Steels," *Ibid.*, 30 (6), Research Suppl., 285-s to 295-s (1951).

Appendix

All the cooling data were obtained from time-temperature traces produced with an oscillograph recorder. Time zero was chosen as the moment just before immersion in the quenchant. Depending upon specimen size, chart speeds of 3 to 30 ipm were used. Recording ceased, when the center thickness of the plate reached 400° F.

The oscillograph recorder was initially calibrated with a millivoltage source to establish a correlation between deflection and temperature. Subsequently, zero settings were checked and adjusted, if necessary, prior to each cooling cycle. In all cases, 32° F was used as a reference junction.

All thermocouples were of the standard chromel-alumel type, insulated with ceramic beads and shielded by stainless steel tubing welded to the test plate as shown in Fig. 2. The tubing prevented water from contacting the thermocouple junction and leads. Hot junctions were made by peening the wire into adjacent holes at the base of $^{5}/_{8}$ in. nominal diameter access holes. The above procedure exhibited satisfactory reliability.

Each test plate was grit blasted before entering the furnace. Heating time to austenitizing temperature was dependent upon the maximum rate of the furnace and a holding period was maintained until equilibrium was obtained.

All dip quenching was done in water agitated with air. Quenching was done in a water volume of either 69 or 131 cu ft. Air cooling consisted of suspending each piece in still air.

Figures 17, 18 and 19 show cooling rate data for the specific point numbers described in Table 2 and material analyses described in Table 3. Cooling rate curves for other point numbers described in Tables 2 and 3 are shown in Figs. 7 through 11. Figures 20 and 21 show comparable cooling rate data obtained from the literature at various distances from the quenched end of Jominy test bars.

Figures 22 through 26 show thickness vs. average °F per second cooling rate from 1750 to 400, 600, 1000, 1200 and 1400° F respectively.

Figures 27 through 31 show the same data plotted with relation to ratio of surface area to volume vs. cooling rate.

ASME Control Traveler

B

Material Control			Weld Joint Control						Quality Control			Auth. Insp.		
Item #	Description	Coded #	Weld #	Welding Procedure & Rev.	Heat Treat Procedure & Rev.	NDE Rqd	NDE Proc.	Welder Name	Fit-up	Com	NDE	Fit-up	Com	NDE
1	PLATE 12" EXCAVATION WELD	N/A	LAYER 1	A03043 REV. A.	B.&P.V. CODE CASE N-432 3.0	Y		Bubash Kitchens Harmon Stilwell		X	X			

*

ISSUE CONTROL			
O	ORIGINAL ISSUE		4-26-89
Rev.	Description	PROJ. MGR.	QA MGR.

PRESSURE TEST

at ________ P.S.I.G.

Q.C. ________

A.I. ________

Customer ________

SYSTEM

PIECE MARK

DAN | CKD

A.N.I. REVIEW

Project: INDIAN POINT

Customer: CON. ED.

X=HOLD POINT

Sheet 1 / 87

QA 00150 - 9.2

ASME Control Traveler

B

Material Control			Weld Joint Control						QUALITY CONTROL			AUTH. INSP.		
Item #	Description	Coded #	Weld #	Welding Procedure & Rev.	Heat Treat Procedure & Rev.	NDE Rqd	NDE Proc.	Welder Name	Fit-up	Com	NDE	Fit-up	Com	NDE
1	PLATE 12"	N/A	LAYER 2	A03043 REV. A.	B: P.V.	Y		Bubash		X	X			
	EXCAVATION				CODE CASE			Kitchens						
	WELD				N-432 3.0			Harmon						

ISSUE CONTROL

Rev.	Description	PROJ. MGR.	QA MGR.
O	ORIGINAL ISSUE		4-26-89

PRESSURE TEST at ________ P.S.I.G.

Q.C. ________________

A.I. ________________

Customer ________________

SYSTEM

PIECE MARK

DAN | CKD

A.N.I. REVIEW

Project: INDIAN POINT

Customer: Con. ED.

X = HOLD POINT

Sheet 2 of 7

QA 00150 - 9.2

ASME Control Traveler

B

Material Control			Weld Joint Control							QUALITY CONTROL			AUTH. INSP.		
Item #	Description	Coded #	Weld #	Welding Procedure & Rev.	Heat Treat Procedure & Rev.	NDE Rqd	NDE Proc.	Welder Name		Fit-up	Com	NDE	Fit-up	Com	NDE
1	PLATE 12" EXCAVATION WELD	N/A	LAYER 3	A03043 REV. A.	B.P.V. CODE CASE N-432 3.0	Y		BUBASH Kitchens HARMON			X	X			

ISSUE CONTROL			
O	ORIGINAL ISSUE		4-26-89
Rev.	Description	PROJ. MGR.	QA MGR.

PRESSURE TEST at ______ P.S.I.G.

Q.C. ______

A.I. ______

Customer ______

SYSTEM

PIECE MARK

DAN | CKD

A.N.I. REVIEW

Project: Indian Point

Customer: Con. ED.

X=HOLD POINT

Sheet 3 2 7

ASME Control Traveler

B

Material Control			Weld Joint Control						QUALITY CONTROL			AUTH. INSP.		
Item #	Description	Coded #	Weld #	Welding Procedure & Rev.	Heat Treat Procedure & Rev.	NDE Rqd	NDE Proc.	Welder Name	Fit-up	Com	NDE	Fit-up	Com	NDE
1	12" PLATE	N/A	LAYER 4	A03043 REV. A.	B. P.V.	Y		Bubash		X	X			
	EXCAVATION				CODE CASE			Kitchens						
	WELD				N-432 3.0			Harmon						
								Poitea						

ISSUE CONTROL

Rev.	Description	PROJ. MGR.	QA MGR.
O	ORIGINAL ISSUE		4-26-89

PRESSURE TEST
at ________ P.S.I.G.

Q.C. ________

A.I. ________

Customer ________

SYSTEM

PIECE MARK

DAN | CKD

A.N.I. REVIEW

Project
Indian Point

Customer
Con. Ed.

X=HOLD POINT

Sheet 4 of 7

ASME Control Traveler

B

Material Control			Weld Joint Control											
Item #	Description	Coded #	Weld #	Welding Procedure & Rev.	Heat Treat Procedure & Rev.	NDE Rqd	NDE Proc.	Welder Name	QUALITY CONTROL Fit-up	QUALITY CONTROL Com	QUALITY CONTROL NDE	AUTH. INSP. Fit-up	AUTH. INSP. Com	AUTH. INSP. NDE
1	12" PLATE	N/A	LAYER 5	A03043 REV. A.	B:P.V.	Y		Bubash		X	X			
	WEXCAVATION				CODE CASE									
	WELD				N-432-3.0			Kitchens						
								Harmon						

ISSUE CONTROL

Rev.	Description	PROJ. MGR.	QA MGR.
O	ORIGINAL ISSUE		4-26-89

PRESSURE TEST at ________ P.S.I.G.

Q.C. ____________

A.I. ____________

Customer ____________

SYSTEM

PIECE MARK

DAN | CKD

A.N.I. REVIEW

Project: Indian Point

Customer: Con. Ed.

X=HOLD POINT

Sheet 5 of 7

ASME Control Traveler

B

Material Control			Weld Joint Control											
Item #	Description	Coded #	Weld #	Welding Procedure & Rev.	Heat Treat Procedure & Rev.	NDE Rqd	NDE Proc.	Welder Name	QUALITY CONTROL Fit-up	QUALITY CONTROL Com	QUALITY CONTROL NDE	AUTH. INSP. Fit-up	AUTH. INSP. Com	AUTH. INSP. NDE
1	12" PLATE	N/A	LAYER 6	A03043 REV. A.	B:P.V. CODE CASE N-432-3.0	Y		HARMON		X	X			
	EXCAVATION							Poitra						
	WELD							Kitchens						

ISSUE CONTROL

Rev.	Description	PROJ. MGR.	QA MGR.
O	ORIGINAL ISSUE		4-26-89

PRESSURE TEST at ________ P.S.I.G.

Q.C. ____________________

A.I. ____________________

Customer ____________________

SYSTEM

PIECE MARK

DAN | CKD

A.N.I. REVIEW

Project: INDIAN POINT

Customer: Con. ED.

X=HOLD POINT

Sheet 6 87

ASME Control Traveler

B

Material Control			Weld Joint Control						QUALITY CONTROL			AUTH. INSP.		
Item #	Description	Coded #	Weld #	Welding Procedure & Rev.	Heat Treat Procedure & Rev.	NDE Rqd	NDE Proc.	Welder Name	Fit-up	Com	NDE	Fit-up	Com	NDE
1	12" PLATE EXCAVATION WELD	N/A	Fill out From Layer 6	A03043 Rev. A.	B. P.V. CODE CASE N-432 3.0	Y		Poitra Kitchens		X	X			

ISSUE CONTROL			
O	ORIGINAL ISSUE		4-26-89
Rev.	Description	PROJ. MGR.	QA MGR.

PRESSURE TEST at ________ P.S.I.G.

Q.C. ________

A.I. ________

Customer ________

SYSTEM

PIECE MARK

DAN | CKD

A.N.I. REVIEW

Project: Indian Point

Customer: Con. Ed.

X=HOLD POINT

Sheet 787

B

FILLER MATERIAL LOG

Project IP 69041G **Dwg** ______ **Control Traveler#** 1-7

Weld No.	Procedure #	Welder	Date	Material Type	Material Ident.	Quantity
12" PLATE	A03043 REV. A	BUBASH KJB-7575	4-26	ER80SD2	HT#083195	25# SPOOL
COUPON		KITCHENS MWK-3480				
		STILWELL JDS-8311				
		HARMON SPH-6517				
		POITRA RLP-4801				

THIS CMTR COVERS WELDING SERVICES INC. PO#N908630; WELDSTAR NUCLEAR SHIPPING
TICKET N908630

L-TEC
WELDING & CUTTING SYSTEMS

Welding Materials Plant
P.O. Box 710, Middle Road
Ashtabula, Ohio 44004

October 23, 1986

WELDSTAR COMPANY'S QUALITY SYSTEM CERTIFICATE
(MATERIALS) QSC-229
EXPIRATION DATE JAN. 5, 1991

CERTIFIED MATERIALS TEST REPORT

CUSTOMER: Weldstar Company
1750 Mitchell Road
Aurora, IL. 60504

YOUR ORDER NO.: 8117-A
LINDE S.O. NO.: 898117 A 01
QUANTITY: 1,452 lbs.

MATERIAL: Linde 83 - Heat No. 083195 - .035" Diameter - 44 lb. Spools

This is to certify that Linde 83 Class ER80S-D2 as supplied under the above order number, shipped from one heat number, has been tested using the test assembly specified in Fig. 1 of AWS A 5.28-79 and ASME SFA5.28 specifications. The wire met all the mechanical and impact property requirements of these specifications using the gas-metal arc welding process with CO^2 shielding gas. This is also to certify that the contents of this report are correct and accurate and the material conforms to ASME Section II, Part C, SFA5.28 and ASME Section III, 1983 Edition, Subsection NB-2400, Summer 1985 Addenda. Above material was manufactured free of Mercury or any of its compounds.

MECHANICAL PROPERTIES OF WELD PER TABLE 4

	AS-WELDED	REQUIRED
Weld Test Number	U1002-1AW	
All-Weld Metal Tensile		
Yield Strength, psi	92,300	68,000 min.
Ultimate Strength, psi	100,700	80,000 min.
Elongation in 2", %	24.0	17 min.
Reduction of Area, %	61.7	- - - -

CHARPY V-NOTCH IMPACT STRENGTH @ -20°F (Ft./Lbs.) As-Welded	LATERAL EXPANSION (MILS) As-Welded	DUCTILE FRACTURE AREA (PERCENT) As-Welded
52	44	75
50	45	65
52	42	55
54	46	60
61	50	65
53 (Avg. 3)		

Required 20 ft./lbs.

REDIOGRAPHIC TESTS: X-Ray met the requirements of Fig. 2 of AWS/ASME SFA5.28-79.

APPLICATION CONDITIONS: 340 Amps, 28 Volts, 13 IPM

CHEMICAL ANALYSIS:

C	Mn	P	S	Si	Ni	Mo	Cu	Cr	V	
.09	1.82	.014	.014	.64	.05	.46	.15	.04	<.01	- Actual
.07 / .12	1.60 / 2.10	.025 max.	.025 max.	.50 / .80	.15 max.	.40 / .60	.50 max.	-	-	- Required
.15				1.0				.5		

ASME Quality Systems Certificate: QSC-323
Expires March 17, 1987

Sworn to before me this

23RD day of October 1986

Kathleen A. Simons

KATHLEEN A. SIMONS, Notary Public
My commission expires January 31, 1991
Recorded in Ashtabula County

R. J. DiDonato
R. J. DiDonato
Special Order Administrator

53
4/12/89

WELDSTAR COMPANY

"WELDERS SERVICE CENTER"

P.O. BOX 711 • AURORA, ILL. 60507 • PHONE (312) 859-3100

April 24, 1989

Welding Service Inc.
3276 Marjan Drive
Atlanta, GA 30340

Gentlemen:

The attached CMTR (one copy) covers the following material shipped against your purchase order number 0207887; Weldstar Nuclear shipping ticket N908630:

132 lbs. .035 ER80SD2 L-TEC bare filler rod
Heat #083195

The above material is in compliance with your purchase order number 0207887, and will meet or exceed code requirements of 1986 Edition, 1988 Addenda.

Sincerely,

WELDSTAR COMPANY

James R. Berry
Quality Assurance Manager

/ck

Attachment

CUSTOMER COPY

WELDSTAR COMPANY

NUCLEAR SHIPPING TICKET

ORDER DATE 4/24/89

"WELDERS SERVICE CENTER"

P.O. BOX 711—AURORA, ILLINOIS 60507—(312) 859-3100

SHIPPING DATE 4/24/89

SOLD TO WELDING SERVICES INC
3276 MARJAN DRIVE
ATLANTA GA 30340

SHIP TO WELDING SERVICES INC
SHIPPING & RECEIVING
3202 MARJAN DRIVE
ATLANTA GA 30340-0000

Paid	Charge	On Acct	Credit	Account Number	Purchase Order Number	Job Number
	X				0207887	

Ordered	Delivered		Price
132#	132#	.035 ER80SD2 L-TEC BARE FILLER ROD	
		HEAT #083195	
		ONE COPY MATERIAL TEST REPORT FOR ABOVE HEAT NUMBER ATTACHED TO THIS SHIPPING TICKET	

WELDSTAR COMPANY'S QUALITY SYSTEM CERTIFICATE
(MATERIALS) QSC-229
EXPIRATION DATE JAN. 5, 1991

WE CERTIFY THAT MATERIAL SHIPPED HAS BEEN HANDLED IN COMPLIANCE UNDER OUR IDENTIFICATION & VERIFICATION PROGRAM.

"The Test Report(s) of which copies are attached hereto were prepared by L-TEC (Manufacturer). Each item in this shipment is a portion or all of the materials received under the original test report applying to such material. The original of each test report is kept on file at Weldstar Company."

TOTAL	
TAX	
FREIGHT	
PAY THIS AMOUNT	

DAMAGE CLAIMS When this equipment is shipped, title passes to the purchaser upon receipt by the carrier. Consequently, claims for material damaged in shipment must be made by the purchaser against the transportation company.

CUSTOMER SIGNATURE ____________________

NO. N908630

NOTE: AN INVOICE MAKING REFERENCE TO THIS DELIVERY TICKET WILL BE MAILED FOLLOWING ALL CHARGE SALES

RECEIVING INSPECTION REPORT

JOB NUMBER	ITEM(S)
IP690416	Indian Point Con. Ed. Weld Inv.

INFORMATION		ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5
MANUFACTURER		L-TEC				
P.O. NUMBER		0207887				
VENDOR		WELD STAR				
MATERIAL		ER80SD2				
HEAT NUMBER		083195				
MATERIAL MILL TEST REPORT		RECEIVED				
LENGTH						
WIDTH						
NOMINAL DIAMETER		.035				
DIAMETER CHECK	A	.035				
	B	.035				
	C	.035				
	D	.035				
NOMINAL THICKNESS						
THICKNESS	1					
	2					
	3					
	4					
	5					
VISUAL INSPECTION		ACCEPT				
REMARKS						
NCR #						
DATE		4-26-89				
BY		A. Lewren[illegible]				

! SZ
D... 4/27/89

Welding Services Inc. ☐
Welding Services Inc. Mfg. Div. ☐

3276 Marjan Drive
Atlanta, Georgia 30340
Telephone (404) 452-0005

Accounts Payable
(404) 455-0929

PURCHASE ORDER N

785900
WELD STAR, INC

00000 0000

SHIP TO
WELDING SERVICES, INC.
SHIPPING & RECEIEVING
3202 MARJAN DRIVE
ATLANTA, GEORGIA
30340-0000

ORDER DATE	TERMS	F.O.B.	SHIP VIA	JOB / PROJECT	P. R. NO.	TAXABLE YES / NO
24/89	NET 30 DAYS	S/P	FED EXP P-1/UPS	INDINA POINT/CON ED; WELD INV.	13754,2663	

QTY.	WHSE	WSI MFG PART NO. G/L CODE	SPEC/VENDOR PART NO.	DESCRIPTION	PRICE	UNIT	EXT.	JOB/P
				MATERIAL TO BE SUPPLIED ON 2# SPOOLS AND MUST CONFORM TO ASME SECTION II, SFA 5.18.				
50.00	07	17631 121-02-00	ER70S3/.035 DIA	WIRE, WELDING, ER70S3, .035 DIA. SPOOLED, 2#, 10#, 25# ETC MATERIAL SUPPLIED ON 2# SPOOLS AND MUST BE IN ACCORDANCE WITH NB2400 & NCA3800 REQUIREMENTS, SECTION III, ASME B & PV CODE, CURRENT EDITION; PART 21 APPLIES; CERTIFIED MILL TEST REPORTS REQUIRED. WELDING SERVICES, INC. RETAINS RIGHT OF ACCESS.	7.520	LB	376.000	0401
.00	07	Q.A. APPROVAL 400-02-00	Q.A. APPROVAL	Q.A. APPROVAL/DATE: 4-24-89 SIGNED: [signature]	.000	EA	.000	0401:
.00	07	CERTS/TEST REP. 400-02-00	CERTS/CMTR'S	CERTS/MATERIAL TEST REPORTS REQUIRED	.000	EA	.000	0401:

CONFIRMATION TO	REQ/DEPT.	QA Approval YES	QA Approval NO	C of C Req'd YES	C of C Req'd NO	QA Insp. Req. YES	QA Insp. Req. NO
DECKER	B.Q;NAUGHTON						

TOTALS → 1,229.200

R.A. Edwards
PURCHASING DEPT.

S.J.
4/27/89

Welding Services Inc. ☐
Welding Services Inc. Mfg. Div.. ☐
3276 Marjan Drive
Atlanta, Georgia 30340
Telephone (404) 452-0005

Accounts Payable
(404) 455-0929

PURCHASE ORDER NC
0207887

785900
WELD STAR, INC

00000 0000

SHIP TO
WELDING SERVICES, INC.
SHIPPING & RECEIEVING
3202 MARJAN DRIVE
ATLANTA, GEORGIA
30340-0000

ER DATE	TERMS	F.O.B.	SHIP VIA	JOB / PROJECT	P. R. NO.	TAXABLE YES NO	WSI / WSI MFG
4/89	NET 30 DAYS	S/P	FED EXP P-1/UPS	INDINA POINT/CON ED; WELD INV.	13754 2663		

QTY.	WHSE	WSI MFG PART NO. G/L CODE	SPEC/VENDOR PART NO.	DESCRIPTION	PRICE	UNIT	EXT.	JOB/PHA
132.00	I5	17626 121-02-00	ER80SD2/.035 DIA	WIRE, WELDING, ER80SD2, .035, DIA, 10#, 25# ETC. SPOOLS MATERIAL MUST BE IN ACCORDANCE WITH NB2400 & NCA3800 REQUIREMENTS. PART 21 APPLIES; SECT. III, ASME B & PV CODE; CURRENT EDITION; CERTIFIED MILL TEST REPORTS REQUIRED. WELDING SERVICES, INC. RETAINS RIGHT OF ACCESS. NOTE; MATERIAL IS BEING SUPPLIED ON 44# SPOOLS.	3.750	LB	495.000	69041-
.00	I5	Q.A. APPROVAL 400-02-00	Q.A. APPROVAL	Q.A. APPROVAL/DATE: 4-24-89 SIGNED: [signature]	.000	EA	.000	69041-
.00	I5	CERTS/TEST REP. 400-02-00	CERTS/CHTR'S	CERTS/MATERIAL TEST REPORTS REQUIRED	.000	EA	.000	69041-
100.00	07	17631 121-02-00	ER70S3/.035 DIA	WIRE, WELDING, ER70S3, .035 DIA. SPOOLED, 2#, 10#, 25# ETC MATERIAL TO BE ON 2# SPOOLS; AND MUST CONFORM TO ASME SECT. II, PART C, SFA 5.18.	1.650	LB	165.000	04011-
120.00	07	4767 121-02-00	ER70S3/.045 DIA	WIRE, WELDING, CARBON, ER70S3 .045 DIA, 25#, 10#, 2# SPOOLS	1.610	LB	193.200	04011-

CONFIRMATION TO	REQ/DEPT.	QA Approval YES / NO	C of C Req'd YES / NO	QA Insp. Req. YES / NO

CONTINUED

TOTALS →

RAE
PURCHASING DEPT.

S-7
4/27/89

AMERICAN ALLOY STEEL, INC.

7721 PINEMONT
P.O. BOX 40469
HOUSTON, TEXAS 77240-0469
(713) 462-8081
TELEX 76-2806

INVOICE NO.

INVOICE DATE:

S/O 72468

TERMS: 1%—15 days—NET 30 DAYS

052650

SOLD TO: ENERGY STEEL & SUPPLY COMPANY
2715 PALDAN DRIVE
AUBURN HILLS, MICHIGAN 48057

SHIPPED TO: SAME (313-377-4990)
c/o WELDING SERVICES, INC.
MFG. DIV.
3275 MARJAN DRIVE, ATLANTA, GEORGIA 30340

VIA: AIR EXPRESS -COLLECT

DATE OF ORDER	YOUR ORDER NO.	F.O.B.	SALESMAN	ORDER	REFERENCE
4-20-89	904060	A.A.S.I.	SK/KK	☐ Complete ☐ Partial	HENRY FLEMMING

ITEM	QUANTITY ORDERED	DESCRIPTION	SHIPPED Pounds or Feet	PRICE EACH	TOTAL AMOUNT
		SA 302-B NORMALIZED		[redacted]	[redacted]
1	1	7-1/4" x 12" x 30" (+1/2", -0")	740# EA		
		TAG: P.O. 207365			

RBA

RUSH SHIPMENTS — OUR SPECIALTY AROUND THE CLOCK.

PACKING LIST

THIS IS A PACKING SLIP — NOT AN INVOICE

marathon Letourneau company

Testing Laboratory

ORIGINAL FILE COPY
DO NOT REMOVE

Report of CHEMICAL and PHYSICAL TESTS of STEEL PLATE

Date: 9-3 1986

Shipped To AMERICAN ALLOY STEEL, INC.

Mill Order No. L147221

Customer's Order No. 12505

AMERICAN ALLOY PLATE # A66341

2". Gage

	Melt No.	Slab No.	Spec.	Carb.	Mang.	Sulph.	Phos.	Sil.	Mol.	Charpy Ft./Lbs.	Yield Point P.S.I.	Ten Strength P.S.I.	% Elongation	Bend Test	Size of Plate
				CHEMICAL ANALYSIS											
D	21629	A323	SA302B	.18	1.15	.016	.013	.26	.55		77,500	97,500	19.0		7 1/4 X 106 X 106
										S-4	79,500	100,000	19.0		

Norm. @ 1700°F for 1 hr. per inch of thickness @ temp. and still air cooled -
Test coupons (after norm.) were stress relieved @ 1125° F for 3 1/2 hours
with S-4 additional tension test ultra sonically inspected per SA578, Level 2,
100% scan

TEST REPORT APPROVED DATE Sept. 22, 1986
AMERICAN ALLOY STEEL BY [signature]
ASST QUALITY CONTROL DIRECTOR

CUSTOMER Energy Steel & Supply Co.
CUST P.O.# 904280
A.A.S. S/O# 72466 PLATE# A66341
DATE MAILED 04/21/89
DESCRIPTION [illegible] 7 1/4" x 12" x 30 [illegible]

Certified a true copy of original, retained in our AMERICAN ALLOY STEEL

I Hereby Certify that the Above Tests Are Correct to the best of My Knowledge and Belief.

marathon Letourneau company

K. B. Wright
Engr. of Tests

C E R T I F I C A T I O N

+ CERTIFICATION OF CONFORMANCE +

+ CERTIFICATION OF COMPLIANCE +

ENERGY STEEL and SUPPLY Co.
2715 Paldan
Auburn Hills, MI 48057

WELDING SERVICES
MANUFACTURING DIVISION
3276 MARJAN DRIVE
ATLANTA, GA 30340

Your Order Number	Our Order Number	Date
207866	WELSE004377 01	4/21/89

Item#	Prod#	Qty	Description	Grade-Spec.	Heat Number
1	C0050	1	PLATE 7-1/4X12X30	ASME SA302 GB	21629

This is to certify that the material furnished for your order and described above, has been reviewed and complies to requirements of the applicable material specifications, and meets all requirements of your purchase order.

>>>

Energy Steel & Supply Co.

Kelly A Pratt

Quality Assurance Specialist

Welding Services Inc. ☐
Welding Services Inc. Mfg. Div. ☐

3276 Marjan Drive
Atlanta, Georgia 30340
Telephone (404) 452-0005

Accounts Payable
(404) 455-0929

PURCHASE ORDER NO.

0207866

990
ENERGY STEEL & SUPPLY CO.
2715 PALDEN DRIVE
AUBURN HILLS,
MICHIGAN
48057-0000

SHIP TO
WELDING SERVICES, INC.
SHIPPING & RECEIEVING
3202 MARJAN DRIVE
ATLANTA, GEORGIA
30340-0000

TE	TERMS	F.O.B.	SHIP VIA	JOB / PROJECT	P. R. NO.	TAXABLE (YES / NO)	WSI ☐ / WSI MFG ☐
	NET 30 DAYS	S/P	AIR BEST	INDIAN POINT II/CON ED.	13735		

TY.	WHSE	WSI MFG PART NO. G/L CODE	SPEC/VENDOR PART NO.	DESCRIPTION	PRICE	UNIT	EXT.	JOB/PHASE N
.00	I5	401-01-00	SA302/GR.B	SA302/GR B STEEL PLATE, 7-1/4" X 12" X 30".	3,900.000	EA	3,900.000	69041-1-1
.00	I5	Q.A. APPROVAL 400-02-00	Q.A. APPROVAL	Q.A. APPROVAL/DATE: 4-22-89 SIGNED: [signature]	.000	EA	.000	69041-1-1
.00	I5	CERTS/TEST REP. 400-02-00	CERTS/TEST REP.	CERTS/MATERIAL TEST REPORTS REQUIRED	.000	EA	.000	69041-1-1

TOTALS → 3,900.000

IRMATION TO	REQ/DEPT.	QA Approval (YES / NO)	C of C Req'd (YES / NO)	QA Insp. Req. (YES / NO)
EMING	BURKHALTER			

PURCHASING DEPT.

AMERICAN ALLOY STEEL, INC.

7721 PINEMONT
P.O. BOX 40469
HOUSTON, TEXAS 77240-0469
(713) 462-8081
TELEX 76-2806

INVOICE NO.
INVOICE DATE:
S/O 72468
TERMS: 1%—15 days—NET 30 DAYS

052650
SOLD TO: ENERGY STEEL & SUPPLY COMPANY
2715 PALDAN DRIVE
AUBURN HILLS, MICHIGAN 48057

SHIPPED TO: SAME (313-377-4990)
C/O WELDING SERVICES, INC.
MFG. DIV.
3275 MARJAN DRIVE, ATLANTA, GEORGIA 30340

VIA: AIR EXPRESS -COLLECT

DATE OF ORDER	YOUR ORDER NO.	F.O.B.	SALESMAN	ORDER	REFERENCE
4-20-89	904060	A.A.S.I.	SK/KK	☐ Complete ☐ Partial	HENRY FLEMMING

ITEM	QUANTITY ORDERED	DESCRIPTION	SHIPPED Pounds or Feet	PRICE EACH	TOTAL AMOUNT
		SA 302-B NORMALIZED		[redacted]	
1	1	7-1/4" x 12" x 30" (+1/2", -0")	740# EA		
		TAG: P.O. 207366			

KBA

RUSH SHIPMENTS — OUR SPECIALTY AROUND THE CLOCK.

PACKING LIST
THIS IS A PACKING SLIP — NOT AN INVOICE

RECEIVING INSPECTION REPORT

JOB NUMBER	ITEM(S)
IP69041G	PlATE - Indian PoirT Con. ED.

INFORMATION	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5
MANUFACTURER	American Alloy STEEL				
P.O. NUMBER	02078666				
VENDOR	ENERGY STEEL Supply				
MATERIAL	ASME SA302 GR B				
HEAT NUMBER	21629				
MATERIAL MILL TEST REPORT	RECEIVED				
LENGTH	30" X 12" X 7¼"				
WIDTH					
NOMINAL DIAMETER					
DIAMETER CHECK A					
B					
C					
D					
NOMINAL THICKNESS					
THICKNESS 1					
2					
3					
4					
5					
VISUAL INSPECTION	Accept				
REMARKS					
NCR #					
DATE	4-26-89				
BY	A. Lewoniec				

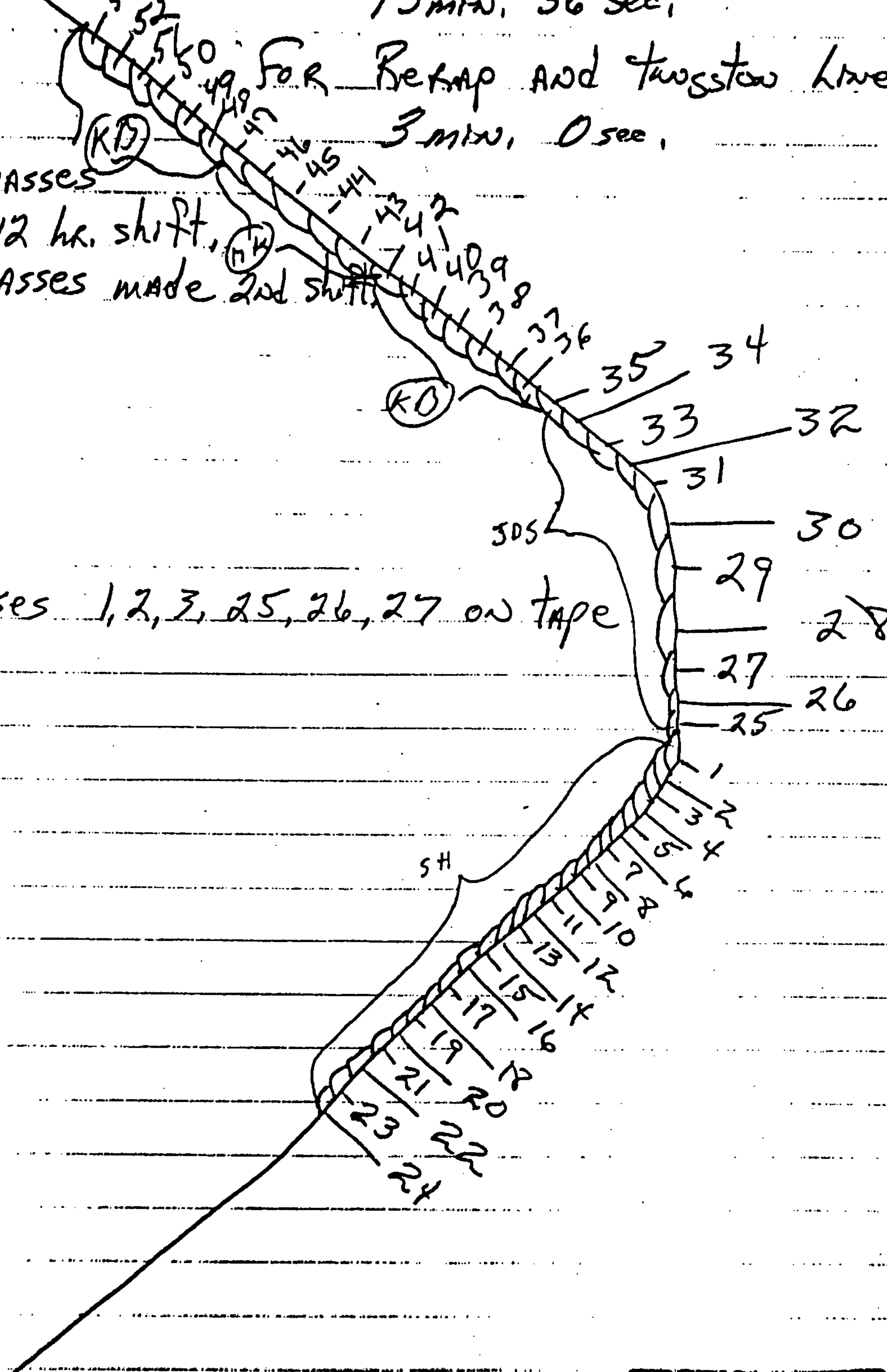
Spartan 50 Sheets W1011-3HP

*

4-26-89

FROM SEQ. START TO SEQ STOP
13 min. 36 sec.
FOR RETRAP AND TUNGSTEN LINE-UP
3 min. 0 sec.

Note: 41.8 passes possible in 12 hr. shift,
35 passes made 2nd shift



Note: Passes 1, 2, 3, 25, 26, 27 on tape

1st LAYER

S.M. 4/27/89

OPERATOR LOG

WELD NUMBER____________ LAYER NUMBER____________

OPERATOR	LAYER	PASS#	START	STOP	NOTES
K. Bubash	2	(1)	5:20	5:34	
K. Bubash	2	(2)	5:38	5:54	.90
K. Bubash	2	(3)	5:58	6:14	.90
K. Bubash	2	(4)	6:18	6:34	.90
K. Bubash	2	5	6:38	6:52	.90
S. HARMON	2	6	7:00	7:16	.70 Steering
S HARMON	2	7	7:19	7:35	Wire Quit Feeding .70
S HARMON	2	8	7:39	7:52	.70 Moth Flew into Puddle
S HARMON	2	9	7:55	8:08	.70
S HARMON	2	10	8:12	8:25	.60
S HARMON	2	11	8:26	8:40	.60 Ran Out of Steering
S HARMON	2	12	8:57	9:10	.860
S HARMON	2	13	9:13	9:27	.60 Change L Arms + Rotate Dove Tail 180°
S HARMON	2	14	9:54	10:06	.800
S HARMON	2	15	10:08	10:22	.60
S. HARMON	2	16	10:24	10:39	.60
S HARMON	2	17	10:41	10:54	.60
S HARMON	2	18	10:56	11:11	.60
S HARMON	2	19	11:14	11:28	.60
S HARMON	2	20	11:30	11:47	.60

OPERATOR LOG

WELD NUMBER________ LAYER NUMBER________

OPERATOR	LAYER	PASS#	START	STOP	NOTES 2 of 3
S HARMON	2	21	11:55	12:11	.60
S. HARMON	2	22	12:33	12:46	60
S. HARMON	2	23	12:50	1:03	60
S HARMON	2	24	1:07	1:20	60
S. HARMON	2	25	1:28	1:42	HEAD WON'T REVERSE
			N/O #1	MACH.	DRIVE ROLLER SPUN 1:48 SHUT DOWN
S HARMON	2	26	2:12	2:26	
S. HARMON	2	27	2:43	2:56	
S. HARMON	2	28	3:02	3:12	#2 MACH. SHUT DOWN 2 WEAR PADS
Bottom		2ND	LAYER		
TOP	2ND	LAYER			
S. HARMON	2	1	3:54	4:08	
M Kitchens	2	2	4:12	4:25	
M Kitchens	2	3	4:29	4:44	
M Kitchens	2	4	4:46	5:00	
M Kitchens	2	5	5:04	5:17	
M Kitchens	2	6	5:20	5:35	
M Kitchens	2	7	5:40	5:49	Stop to put 2ND Weldhead Boot on track
M Kitchens	2	8	6:28	6:43	~~Stop~~
M Kitchens	2	9	6:55	7:08	

OPERATOR LOG

WELD NUMBER__________ LAYER NUMBER__________

OPERATOR	LAYER	PASS#	START	STOP	NOTES 3 of 3
M Kitchens	2	9	7:23	7:36	
M Kitchens	2	10	7:47	8:00	
M Kitchens	2	11	8:08	8:24	
M Kitchens	2	12	8:33	8:46	
M Kitchens	2	13	8:50	9:03	
M Kitchens	2	14	9:15	9:28	
M Kitchens	2	15	9:43	9:52	
M Kitchens	2	16	10:10	10:24	
M Kitchens	2	17	10:35	10:48	
M Kitchens	2	18	10:57	11:12	
M Kitchens	2	19	11:20	11:34	
M Kitchens	2	20	11:45	11:59	
M Kitchens	2	21	12:02	12:15	
M Kitchens	2	22	12:20	12:33	
M Kitchens	2	23	12:37	12:52	

OPERATOR LOG

WELD NUMBER__________ LAYER NUMBER__________

OPERATOR	LAYER	PASS#	START	STOP	NOTES
M Kitchens	3	1	1:17	1:31	Top Part of 3Rd layer
M Kitchens	3	2	1:36	1:50	
M Kitchens	3	3	2:05	2:18	
M Kitchens	3	4	2:30	2:42	
M Kitchens	3	5	2:53	3:03	
M Kitchens	3	6	3:45	3:58	
M Kitchens	3	7	4:09	4:23	
M Kitchens	3	8	4:32	4:47	
M Kitchens	3	9	4:56	5:10	
M Kitchens	3	10	5:16	5:31	
M Kitchens	3	11	5:35	5:50	
M Kitchens	3	12	6:05	6:18	
M Kitchens	3	13	6:27	6:45	90 dial.
S Harmon	3	14	7:54	8:07	
S Harmon	3	15	8:30	8:43	
S Harmon	3	16	9:58	10:12	
S Harmon	3	17	10:26	10:38	
S Harmon	3	18	10:48	11:01	
S Harmon	3	19	11:25	11:37	
S Harmon	3	20	11:53	12:06	

OPERATOR LOG

WELD NUMBER Indian Point

LAYER NUMBER 3

OPERATOR	LAYER	PASS#	START	STOP	NOTES Bottom
S. Harmon	3	1	6:24	6:37	
S. Harmon	3	2	6:48	7:04	
K. Bubash	3	3	7:21	7:33	
K. Bubash	3	4	7:45	7:58	
K. Bubash	3	5	8:07	8:20	
K. Bubash	3	6	8:31	8:45	
K. Bubash	3	7	8:52	9:08	
K. Bubash	3	8	9:15	9:33	
K. Bubash	3	9	9:40	9:54	
K. Bubash	3	10	10:05	10:19	
K. Bubash	3	11	10:30	10:44	
K. Bubash	3	12	10:51	11:06	
K. Bubash	3	13	11:15	11:34	
K. Bubash	3	14	11:41	11:55	
K. Bubash	3	15	1:05	1:23	
K. Bubash	3	16 KTB ~~165~~	1:27	1:45	
K. Bubash	3	17	2:02	2:17	
K. Bubash	3	18	2:31	2:44	
K. Bubash	3	19	3:40	3:55	

OPERATOR LOG

WELD NUMBER Indian Point

LAYER NUMBER 3

NOTES Bottom

OPERATOR	LAYER	PASS#	START	STOP	
K. Bubash	3	20	4:07	4:18	
K. Bubash	3	21	4:32	4:50	
K. Bubash	3	22	4:54	5:08	
K. Dubash	3	23	5:16	5:29	

OPERATOR LOG

WELD NUMBER Indian Point

LAYER NUMBER 4

NOTES Bottom

OPERATOR	LAYER	PASS#	START	STOP	NOTES
R. Poitra	4	21	3:51	4:04	60-350
R. Poitra	4	22	4:25	4:38	60-290
R. Poitra	4	23	5:02	5:15	60-230
R. Poitra	4	24	5:26	5:39	60-170
K. Bubash R. Poitra	4	25	8:12	8:27	60-110 Machine Down 6:00
K. Bubash	4	26	8:35	8:49	complete

OPERATOR LOG

WELD NUMBER Indian Point

LAYER NUMBER 4

NOTES Bottom

OPERATOR	LAYER	PASS#	START	STOP	NOTES
K. Bubash (Goodes)	4	1	6:01	6:15	
K. Bubash	4	2	6:26	6:42	
S. Harmon	4	3	6:58	7:11	720-70 650
S. Harmon	4	4	7:13	7:26	70
S. Harmon	4	5	7:34	7:46	70
R. Poitra	4	6	7:~~48~~49	8:03	70
R. Poitra	4	7	8:20	8:34	60
R. Poitra	4	8	9:00	9:14	
R. Poitra	4	9	9:41	9:54	~~30~~ 70-240
R. Poitra	4	10	10:20	10:34	70-170
R. Poitra	4	11	10:43	10:56	60-110
R. Poitra	4	12	11:13	11:25	70-40
R. Poitra	4	13	11:45	11:57	800
R. Poitra	4	14	12:09	12:23	60-740
R. Poitra	4	15	12:45	12:59	60-680
R. Poitra	4	16	1:13	1:26	~~40-640~~ 60-620
R. Poitra	4	17	1:38	1:52	40-580
R. Poitra	4	18	2:04	2:17	50-530
R. Poitra	4	19	2:27	2:40	60-470 Down Time To Hot 2:40-3:19
R. Poitra	4	20	3:19	3:33	60-410

OPERATOR LOG

WELD NUMBER__________ LAYER NUMBER__________

OPERATOR	LAYER	PASS#	START	STOP	NOTES
M Kitchens	4	19	9:42	9:59	
M Kitchens	4	20	~~9:59~~ 10:10	10:21	
M Kitchens	4	21	10:33	10:45	
M Kitchens	4	22	10 57	11 09	
M Kitchens	4	23	11:30	11 48	

OPERATOR LOG

WELD NUMBER__________ LAYER NUMBER__________

OPERATOR	LAYER	PASS#	START	STOP	NOTES
S HARMON	3	21	12:20	12:34	
S HARMON	4	1	12:50	1:03	Rec
S HARMON	4	2	1:19	1:32	Rec
S HARMON	4	3	1:43	1:57	Rec
S HARMON	4	4	2:09	2:22	
S. HARMON	4	5	2:32	2:44	
S HARMON	4	6	3:24	3:38	To Hot Shut Down Few Min
S. HARMON	4	7	3:56	4:11	
S HARMON	4	8	4:29	4:41	
S. HARMON	4	9	5:08	5:21	
S. HARMON	4	10	5:28	5:43	
S HARMON	4	11	6:05	6:18	
S HARMON	4	12	6:26	6:39	
M Kitchens	4	13	7:25	7:42	
M Kitchens	4	14	7:45	7:58	
M Kitchens	4	15	8:14	8:27	
M Kitchens	4	16	8:34	8:48	
M Kitchens	4	17	9:04	9:18	
M Kitchens	4	18	9:24	9:40	

OPERATOR LOG

WELD NUMBER Indian point

LAYER NUMBER 5 Th

NOTES Bottom

OPERATOR	LAYER	PASS#	START	STOP	NOTES
K. Bubash good	5	(1)	9:02	9:16	
K. Bubash	5	2	9:25	9:38	
K. Bubash	5	3	9:45	9:59	
K. Bubash	5	4	10:08	10:22	
K. Bubash	5	5	10:29	10:43	
K. Bubash	5	6	10:52	11:06	
K. Bubash	5	7	11:22	11:36	
K. Bubash	5	8	11:45	11:59	
K. Bubash	5	9	12:03	12:17	
K. Bubash	5	10	12:21	12:35	
K. Bubash	5	11	12:42	12:56	
K. Bubash	5	12	1:08	1:24	
K. Bubash	5	13	1:30	1:44	
K. Bubash	5	14	1:52	2:06	SHUT DOWN BECAUS OF HEAT 2:10 TO 3:10
K. Bubash	5	15	3:35	3:45	
K. Bubash	5	16	4:02	4:18	SHUT DOWN BECAUS OF HEAT.
K. Bubash	5	17	5:01	5:16	
K. Bubash	5	18	5:26	5:40	
K. Bubash	5	19	5:55	6:14	
K. Bubash	5	20	6:35	6:48	SHUT DOWN HEAT PROBLEM.

OPERATOR LOG

WELD NUMBER ____________

LAYER NUMBER ____________

OPERATOR	LAYER	PASS#	START	STOP	NOTES Top
M Kitchens	5	1	12:45	12:58	upward from center
M Kitchens	5	2	1:08	1:22	
M Kitchens	5	3	1:32	1:47	
M Kitchens	5	4	2:09	2:18	
M Kitchens	5	5	2:24	2:39	temperatura 450° Stop to ~~cool~~ cool down
M Kitchens	5	6	3:17	3:30	
M Kitchens	5	7	3:36	3:52	
M Kitchens	5	8	4:05	4:23	
M Kitchens	5	9	4:35	4:49	
M Kitchens	5	10	5:06	5:25	
M Kitchens	5	11	5:33	5:46	
M Kitchens	5	12	6:00	6:13	Stop for cool down
M Kitchens	5	13	6:37	6:51	
S Harmon	5	14	7:46	8:00	
S Harmon	5	15	8:37	8:51	
S Harmon	5	16	9:00	9:13	
S Harmon	5	17	9:27	9:40	
S Harmon	5	18	9:51	10:04	
S Harmon	6	1	10:18	10:31	
S Harmon	6	2	10:47	11:00	

OPERATOR LOG

WELD NUMBER ______

LAYER NUMBER ______

OPERATOR	LAYER	PASS#	START	STOP	NOTES Bottom
R. Poitra	6	1	7:34	7:47	
R. Poitra	6	2	8:25	8:39	780
R. Poitra	6	3	8:55	9:08	70-710
R. Poitra	6	4	9:20	9:33	80-630
R. Poitra	6	5	9:45	9:58	80-550
R. Poitra	6	6	10:13	10:26	80-440
R. Poitra	6	7	10:40	10:53	~~140~~ ~~330~~ 350
R. Poitra	6	8	11:18	11:31	280
R. Poitra	6	9	11:43	11:56	200
R. Poitra	6	10	12:10	12:23	130
R. Poitra	6	11	12:45	12:59	
R. Poitra	6	12	1:19	1:32	890
R. Poitra	6	13	2:04	2:17	810
R. Poitra	6	14	2:43	2:56	730
R. Poitra	6	15	3:06	3:19	650
R. Poitra	6	16	3:32	3:45	600
R. Poitra	6	17	4:09	4:22	530
R. Poitra	6	18	4:39	4:52	450
R. Poitra	6	19	5:14	5:27	450
R. Poitra	6	20	5:47	6:00	360

OPERATOR LOG

FIELD NUMBER ____________ LAYER NUMBER ____________

OPERATOR	LAYER	PASS#	START	STOP	NOTES TOP
S. Harmon	6	3	11:27	11:40	
R. Poitra	6	4	11:50	12:03	
R. Poitra	6	5	12:16	12:29	210
R. Poitra	6	6	12:52	1:05	290 Stop To Cool Down
R. Poitra	6	7	1:48	2:01	90
R. Poitra	6	8	2:11	2:24	170
R. Poitra	6	9	2:49	3:02	250
R. Poitra	6	10	3:11	3:24	330
R. Poitra	6	11	3:37	3:50	410
R. Poitra	6	12	4:14	4:27	490
R. Poitra	6	13	4:45	4:58	570
R. Poitra	6	14	5:20	5:33	650
R. Poitra	6	15	5:53	6:06	730
R. Poitra	6	16	6:28	6:41	810
M Kitchens	6	17	7:44	7:51	
M Kitchens	6	18	7:58	8:09	Cool Down
M Kitchens	6	19	8:30	8:41	
M Kitchens	6	20	8:45	8:54	

OPERATOR LOG

WELD NUMBER__________

LAYER NUMBER__________

OPERATOR	LAYER	PASS#	START	STOP	NOTES Bottom
R. Poitra	6	21	6:22	6:35	280
M Kitchens	6	22	7:07	7:20	
M Kitchens	6	23	7:25	7:37	

ATS
APPLIED TECHNICAL SERVICES, INCORPORATED

Branch Office
1218 Donaldson Road
Greenville, South Carolina 29605
(803) 299-0523

Main Office
1190 Atlanta Industrial Drive
Marietta, Georgia 30066
(404) 423-1400
FAX # (404) 424-6415

Branch Office
106-A Castle Drive
Madison, Alabama 35758
(205) 837-7777

*

Ref. AO-0394
Date 5/9/89
Purchase Order # 207593

MAGNETIC PARTICLE INSPECTION REPORT

Welding Services Inc.
Atlanta, GA.

MATERIAL: Steel / P-3
PART SIZE: 30" x 12"

INSPECTION PROCEDURE

Specification(s) ASME Section V, III, NB2500 NB5000
ATS 140.1, Rev 1

- ☑ DRY
- ☐ WET
- ☐ RECTIFIED
- ☑ DC
- ☑ AC
- ☐ CENTRAL CON. (AMPS)
- ☐ HEAD (AMPS)
- ☐ COIL (AMPS)
- ☐ DEMAG

M.T. EQUIP. Parker Probe DA-200
PARTICLE MFG. Parker Research
PARTICLE BATCH NO. 3844
PARTICLE COLOR Red
PROD SPACING 6"-8"
AMPERAGE Max.
METER CAL DATE N/A
YOKE CAL DATE 5/1/89

INSPECTION RESULTS

IDENTIFICATION	ACCEPT	REJECT	QUANTITY	REMARKS
Temper Bead Qual.	✓		1	Temper Bead GTAW
				Reference Code Case
				ATS 1 ACCEPTED ·MT·
				LINEAR INDICATION ≈ 3/4"
				WAS REMOVED BY GRINDING
Witness by ANI Kemper / P-2.				
S.K. 5/8/89. 10:30 PM				

A-2-88

Client Approval

Inspection Performed By: John A. Barnard Level II M.T.

J.J. Hills JIM J. HILLS Level III M.T.

APPLIED TECHNICAL SERVICES, INCORPORATED

Branch Office
1218 Donaldson Road
Greenville, South Carolina 29605
(803) 299-0525

Main Office
1190 Atlanta Industrial Dr.
Marietta, Georgia 30066
(404) 423-1400
Fax #424-6415

Branch Office
108-A Castle Drive
Madison, Alabama 35758
(205) 837-7777

Ref. AO-0394
P.O. No. 207593
Date 5-8-89

RADIOGRAPHIC INSPECTION REPORT

Welding Services Inc.
Atlanta, GA.

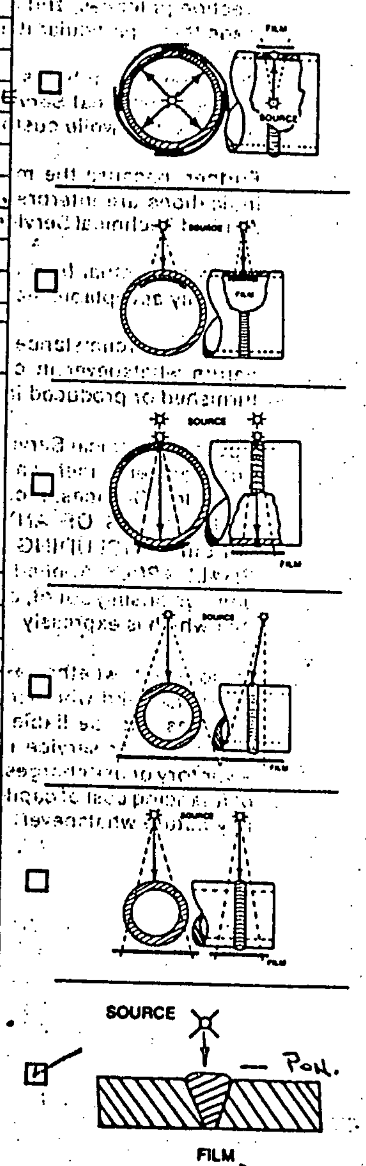
Part No.: N/A
Part Name: Temper Bead Qualification
Material: P-3
Thickness: 7.25"
Type Weld: Temper Bead, GTAW
REFERENCE CODE CASE

Radiographic Inspection Technique

Specification(s) ASME V, IX, III, NB2500, NB5000 ATS120.1
Isotope Co 60
Curies 13
KV N/A
MA N/A
Time 14 hrs.
SFD 30
OD 22.75"
Source Size (Physical) .153 sphere
Geometric Unsharpness Ug = Fd/D .048

Film Size 14" x 17"
Film Type NDT 65 Double load 2 film/cassette
Sensitivity 2-2T
Penetrameter 80
Shim(s) Bare
Develop: Temp: 68° Time: 8 min
Screen(s) .010" F+B, .010 CS
Effective .153

Set-Up



INTERPRETATION

PART I.D./ FILM VIEW	Accept	Reject	Crack	Slag Inclusion	Tungsten Inclusion	Porosity	Undercut	Incomplete Fusion	Incomplete Penetration	Root Concavity	Root Convexity	DENSITY Penetrameter	DENSITY Area of Interest	REMARKS
														Composite Viewing
0-1	✓											3.4	3.2	COMPOSITE VIEW
												1.6	1.5	SINGLE VIEW 1.8, 1.7
1-2	✓											3.4	3.4	COMPOSITE VIEW
												[illegible]	[illegible]	SINGLE VIEW
2-3	✓											3.5	3.5	COMPOSITE VIEW
												[illegible]	[illegible]	SINGLE VIEW

SKETCH

Witness by ANI Kemper / P-2
[signature] 5/8/89 10:30 PM

A-6-88 NOTE: 2 SETS OF EACH VIEW PROVIDED TO CUSTOMER

Radiographer(s): [signature] Level II R.T.

Client Approval ______

Interpreter: [signature] Level II R.T.

APPLIED TECHNICAL SERVICES, INCORPORATED

Branch Office
1218 Donaldson Road
Greenville, South Carolina 29605
(803) 299-0525

Main Office
1190 Atlanta Industrial Drive
Marietta, Georgia 30066
(404) 423-1400
FAX # (404) 424-6415

Branch Office
108-A Castle Drive
Madison, Alabama 35758
(205) 837-7777

Ref. AO-0394

Purchase Order # 207593

Date 5-8-89

ULTRASONIC INSPECTION REPORT

WELDING SVCS., INC.

MATERIAL: STEEL / P-3

INSPECTION PROCEDURE

Specification(s): ASME SECTION V ARTICLE 5 A/R IAW ASME SECTION III NB 5330. DAC REQ. 4 DIRECTIONS STRAIGHT BEAM, 45°; 60°

☐ SHEAR ☐ SURFACE ☒ CONTACT

☒ LONGITUDINAL ☐ THICKNESS ☐ IMMERSION

☐ SKETCH ATTACHED

SCANNING METHOD MANUAL

SURFACE CONDITION SMOOTH

U.T. EQUIPMENT NORTEC NDT 131 S/N 419

TRANSDUCER: MFG. S/N HARISONIC CM0208

TRANSDUCER FREQUENCY 2.25

TRANSDUCER SIZE 1/2" DIA.

TRANSDUCER ANGLE STRAIGHT

REFERENCE STD.: S/N AO3N432

MATERIAL SIZE: THICK./DIA. 30"X12"X7/8"T

COUPLANT/BATCH NO. ULTRAGEL

DAC METHOD ON SCREEN

INSPECTION RESULTS

IDENTIFICATION	ACCEPT	REJECT	INDICATION LEVEL	REFERENCE LEVEL	REMARKS
MULTIBLE RANDOM	LINEAR	INDICATIONS	RANGING FROM 20% TO 100% OF DAC.		

SKETCH AND TECHNIQUE DESCRIPTION:

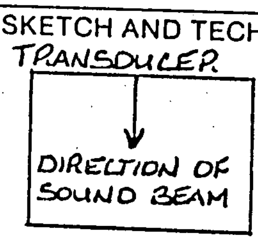
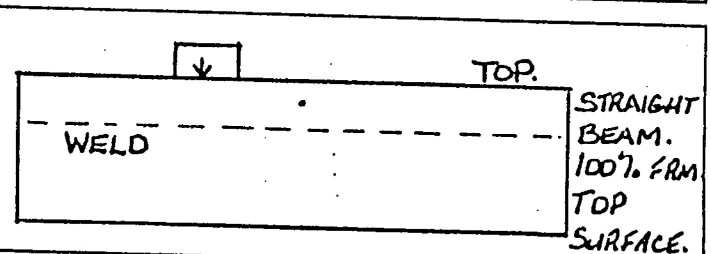


PLATE / SIDE VIEW



A-3

THICKNESS MEASUREMENTS N/A.

MIN. THICKNESS REQUIRED ______

MIN. THICKNESS RECORDED ______

ACCEPT ☐

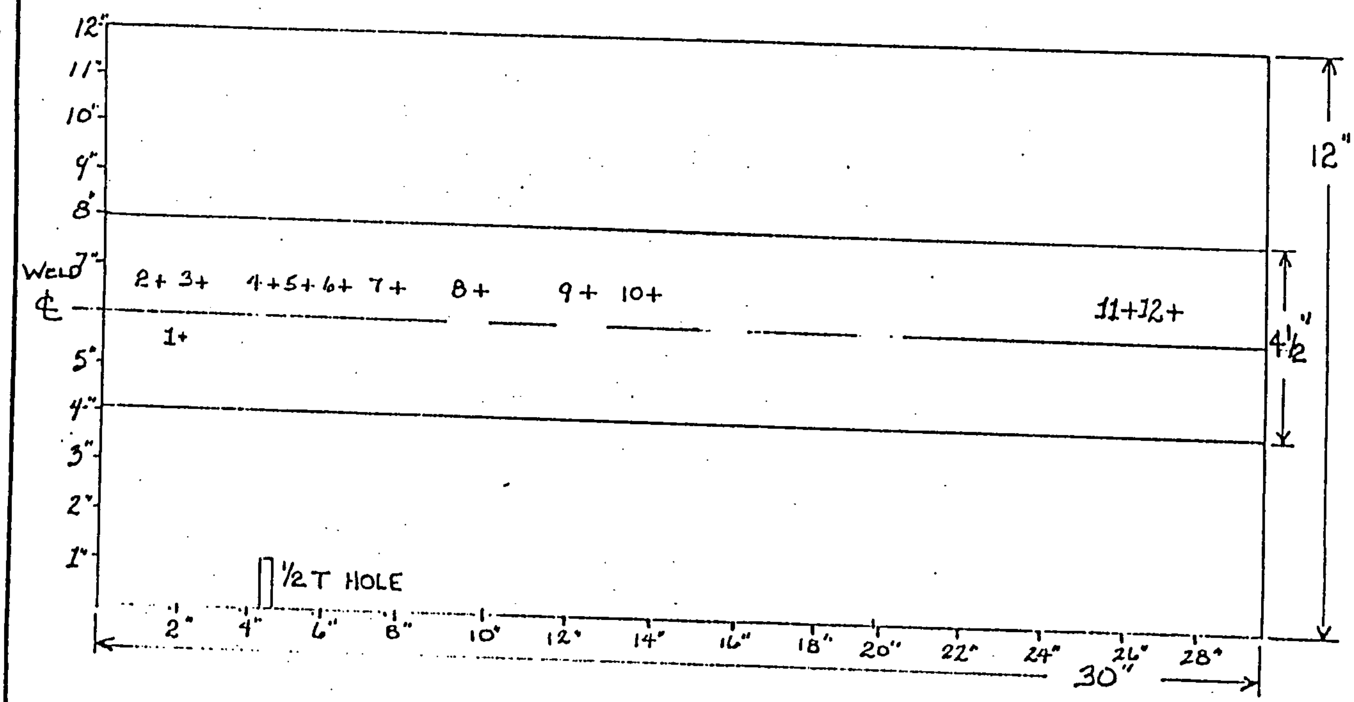
REJECT ☐

Client Approval ______

Inspection Performed By: John A. Burnard Level II U.T.

Approved: J. J. Hills, JIM J HILLS Level III U.T.

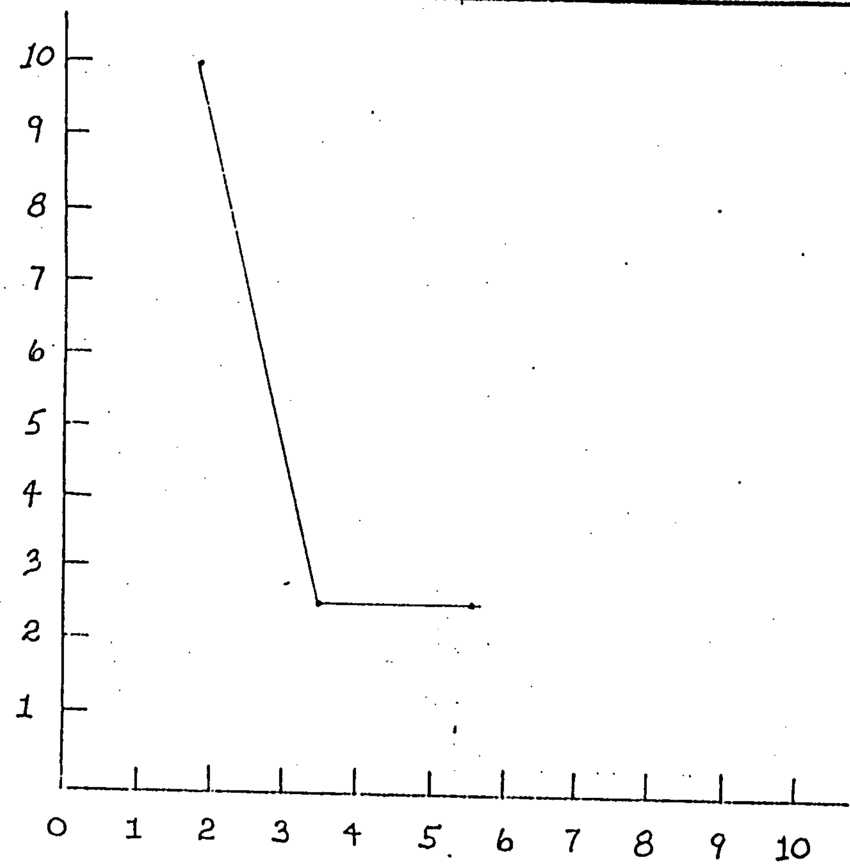
PREPARED BY		PAGE
R. Leimenstoll	**Applied Technical Services, Inc.**	2 of 9
CHECKED		DATE
		5-9-89
APPROVED	TITLE	REPORT NO.
J. Hills	Indication Map for: Straight Beam Scan	A0-0394



INDICATION No.	% DAC	DEPTH
1	40	
2	70	
3	50	
4	>100	
5	70	
6	40	
7	40	
8	30	
9	20	
10	20	
11	40	
12	40	

INDICATION No.	% DAC	DEPTH

PREPARED BY	Applied Technical Services, Inc.	PAGE
R. LEIMENSTOLL		3 OF 9
CHECKED		DATE
		5-8-89
APPROVED	TITLE	REPORT NO.
J. HILLS	D.A.C. ⅓ INST. SETTINGS FOR STRAIGHT BEAM	AO-0394



¼ T 100 @ 61 db
½ T 25 @ 61 db
¾ T 25 @ 61 db

REFERENCE LEVEL : 61 db
SCANING LEVEL : 67 db
TEMP. : 74°F

DELAY CALIB. : 217
RANGE CALIB. : 887
RANGE : 10
DELAY : 0
REJECT : 6
FILTER : +
FREQ. : 2.25
D.B. FINE : 1
COARSE : 60
DAMP. : OFF
REP. RATE : HIGH

APPLIED TECHNICAL SERVICES, INCORPORATED

Main Office
1190 Atlanta Industrial Drive
Marietta, Georgia 30066
(404) 423-1400
Fax # (404) 424-6415

Branch Office
90 Lenhardt Road
Piedmont, South Carolina 29673
(803) 299-0525

Ref. A0-0394
Purchase Order # 207593
Date 5-8-89

ULTRASONIC INSPECTION REPORT

WELDING SERVICES, INC.

MATERIAL: STEEL / P-3

INSPECTION PROCEDURE

Specification(s): ASME SECTION V ARTICLE 5 A/R IAW ASME SECTION III NB5330. DAC REQ. 4 DIRECTIONS STRAIGHT BEAM, 45° + 60°

- [x] SHEAR
- [ ] SURFACE
- [x] CONTACT
- [ ] LONGITUDINAL
- [ ] THICKNESS
- [ ] IMMERSION
- [ ] SKETCH ATTACHED

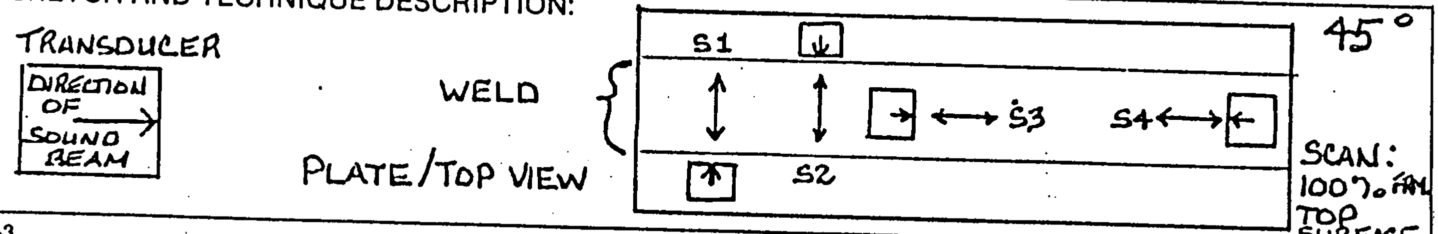
SCANNING METHOD: MANUAL
SURFACE CONDITION: SMOOTH
U.T. EQUIPMENT: NORTEC NDT 131 S/N 419
TRANSDUCER: MFG. S/N: KB AEROTECH S/N B21521

TRANSDUCER FREQUENCY: 2.25
TRANSDUCER SIZE: 3/4" x 5/8"
TRANSDUCER ANGLE: 45°
REFERENCE STD.: S/N A03N432
MATERIAL SIZE: THICK./DIA. 30" x 12" x 7 1/8" T
COUPLANT/BATCH NO. ULTRAGEL
DAC METHOD: ON SCREEN

INSPECTION RESULTS

IDENTIFICATION	ACCEPT	REJECT	INDICATION LEVEL	REFERENCE LEVEL	REMARKS
MULTIBLE RANDOM &	LINEA	R INDI	CATIONS	RANGING	FROM 20% TO 70% OF DAC.

SKETCH AND TECHNIQUE DESCRIPTION:



A-3

THICKNESS MEASUREMENTS N/A

MIN. THICKNESS REQUIRED ______
MIN. THICKNESS RECORDED ______

- [ ] ACCEPT
- [ ] REJECT

Client Approval ______

Inspection Performed By: John A. Barnard Level II U.T.
Approved: Jim J. Hills, JIM J. HILLS Level III U.T.

PREPARED BY	Applied Technical Services, Inc.	PAGE
R LEIMENSTOLL		5 OF 9
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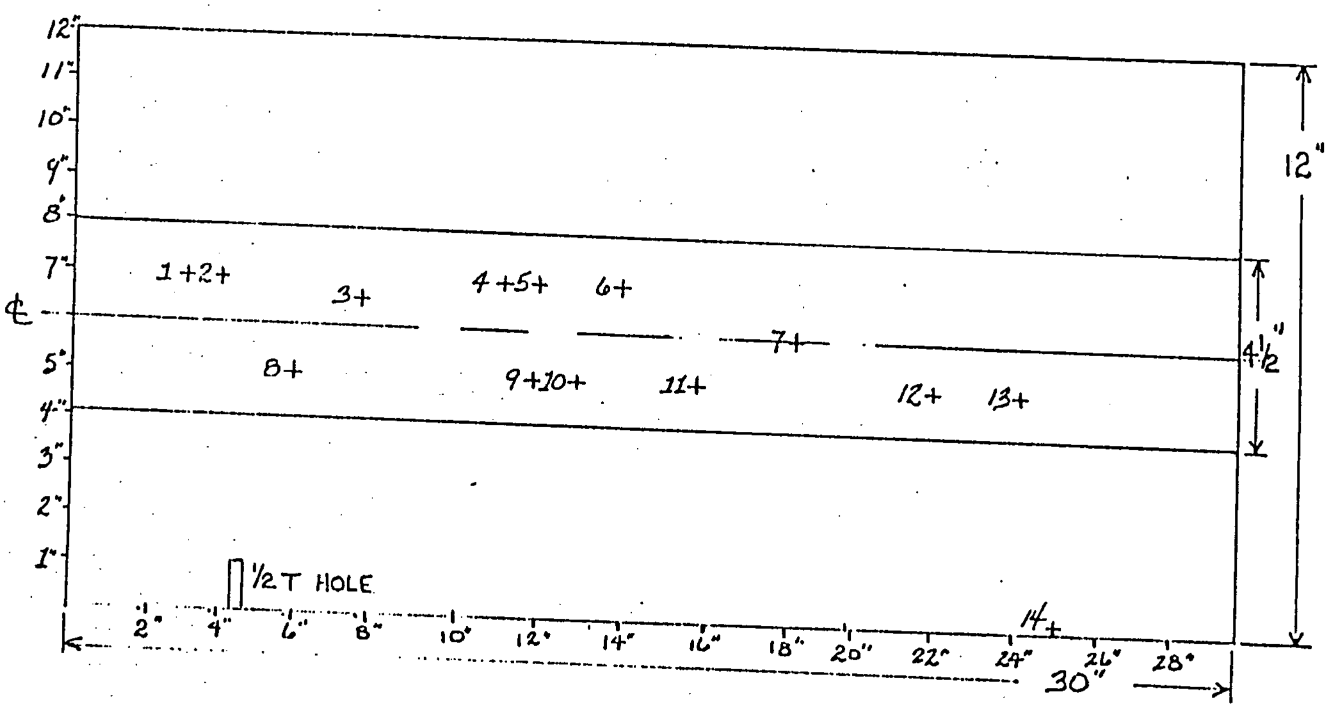
		5-9-89
APPROVED	TITLE	REPORT NO.
J. HILLS	INDICATION MAP FOR : 45° SW SCAN	AO-0394



INDICATION No.	% DAC	DEPTH(IN)
1	20	2.45
2	20	2.45
3	40	1.20
4	50	2.44
5	50	2.45
6	40	2.45
7	30	3.41
8	70	1.30
9	60	1.30
10	50	1.31
11	40	1.31
12	40	1.31
13	30	1.31
14	LAMINATION	3.60

INDICATION No.	% DAC	DEPTH

*POINTS PLOTTED FROM APPARENT CONTINUOUS INDICATION.

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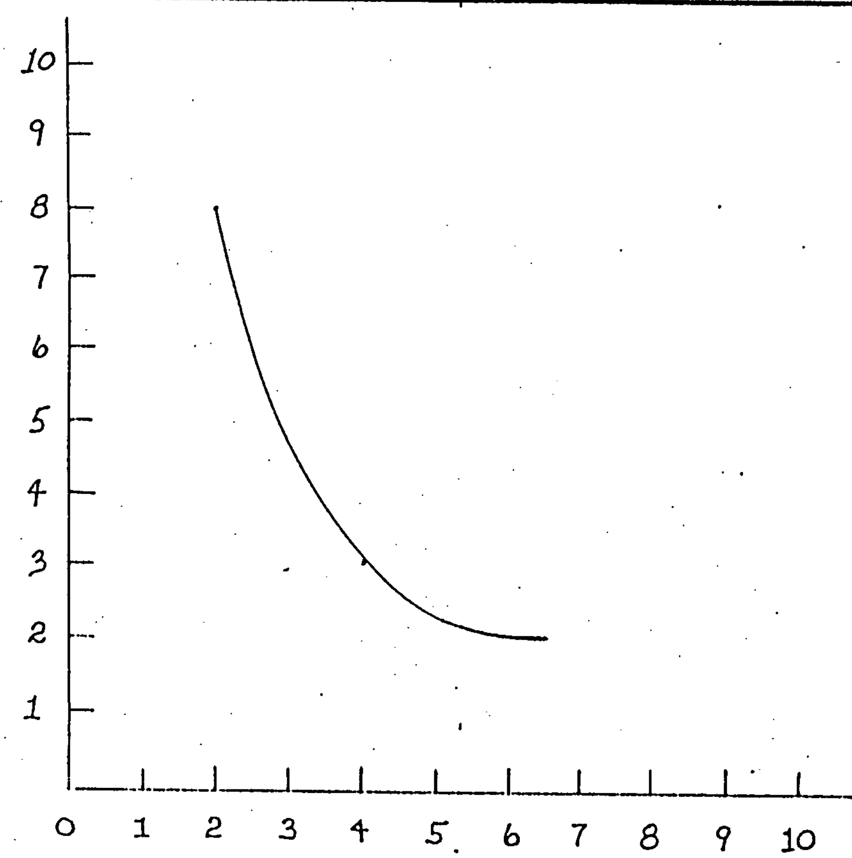
R. LEIMENSTOLL	**Applied Technical Services, Inc.** ats	6 OF ~~8~~ 9
CHECKED		DATE
		5-8-89
APPROVED	TITLE	REPORT NO.
J. HILLS	D.A.C. ? INST. SETTINGS FOR 45° SHEAR WAVE	AO-0394



1/4 T 80 @ 55 db

1/2 T 30 @ 55 db

3/4 T 20 @ 55 db

REFERENCE LEVEL : 55 db

SCANING LEVEL : 61 db

TEMP. : 74°F

DELAY CALIB.	: 120
RANGE CALIB.	: 72
RANGE	: 10
DELAY	: 0
REJECT	: 6
FILTER	: +
FREQ.	: 2.25
D.B. FINE	: 5
D.B. COARSE	: 50
DAMP.	: OFF
REP. RATE	: HIGH

APPLIED TECHNICAL SERVICES, INCORPORATED

Branch Office
1218 Donaldson Road
Greenville, South Carolina 29605
(803) 299-0525

Main Office
1190 Atlanta Industrial Drive
Marietta, Georgia 30066
(404) 423-1400
FAX # (404) 424-6415

Branch Office
108-A Castle Drive
Madison, Alabama 35758
(205) 837-7777

Ref. A0-0394
Purchase Order # 207593
Date 5-8-89

ULTRASONIC INSPECTION REPORT

WELDING SVCS. INC.

MATERIAL: STEEL / P-3

INSPECTION PROCEDURE

Specification(s): ASME SECTION V ARTICLE 5 A/R IAW ASME SECTION III NB 5330. DAC REQ. 4 DIRECTIONS STRAIGHT BEAM, 45° + 60°

☒ SHEAR ☐ SURFACE ☒ CONTACT
☐ LONGITUDINAL ☐ THICKNESS ☐ IMMERSION
☐ SKETCH ATTACHED

SCANNING METHOD MANUAL
SURFACE CONDITION SMOOTH
U.T. EQUIPMENT NORTEC NDT 131 S/N 419
TRANSDUCER: MFG. S/N KB AEROTECH S/N B21521

TRANSDUCER FREQUENCY 2.25
TRANSDUCER SIZE 3/4" x 5/8"
TRANSDUCER ANGLE 60°
REFERENCE STD.: S/N AD3N432
MATERIAL SIZE: THICK./DIA. 30" x 12" x 7/8" T
COUPLANT/BATCH NO. ULTRAGEL
DAC METHOD ON SCREEN

INSPECTION RESULTS

IDENTIFICATION	ACCEPT	REJECT	INDICATION LEVEL	REFERENCE LEVEL	REMARKS
MULTIBLE RANDOM	LINEAR	INDICATIONS		RANGING	FROM 20% TO 100% OF
					DAC.

SKETCH AND TECHNIQUE DESCRIPTION: SEE 45° REPORT FOR SKETCH.

60°

A-3

THICKNESS MEASUREMENTS N/A

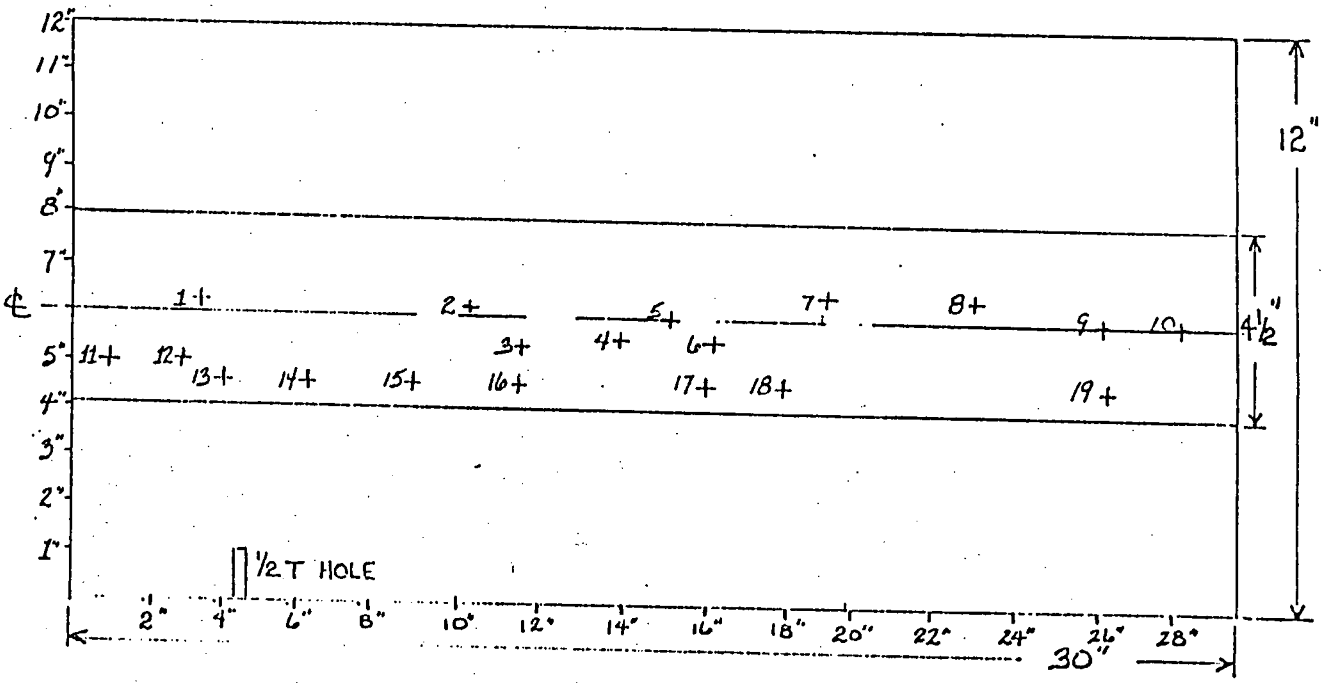
MIN. THICKNESS REQUIRED ____
MIN. THICKNESS RECORDED ____

ACCEPT ☐
REJECT ☐

Client Approval ____

Inspection Performed By: John A. Banard Level II U.T.
Approved: Jim J. Hills, JIM J. HILLS Level III U.T.

PREPARED BY		PAGE
R. LEIMGNSTOLL	**Applied Technical Services, Inc.** ats	8 OF 9
CHECKED		DATE
	TITLE	5-9-89
APPROVED		REPORT NO.
J. HILLS	INDICATION MAP FOR : 60° SW SCAN	AO-0394



INDICATION No.	% DAC	DEPTH
1	20	2.25
2	25	2.59
3	25	1.00
4	20	1.00
5	20	2.50
6	20	1.10
7	20	2.28
8	20	2.29
9	25	2.41
10	25	1.26
11	40	1.20
12	100	1.30
13	100	0.34
14	100	0.33
15	100	0.33

INDICATION No.	% DAC	DEPTH
16	100	1.22
17	40	0.33
18	60	0.30
19	30	0.15

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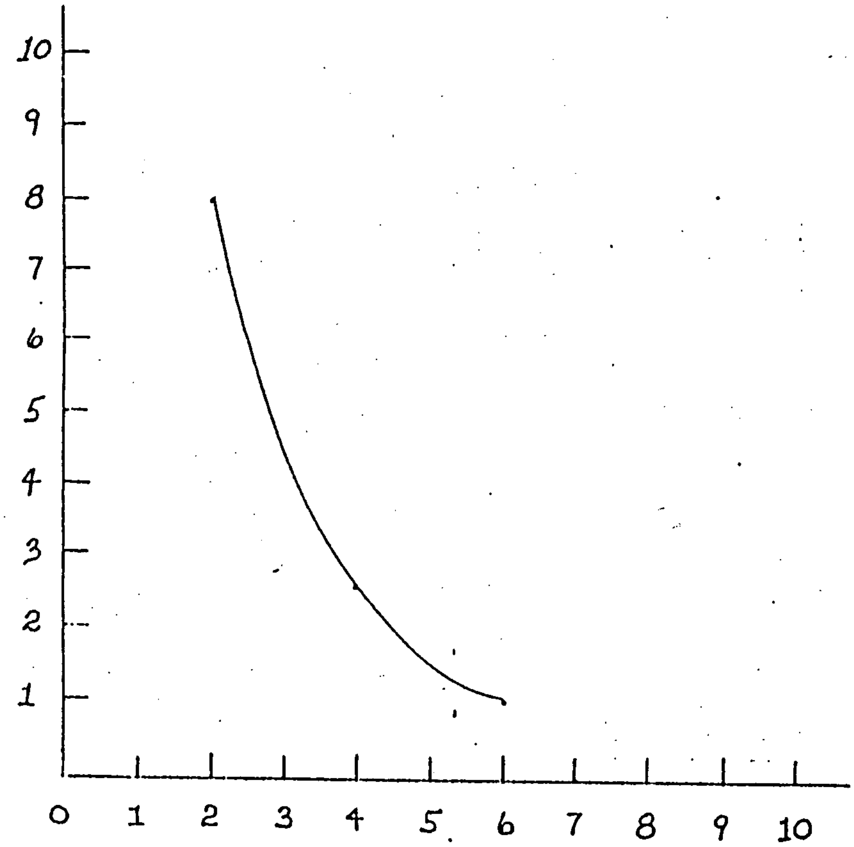
APPROVED	TITLE	REPORT NO.
J. HILLS	D.A.C. & INST. SETTINGS FOR 60° SHEAR WAVE	AO-0394



¼ T 80 @ 67 db
½ T 25 @ 67 db
¾ T 10 @ 67 db

REFERENCE LEVEL : 67 db
SCANING LEVEL : 73 db
TEMP. : 74°F

DELAY CALIB. : 162
RANGE CALIB. : 774
RANGE : 25
DELAY : 0
REJECT : 6
FILTER : +
FREQ. : 2.25
D.B. FINE : 7
D.B. COARSE : 60
DAMP. : OFF
REP. RATE : HIGH

+18/Lwn 60
Sixth Welds

Consulting Metallurgical Services, Inc.

April 27, 1989

Welding Services Inc.
3276 Marjan Drive
Atlanta, Georgia 30340

CMS 405-89

Attn: Mr. Steve Burkhalter

Subject: Microhardness Testing of Various Welds Involved in Temper Bead Pass Welding.

Dear Steve:

At your request we have performed microhardness surveys through the HAZ of various weld samples that you had welded with different parameters in order to determine the required technique for proper temper bead welding of SA 302 grade A with ER 805-D2 filler metal.

We used a Knoop indenter with a 500 gram load, observed at 200 x magnification, in locations A, B, C, and D as shown in the attached sketch.

In addition we performed microhardness surveys in locations A, B, and C on P-2 and P-6 single bead weldments in order to determine the highest hardness produced in the HAZ without tempering.

Photomacrographs and photomicrographs of the areas that you requested are enclosed.

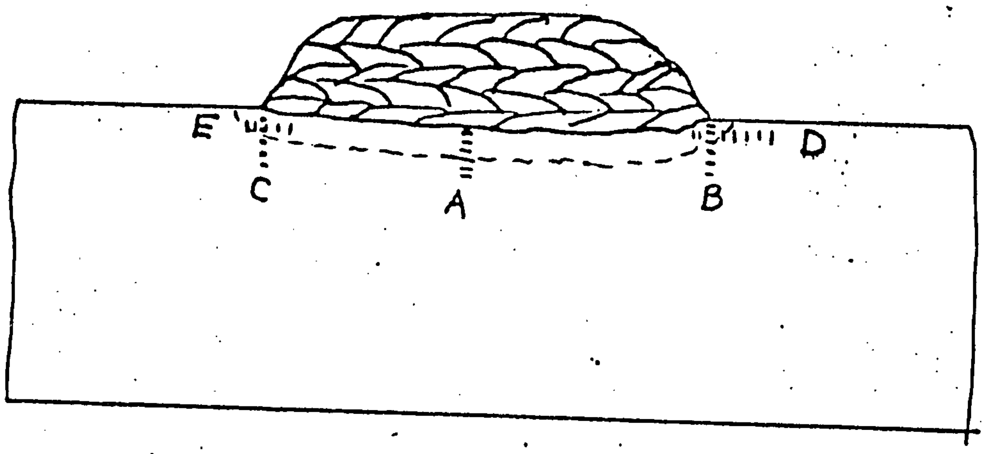
Respectfully submitted,

W. F. Jones III

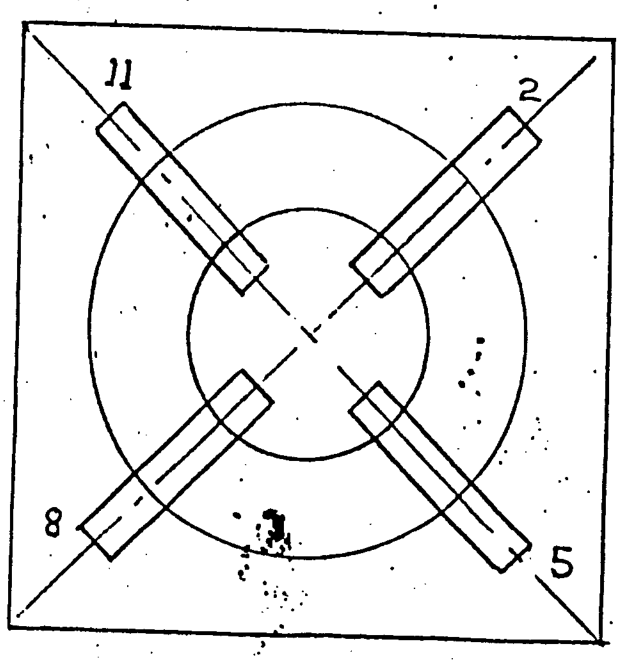
William F. Jones III
Consulting Metallurgical Services

WFJ/lc

1700 CUMBERLAND POINT DRIVE, SUITE 10, MARIETTA, GA 30067 • (404) 952-0038
Fax. (404) 955-7310



Sketch of Microhardness Survey and Sample Locations.



P-2 Single Bead Weld

		A				
Distance from ℄ fusion	Filars	KHN_{500}	Filars	KHN_{500}	Filars	KHN_{500}
0.005"	264	463				
0.015"	248	525				
0.025"	254	500				
0.045"	254	500				
0.065"	254	500				
0.085	254	500				
0.105"	252	508				

High Hardness

A – $\frac{KHN_{500}}{525}$ $\frac{Rc(conv.)}{49.0}$

P6 - Single Bead Weld

Distance from fusion	Filars	A KHN_{500}	Filars	KHN_{500}	Filars	KHN_{500}
0.005"	255	495				
0.015"	257	486				
0.025"	255	495				
0.045"	248	525				
0.065"	252	508				
0.085"	254	500				
0.105"	254	500				

High Hardness

A - $\frac{KHN}{525}$-500 $\frac{Rc(conv.)}{49.0}$

P-6 Weld

Distance from Surface	Filars	A KHN500	Filars	KHN500	Filars	KHN500
0.005"	328	299				
0.025"	348	265				
0.045"	350	263				
0.065"	354	256				
0.085"	373	231				
0.105"	358	251				
0.145"	365	241				
0.185"	368	237				
0.225"	354	256				
0.265"	358	251				
0.345"	360	248				

High Hardness

A - KHN500: 299 Rc (conv.): 28.3

P-2 SINGLE BEAD

	A		B		C	
Distance from fusion	Filars	KHN_{500}	Filars	KHN_{500}	Filars	KHN_{500}
0.00	256	492	258	485	253	504
0.008	256	492	252	508	249	520
0.016	256	492	257	489	261	473
0.024	258	485	258	485	270	443
0.032	258	485	258	485	248	525
0.040	284	400	264	463	297	365
0.048	290	384	270	443	281	418
0.056	302	353	263	466	285	396
0.072	363	244	286	396	369	236
0.080	365	241	370	234	341	277
Base Metal	374	229	375	228	371	234

High Hardness

A - KHN 492	Rc (conv.) 46.8
B - KHN 508	Rc (conv.) 47.9
C - KHN 525	Rc (conv.) 49.0

P- 6 SINGLE BEAD

Distance from fusion	A Filars	A KHN_{500}	B Filars	B KHN_{500}	C Filars	C KHN_{500}
0.00	251	512	261	473	268	449
0.008	257	487	261	473	265	459
0.016	253	503	279	414	269	446
0.024	254	500	284	400	428	176
0.032	253	503	292	378	278	417
0.040	253	503	316	322	318	319
0.048	295	370	283	403	346	269
0.056	284	400	356	254	365	241
0.064	356	254	370	234	367	239
0.072	357	253	372	232	376	228
0.080	361	247	358	251	385	217
Base Metal	367	239				

HIGH HARDNESS

A - KHN 512	Rc (conv.) 48.1
B - KHN 473	Rc (conv.) 45.4
C - KHN 459	Rc (conv.) 44.5

P-6 A

Distance Inches	A Filars	A KHN_{500}	B Filars	B KHN_{500}	C Filars	C KHN_{500}	D Filars	D KHN_{500}
.002	312	331	320	315	325	304	315	324
.004	304	348	310	335	326	303	298	363
.012	304	348	328	298	320	315	295	370
.020	298	*363	305	346	325	304	313	328
.028	302	353	304	348	328	298	315	324
.036	305	346	315	324	328	298	320	315
.044	304	348	295	*370	351	262	328	298
.052	308	340	330	296	338	282	322	310
.060	304	348	332	292	323	308	313	328
.076	348	266	326	303	323	308	293	*380
.084	345	270	325	304	319	316	296	368
.108	343	273	314	326	329	297	310	335
.116			298	363	330	296	305	346
.132			295	370	320	315	310	335
.148			304	348	318	318	358	251
.164			304	348	314	*326		
.180			306	344	325	304		
.188			300	358	354	257		
.196			323	308				

Base Metal High Hardness

	KHN	Rc(conv)		KHN	Rc(conv.)
A –	363	36.3	C–	326	32.0
B –	370	37.0	D–	380	38.0

Distance Inches	A Filars	A KHN_{500}	B Filars	B KHN_{500}	C Filars	C KHN_{500}	D Filars	D KHN_{500}
.002	327	302	304	349	298	364	297	366
.004	325	305	293	375	296	368	296	368
.012	318	319	298	363	310	336	298	364
.020	302	354	314	327	310	336	304	349
.028	324	308	319	317	304	349	312	332
.036	320	316	296	368	318	319	312	332
.044	327	302	296	368	330	296	327	302
.052	329	298	315	325	318	319	368	238
.060	314	327	345	271	310	336	367	239
.076	313	329	376	228	300	359	356	254
.084	332	294	381	222	298	364		
.108	374	231	355	256	365	242		

Highest KHN_{500}	Rc(conv.)
A-354	35.3
B-375	37.5
C-368	36.8
D-368	36.8

P-2

Distance Inches	A Filars	A KHN_{500}	B Filars	B KHN_{500}	C Filars	C KHN_{500}	D Filars	D KHN_{500}
.002	308	340	299	361	294	374	336	236
.004	310	336	295	371	295	371	322	312
.012	330	296	308	340	291	382	308	340
.020	324	308	308	340	274	430	318	319
.028	324	308	303	352	289	386	315	325
.036	319	317	302	354	291	381	322	312
.044	320	317	312	332	297	366	304	349
.052	299	361	305	347	287	393	297	366
.060	322	312	325	305	307	343	310	336
.076	336	236	322	312	319	317	322	312
.084	350	264	320	317	319	317		
.108	374	231	372	233	369	237		

Highest KHN_{500}	Rc (conv.)
A-361	36.1
B-371	37.1
C-430	42.3
D-366	36.6

P-3

Distance Inches	A Filars	A KHN_{500}	B Filars	B KHN_{500}	C Filars	C KHN_{500}	D Filars	D KHN_{500}
.002	342	276	318	319	345	271	318	319
.004	330	296	300	358	316	324	296	368
.012	335	238	315	326	315	326	299	361
.020	321	314	297	366	312	332	307	340
.028	320	315	313	329	312	332	318	319
.036	332	293	316	323	308	340	304	349
.044	332	293	325	305	308	340	304	349
.052	331	295	310	336	305	347	298	364
.060	325	305	304	349	302	354	293	375
.076	334	289	295	371	297	366	294	373
.084	333	291	297	366	300	358		
.108	365	238	360	249	377	226		

Highest KHN_{500}	Rc(conv.)
A-315	30.6
B-371	37.1
C-366	36.6
C-375	37.5

P-4

Distance Inches	A Filars	A KHN_{500}	B Filars	B KHN_{500}	C Filars	C KHN_{500}	D Filars	D KHN_{500}
.002	351	262	316	324	305	347	315	325
.004	344	273	306	345	298	364	325	305
.012	329	298	304	349	303	352	322	312
.020	325	305	321	313	302	355	310	336
.028	334	289	318	319	318	319	320	315
.036	326	303	314	327	320	315	320	315
.044	328	300	318	319	303	352	315	325
.052	326	303	314	327	298	364	306	345
.060	326	303	304	349	306	345	298	364
.076	376	228	326	304	304	349	297	366
.084	378	226	356	254	335	288		
.108	366	241	350	263	364	243		

Highest KHN_{500}	Rc(conv.)
A-305	29.1
B-349	34.8
C-364	36.4
D-366	36.6

P-5

Distance Inches	A Filars	A KHN_{500}	B Filars	B KHN_{500}	C Filars	C KHN_{500}	D Filars	D KHN_{500}
.002	340	279	340	279	340	279	368	238
.004	352	260	333	291	326	303	353	258
.012	348	266	340	279	326	303	344	273
.020	348	266	347	268	324	307	332	293
.028	356	254	348	266	327	302	342	276
.036	346	269	329	298	326	303	344	273
.044	347	268	336	286	334	289	338	282
.052	345	271	337	284	328	300	333	291
.060	348	266	337	284	329	298	328	300
.076	384	218	334	289	326	303	330	296
.084	384	218	345	271	312	332		
.108	365	242	325	305	380	223		

Highest KHN_{500}	Rc (conv.)
A-279	25.2
B-305	29.1
C-332	32.8
D-300	28.4

P-6

Distance Inches	A Filars	A KHN_{500}	B Filars	B KHN_{500}	C Filars	C KHN_{500}	D Filars	D KHN_{500}
.002	347	268	338	282	336	286	338	282
.004	335	287	321	313	323	309	333	291
.012	345	271	331	294	323	309	322	312
.020	329	297	330	296	321	313	322	312
.028	333	291	322	312	313	330	334	289
.036	336	286	329	298	309	338	348	266
.044	338	282	327	302	318	319	350	263
.052	335	287	337	284	322	312	342	276
.060	346	269	338	282	320	315	342	276
.076	350	263	340	279	329	298	338	282
.084	356	254	318	319	335	287		
.108	352	260	354	257	330	296		

Highest KHN_{500}	Rc(conv.)
A-297	28.9
B-319	31.1
C-338	33.5
D-312	30.0

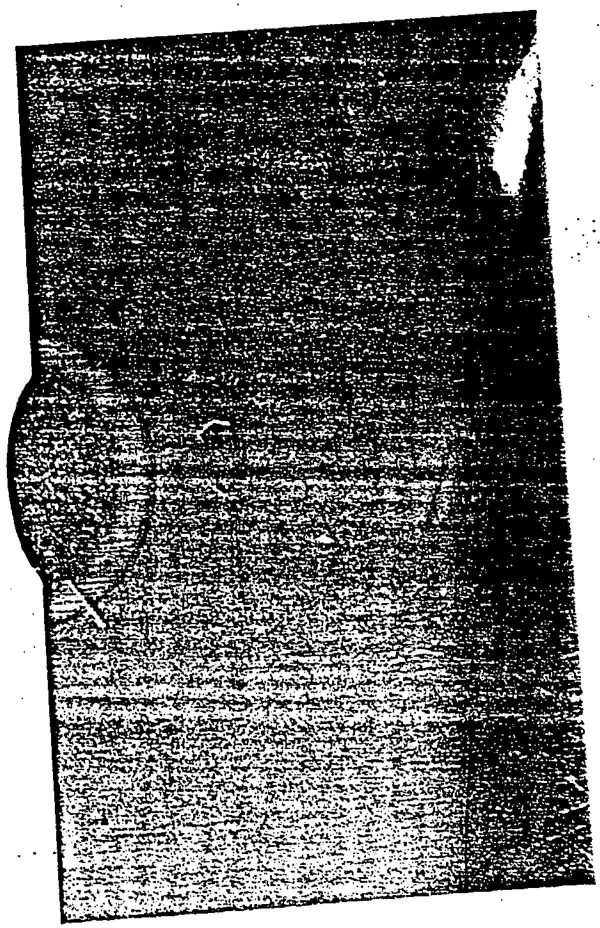
Distance Inches	A Filars	A KHN_{500}	B Filars	B KHN_{500}	C Filars	C KHN_{500}	D Filars	D KHN_{500}
.002	337	284	339	281	343	271	341	277
.004	362	246	337	284	334	289	322	312
.012	345	271	335	287	337	284	322	312
.020	351	261	322	312	328	300	327	302
.028	384	218	330	296	327	302	333	291
.036	325	306	337	284	340	279	339	281
.044	340	279	328	300	323	309	372	233
.052	327	302	335	287	323	309	499	139
.060	332	293	330	296	336	286	343	271
.076	328	300	337	284	344	272	350	263
.084	328	300	335	287	328	300		
.108	351	261	322	312	388	214		

Highest KHN_{500}	Rc (conv.)
A-302	28.5
B-311	30.0
C-309	29.7
D-311	30.0

P-8

Distance Inches	A		B		C		D	
	Filars	KHN_{500}	Filars	KHN_{500}	Filars	KHN_{500}	Filars	KHN_{500}
.002	308	340	359	250	389	213	346	269
.004	302	354	340	279	358	252	346	269
.012	312	332	337	284	349	264	341	277
.020	345	271	337	284	345	271	336	286
.028	356	254	334	289	343	274	327	301
.036	350	263	332	293	335	287	330	296
.044	356	254	315	326	333	291	335	287
.052	343	274	326	303	348	266	335	287
.060	366	241	329	298	340	279	338	283
.076	366	241	331	294	345	271	339	281
.084	367	239	330	296	337	284		
.108	394	230	327	302	335	287		

Highest KHN_{500}	Rc(conv.)
A-354	38.1
B-326	32.0
C-291	27.1
D-301	28.5



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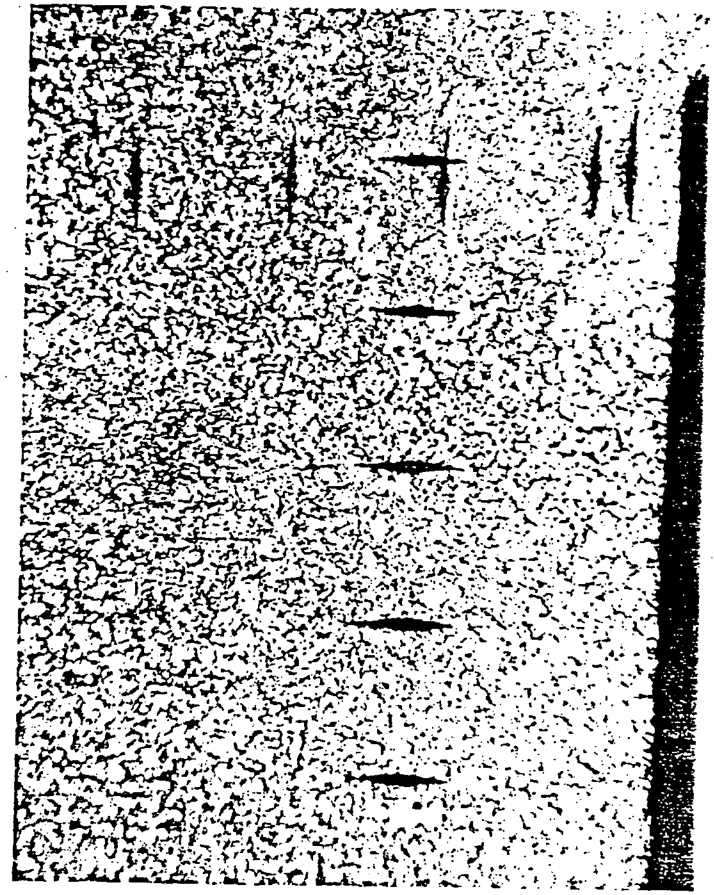

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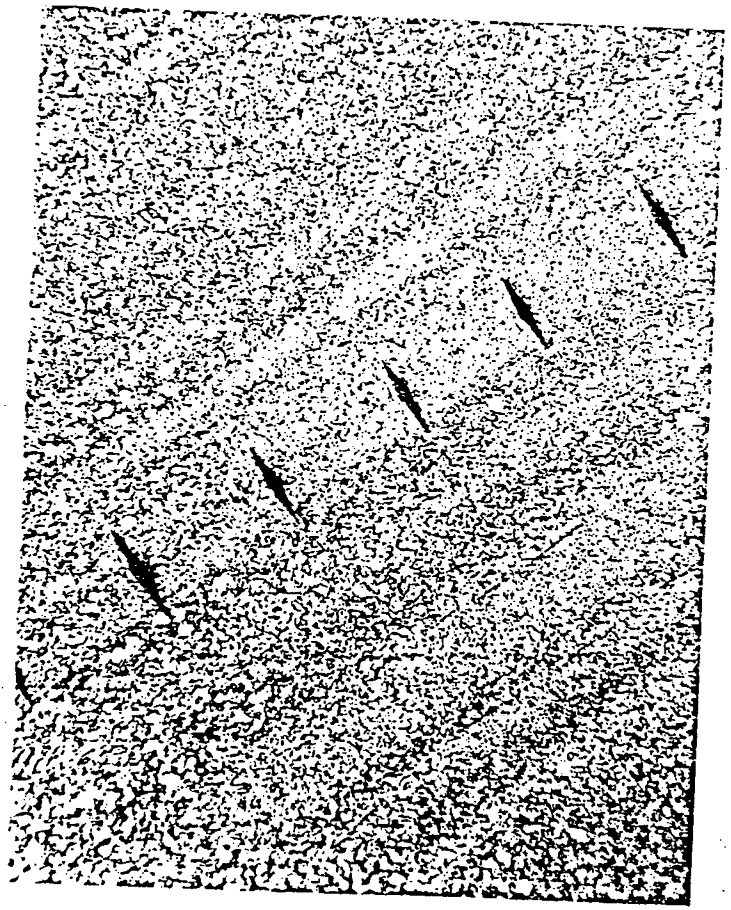

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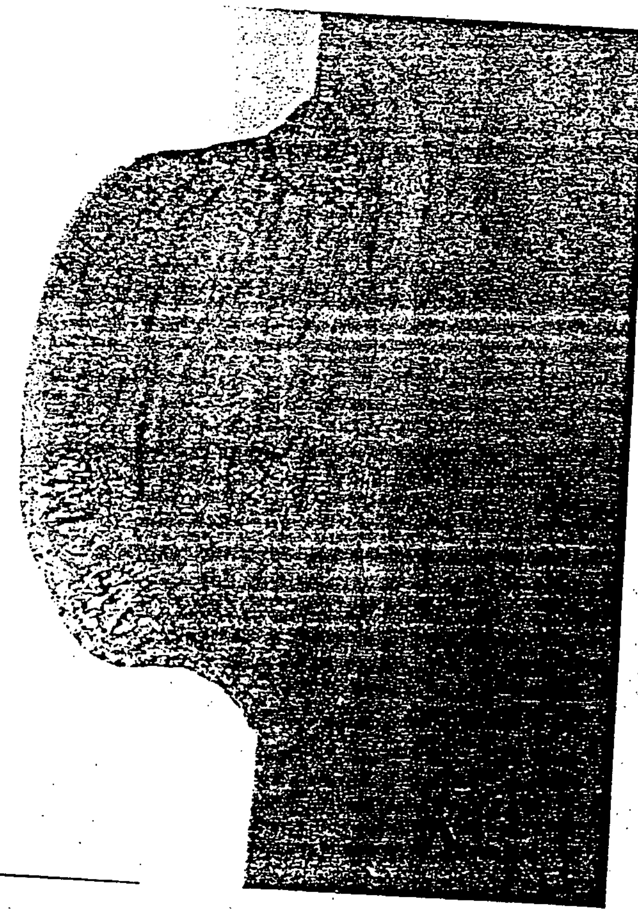

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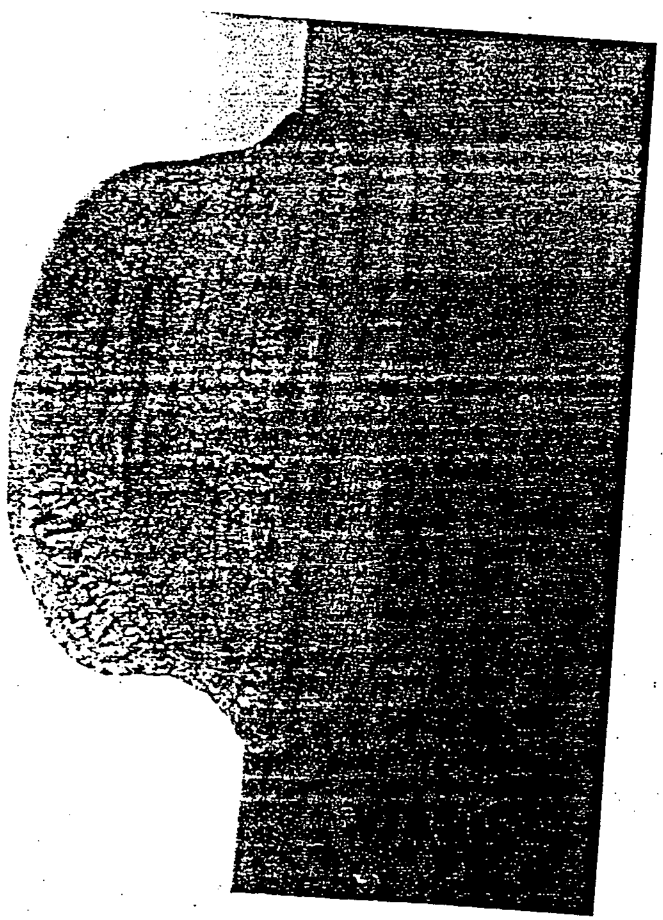

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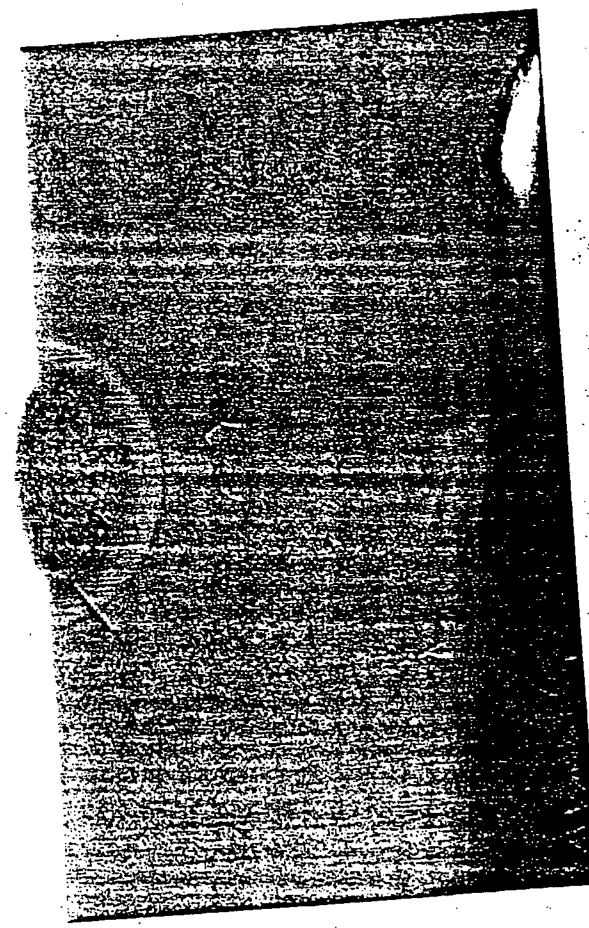

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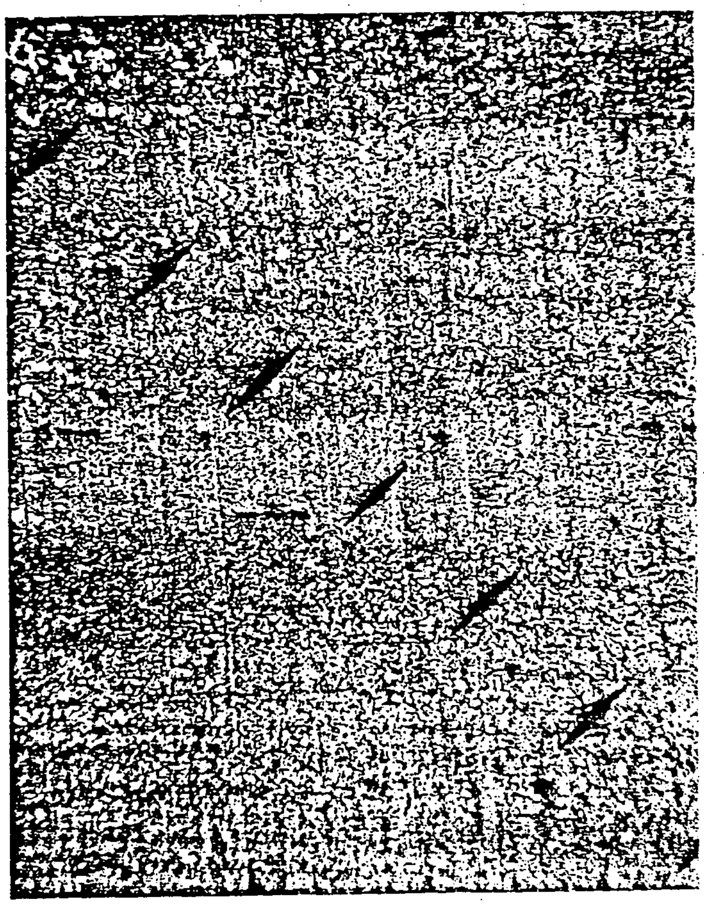

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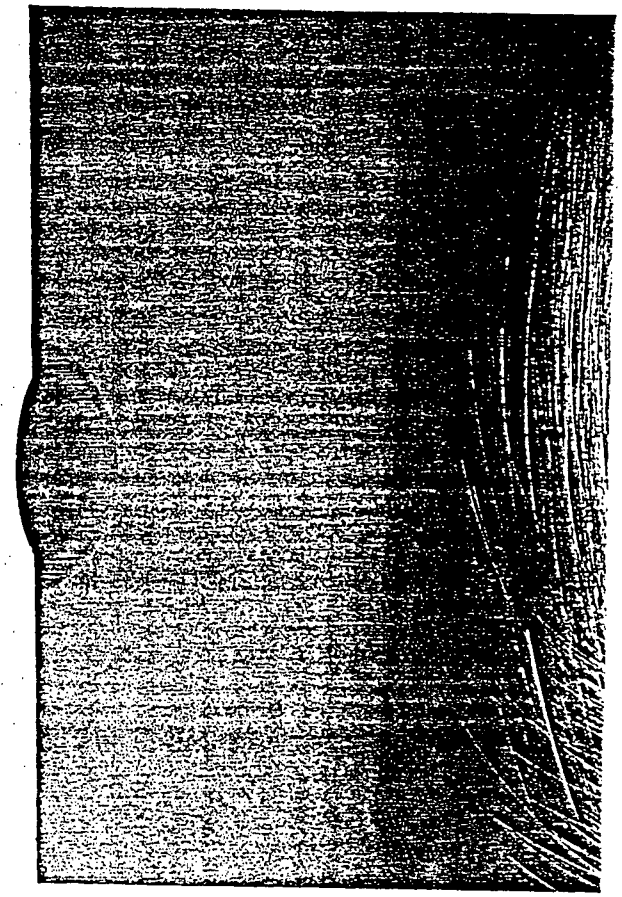

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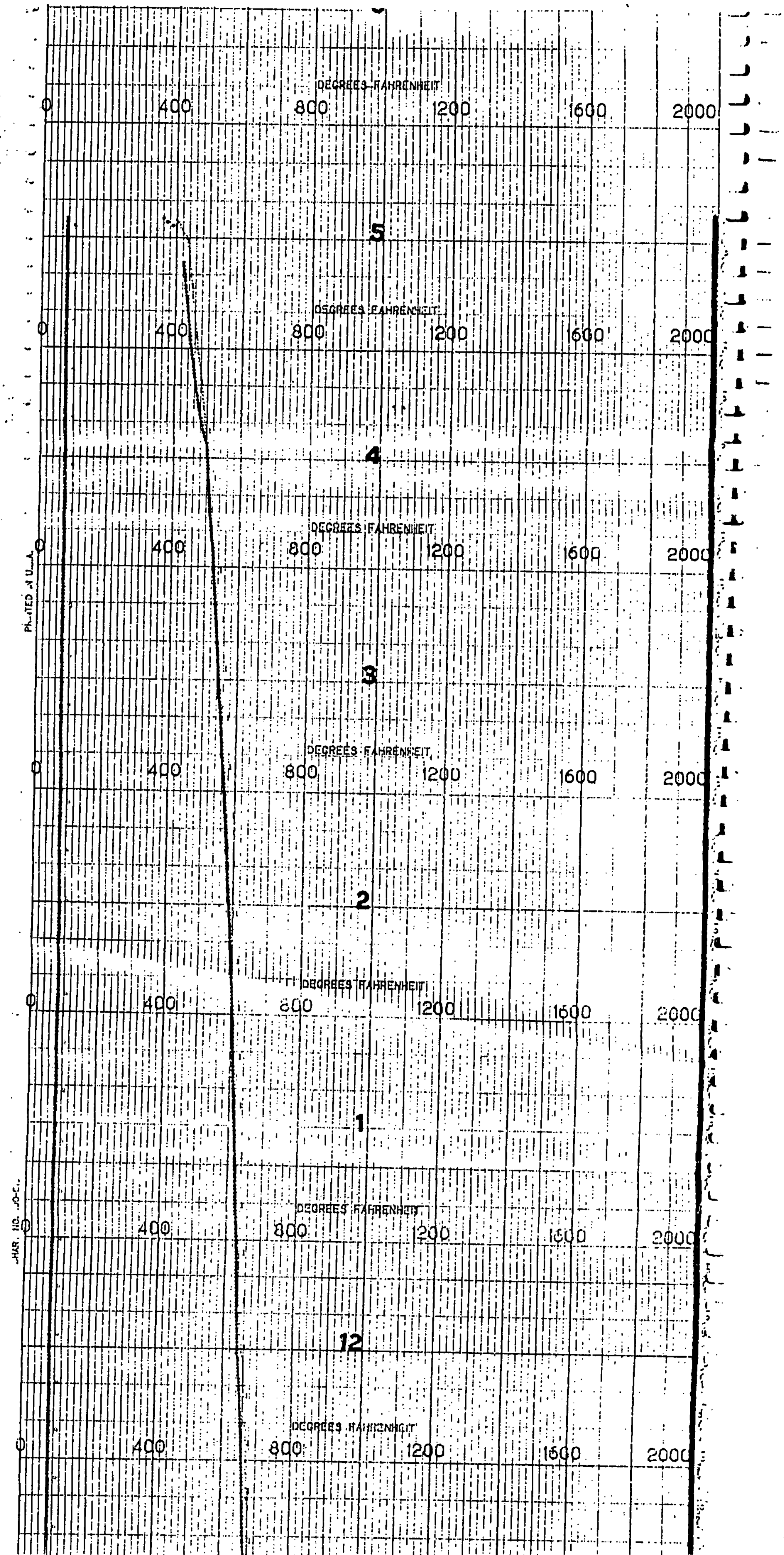
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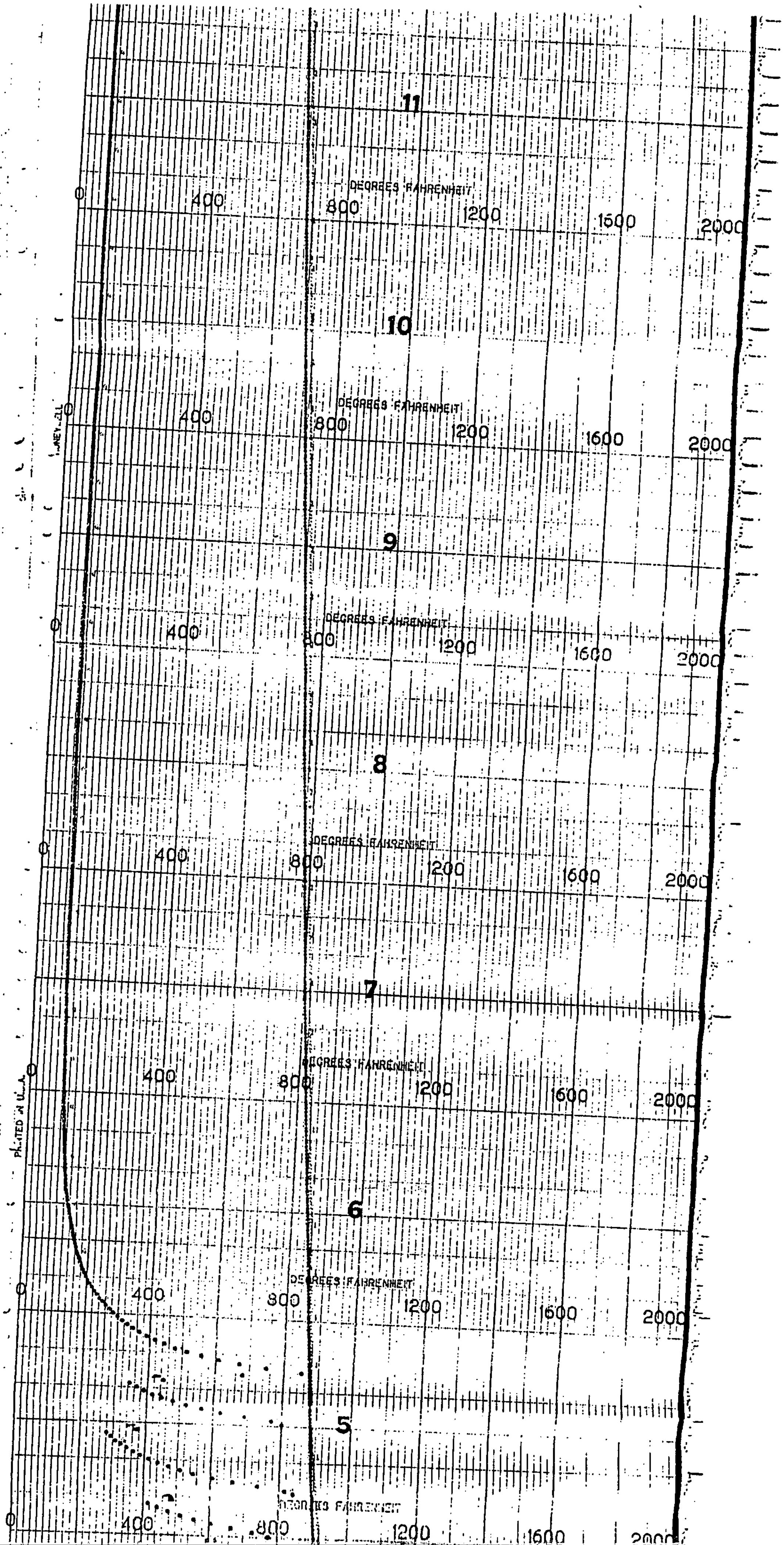
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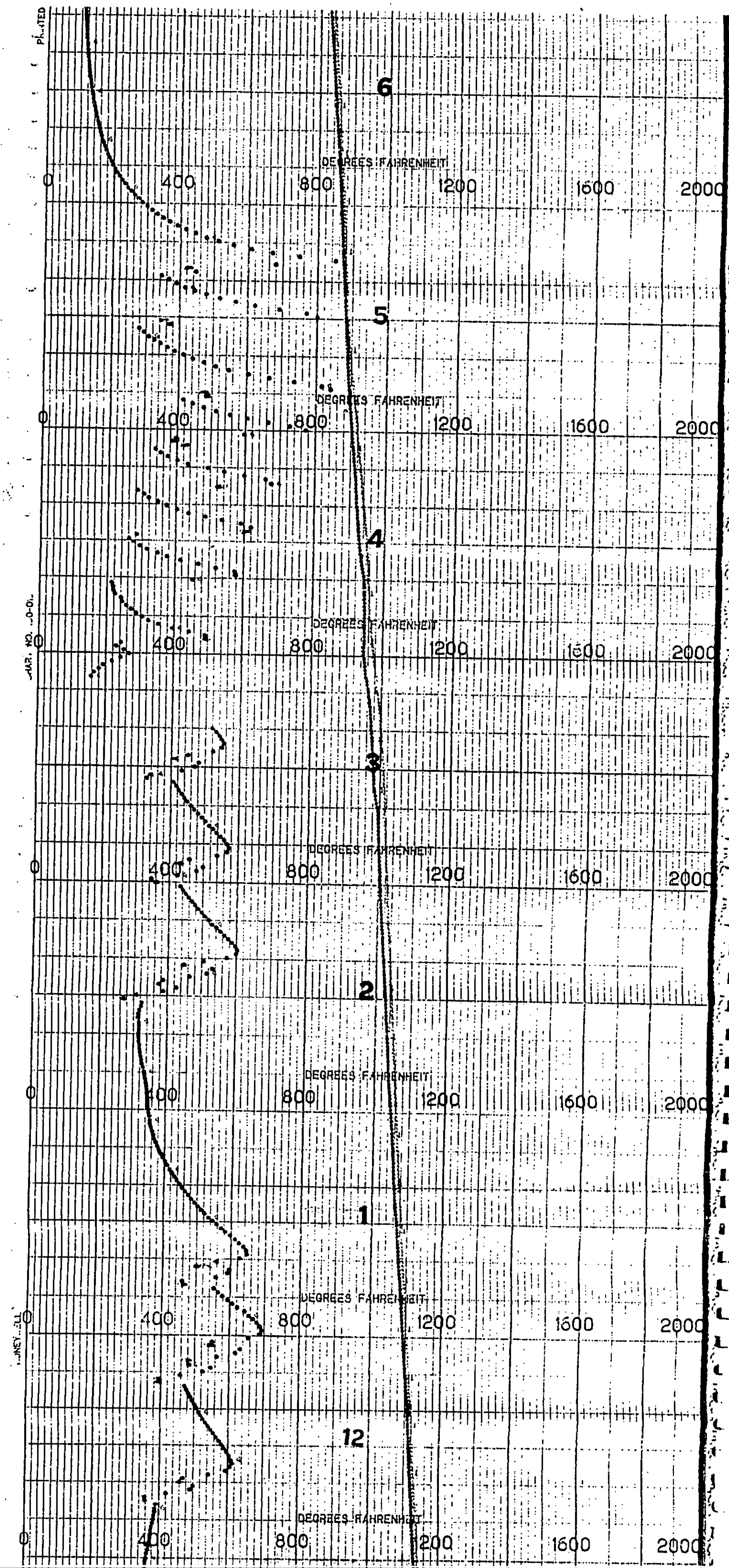
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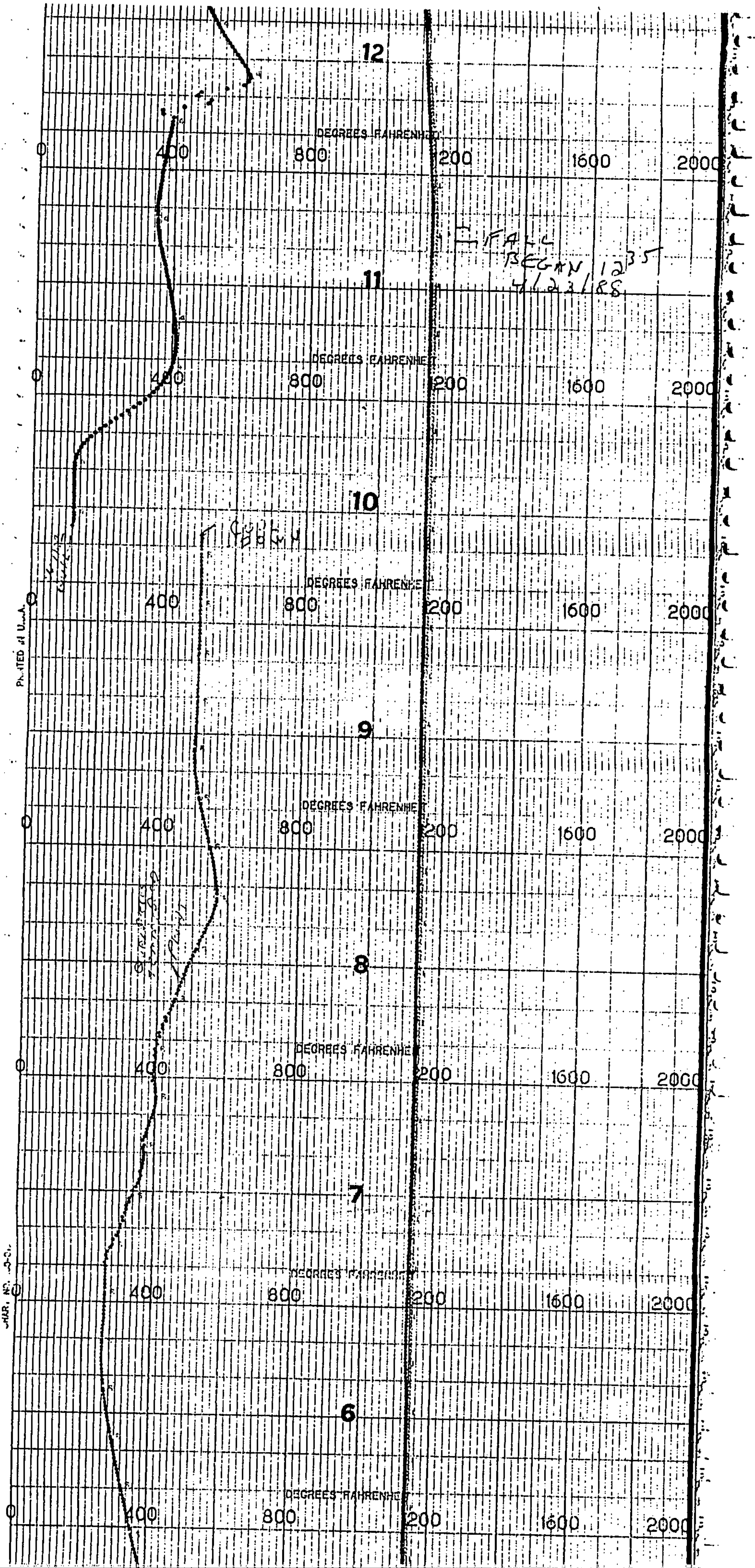
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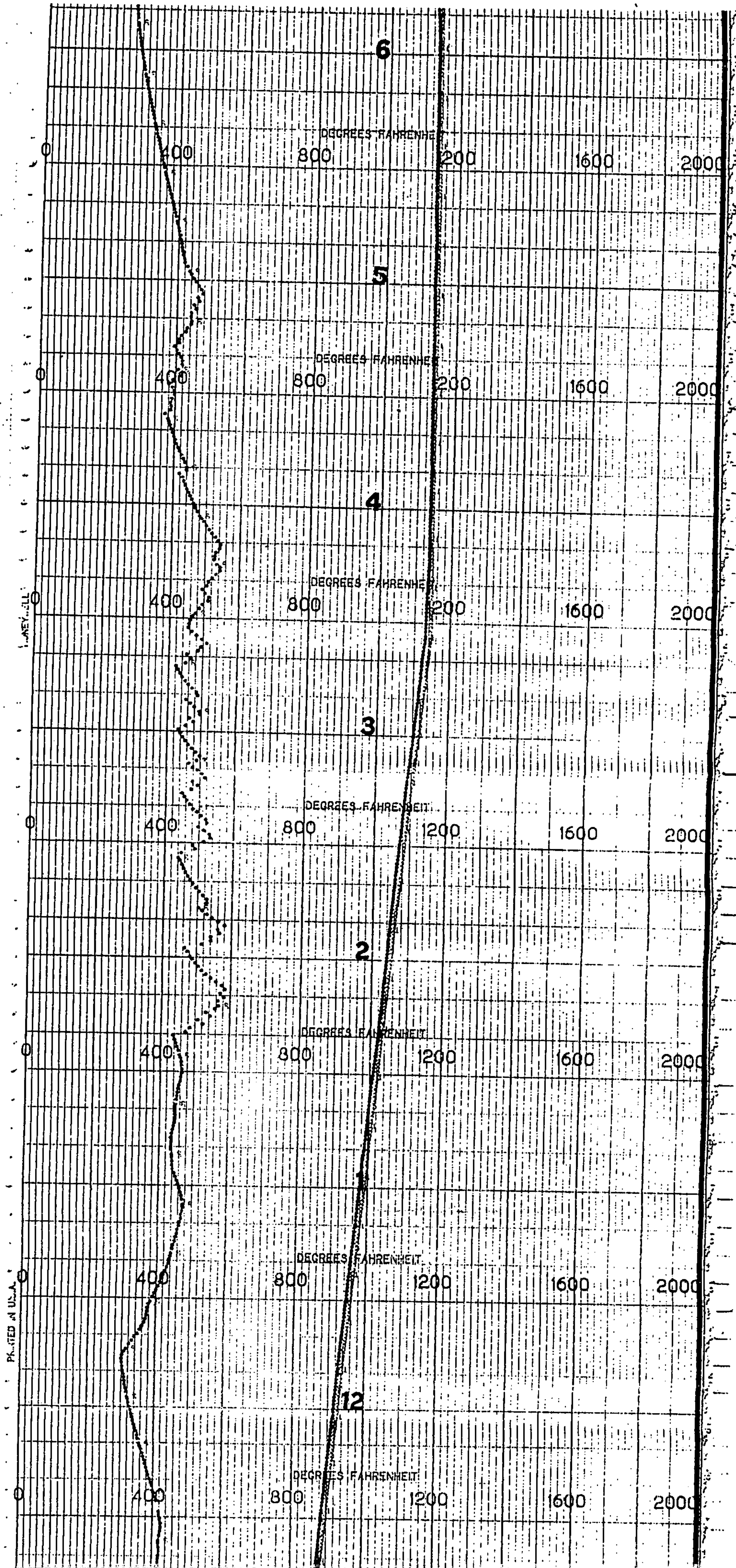
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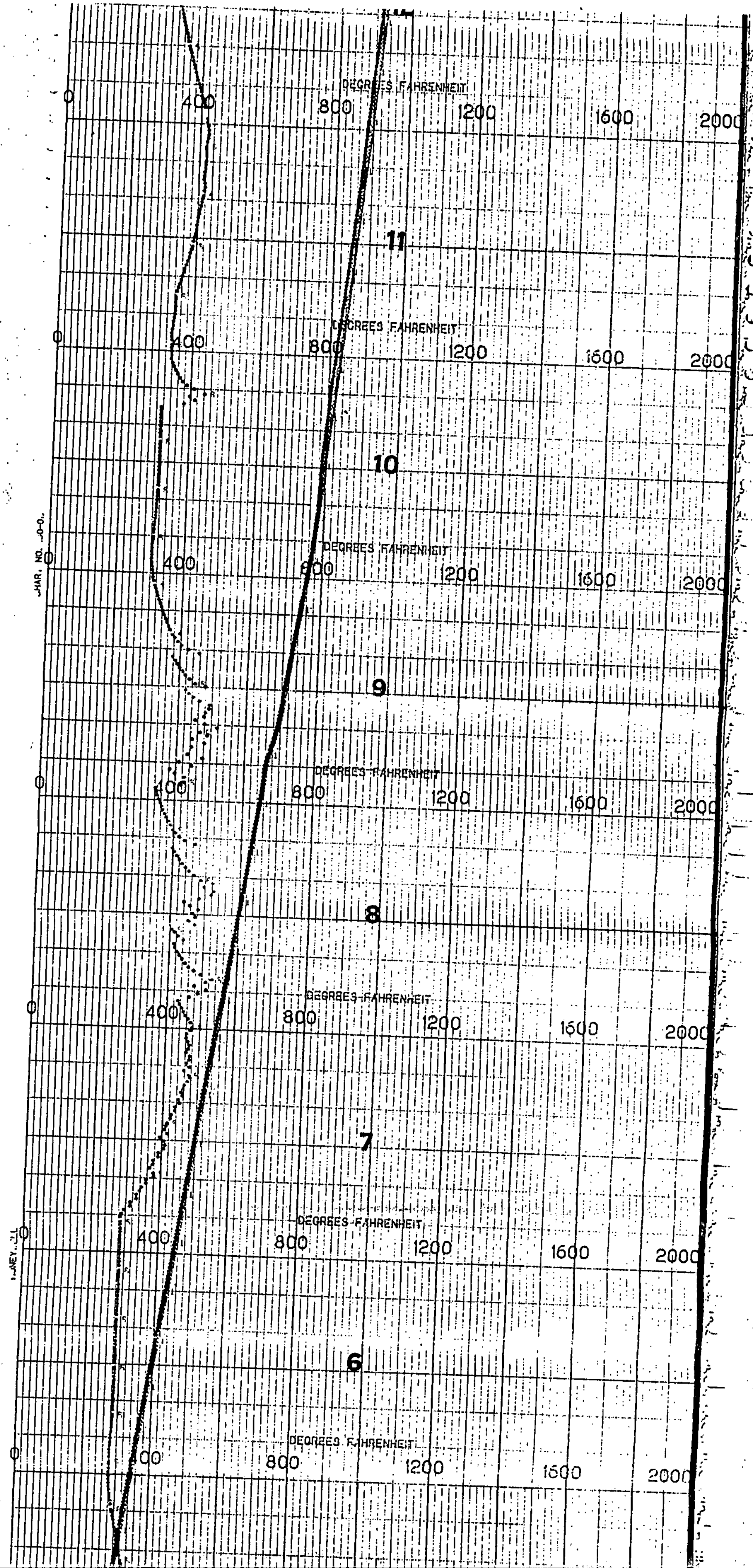
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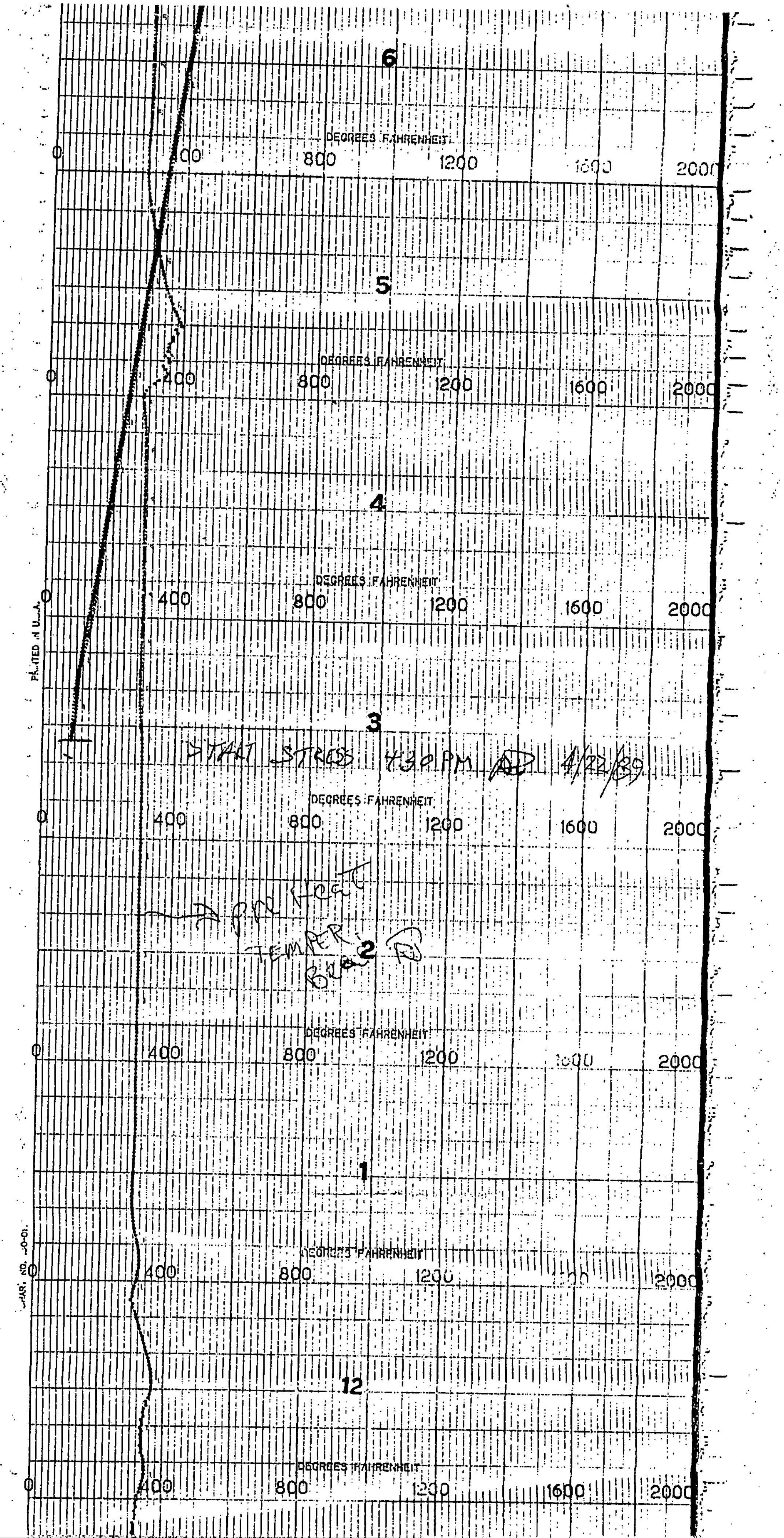
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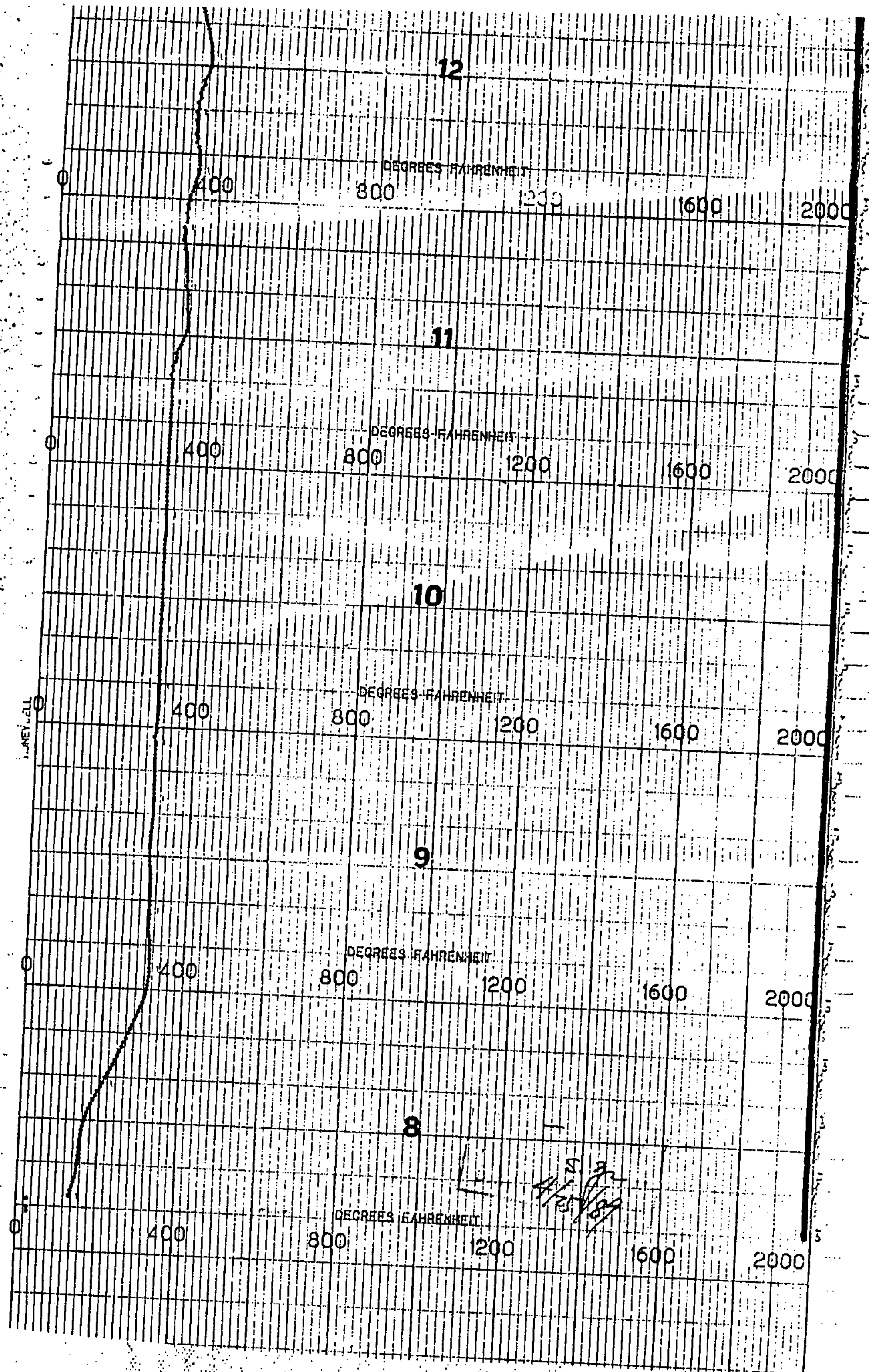

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Relief Request 29

1. Request for Which Relief is Requested

(a) Name: Automatic Gas Tungsten Arc Welding (GTAW) Temperbead Process

(b) Function: Facilitate repairs involving welding on ASME Section III Class I Components

(c) ASME Section XI Code Case N-432, Repair Welding Using Automatic or Machine Gas Tungsten - Arc Welding (GTAW) Temperbead technique Section XI, Division 1.

2. Reference Code Requirements That Have Been Determined to be Impractical

The Code case weld procedure qualification required the test material be of the same specification type, grade, and class as the material to be repaired. Indian Point 2 steam generators were built to the requirements of ASME Section III 1965 edition including addenda through summer 1966. The steam generators were fabricated from ASME Section III SA 302 Grade B material which has an impact value requirement of 30 ft-lbs absorbed energy (N-330). The test specimen also used SA302 Grade B material and met the 1965 code edition of Section III impact requirement of 30 ft-lbs. However, the operative Section XI Code edition is 1980; the corresponding ASME Section III (1980 edition) imposes a 50 ft-lb requirement from which relief is requested. Achievement of this impact strength in a thick test piece is impractical.

3. Alternative proposal

It is proposed that Automatic Gas Tungsten Arc Welding (GTAW) Temperbead Process be accepted on the premise that the qualification procedure utilized test material whose properties correspond to the original code, ASME Section III, 1965 edition. Furthermore, the test results verify that the impact strength of the heat affected zone (HAZ) of the base metal is enhanced, as illustrated by the following test results:

	Weld Metal ($40^{o}F$)	HAZ ($90^{o}F$)	Base Metal ($90^{o}F$)
Ft-lbs	83	44	32
Lateral exp	65	39	31

Material records on file indicate that the impact strength of the material actually used in steam generator construction corresponded to values ranging from 55 ft-lbs to 105 ft-lbs. Based on the test results, any repair using the GTAW method should result in improved values.

It is understood that the difficulties presented by Code Case N-432 are acknowledged by ASME personnel and that a Code change is currently under way incorporating the current proposed code modification for Shielded Metal Arc Welding (SMAW). The proposed changes in the code, as presently stated for SMAW, and as are to be proposed for GTAW, include:

- The test assembly shall be of the same P number and Group number as the component and will be post weld heat treated in a manner which is similar to the component (on the order of 80% of the heat treatment time at temperature).

- The Charpy-v-notch impact requirements of the test assembly shall meet the following:

  - The base metal impact properties shall meet the design specification.

  - The impact properties of the heat affected zone shall be taken at or below the lowest service temperature.

  - The average of the three charpy-v-notch heat affected zone results shall be equal or greater than the average of the three base metal test results.

The results of the qualification process for the proposed GTAW in general meet these requirements.

4. Basis for Requesting Relief

Consolidated Edison has developed a temperbead weld qualification program for the Indian Point Unit No. 2 steam generator shell. The shell material is Section III SA302 Grade B low alloy steel, designated by the ASME Code as P-3 Group 3 material. The purpose of the temperbead qualification is advance preparation for performing a cavity weld repair to one or more of the IP-2 steam generator shells using this welding approach. ASME Code Case N-432, issued on February 1986, provided guidance for the temperbead qualification activity. Both weld parameter trial tests (on a thinner plate of section II SA302 Grade B material) and procedure qualification tests (on a thicker plate) were performed in order to select a weld procedure and then to qualify it. Although the thicker plate was not entirely representative in terms of toughness, the results on the thinner and thicker plates, taken together, demonstrate that the procedure is technically acceptable for use on the 3.5 inch thick steam generator shell at IP-2.

The properties of the base metal used in the temperbead qualification program did not meet all of the requirements of Code Case N-432 and the Code of repair. However, application of these requirements in this case would be overly restrictive and unnecessary. The plant was constructed to ASME Section III, 1965 with addenda through 1966, a Code which prescribed less in the way of toughness requirements for this material than either the Code of repair or Code Case N-432. The intent of Code Case N-432 is to assure that the weld procedure is qualified as a process on representative material which provides assurance that the welding process will not degrade the base metal. The HAZ Charpy-v-notch energy absorbed and lateral expansion were clearly greater than those of the unaffected base metal in this test program. The 7.125 inch thick SA302B plate used in this test program is representative material in that section thickness. One characteristic of this material is its poor through thickness hardenability, thereby resulting in plate which, in this thickness, may have poor notch toughness in the 1/4t to 3/4t region. In reduced section thicknesses, this material is expected to have better toughness.

The steam generator shell at IP-2 is significantly thinner, 3.5 inches thick, and has superior Charpy-v-notch impact properties compared to the test plate, as would be expected for this grade of material. Were the test plate of a more representative thickness, it is believed that the notch impact properties would have been significantly improved. This observation is substantiated by the weld trial tests in the thinner plate, 2.25 inches thick, where hardness measurements revealed a softened HAZ consistent with increased toughness for a representative material. The restrictions of code Case N-432 required a thicker plate than is to be welded to in the field, thereby restricting the qualification program to use of a base metal which could not be reasonably expected to meet the notch toughness requirements in the Code Case. Consequently, while all requirements of Code Case N-432 could not be literally adhered to in this instance, the trial weld tests and the procedure qualification tests taken together demonstrate that the HAZ properties have not been degraded in the SA302 Grade B plate and that the temperbead process is technically qualified for use at IP-2.

Enclosed are records pertaining to the test plate.

RECEIVING INSPECTION REPORT

JOB NUMBER	ITEM(S)
IP690416	PlATE - Indian Point Con. Ed.

INFORMATION	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5
MANUFACTURER	American Alloy STEEL				
P.O. NUMBER	02078666				
VENDOR	ENERGY STEEL : Supply				
MATERIAL	ASME SA302 Gr B				
HEAT NUMBER	21629				
MATERIAL MILL TEST REPORT	RECEIVED				
LENGTH	30" X 12" X 7¼"				
WIDTH					
NOMINAL DIAMETER					
DIAMETER CHECK A					
B					
C					
D					
NOMINAL THICKNESS					
THICKNESS 1					
2					
3					
4					
5					
VISUAL INSPECTION	Accept				
REMARKS					
NCR #					
DATE	4-26-89				
BY	A. Lawrence				

AMERICAN ALLOY STEEL, INC.

7721 PINEMONT
P.O. BOX 40469
HOUSTON, TEXAS 77240-0469
(713) 462-8081
TELEX 76-2806

INVOICE NO.

INVOICE DATE:

S/O 72468

TERMS: 1%—15 days—NET 30 DAYS

052650

SOLD TO: ENERGY STEEL & SUPPLY COMPANY
2715 PALDAN DRIVE
AUBURN HILLS, MICHIGAN 48057

SHIPPED TO: SAME (313-377-4990)
C/O WELDING SERVICES, INC.
MFG. DIV.
3276 MARJAN DRIVE, ATLANTA, GEORGIA 30340

VIA: AIR EXPRESS -COLLECT

DATE OF ORDER	YOUR ORDER NO.	F.O.B.	SALESMAN	ORDER	REFERENCE
4-20-89	904060	A.A.S.I.	SK/KK	☐ Complete ☐ Partial	HENRY FLEMMING

ITEM	QUANTITY ORDERED	DESCRIPTION	SHIPPED Pounds or Feet	PRICE EACH	TOTAL AMOUNT
		SA 302-B NORMALIZED			
1	1	7-1/4" x 12" x 30" (+1/2", -0")	740# EA		
		TAG: P.O. 207365			

KBA

RUSH SHIPMENTS — OUR SPECIALTY AROUND THE CLOCK.

PACKING LIST

THIS IS A PACKING SLIP — NOT AN INVOICE

marathon Letourneau company

Testing Laboratory

ORIGINAL FILE COI
DO NOT REMOVE

Report of CHEMICAL and PHYSICAL TESTS of ....STEEL PLATE....

Date: 9-3 19 86

Shipped To ...AMERICAN ALLOY STEEL, INC....

Mill Order No. L147221

Customer's Order No. 12505

AMERICAN ALLOY
PLATE # A66341

2". Gage

			CHEMICAL ANALYSIS											
Melt No.	Slab No.	Spec.	Carb.	Mang.	Sulph.	Phos.	Sil.	Mol.	Charpy Ft./Lbs.	Yield Point P.S.I.	Ten. Strength P.S.I.	% Elongation	Bend Test	SIZE OF PLATE
D 21629	A323	SA302B	.18	1.15	.016	.013	.26	.55		77,500	97,500	19.0		7 1/4 X 106 X 106
									S-4	79,500	100,000	19.0		

Norm. @ 1700°F for 1 hr. per inch of thickness @ temp. and still air cooled - Test coupons (after norm.) were stress relieved @ 1125° F for 3 1/2 hours with S-4 additional tension test ultra sonically inspected per SA578, Level 2, 100% scan.

TEST REPORT APPROVED DATE Sept. 22, 1986
AMERICAN ALLOY STEEL BY [signature]
ASST QUALITY CONTROL DIRECTOR

CUSTOMER Energy Steel & Supply Co.
CUST P.O.# 90460
A.A.S. S/O# 72466 PLATE# A66341
DATE MAILED 04/21/89
DESCRIPTION Ht# ① 7 1/4" X 12" X 30"

Certified a true copy original, retained in or AMERICAN ALLOY STEE

I Hereby Certify that the Above Tests Are Correct to the best of My Knowledge and Belief.

marathon Letourneau company

K. B. Wright
Engr. of Tests

C E R T I F I C A T I O N

CERTIFICATION OF CONFORMANCE | **CERTIFICATION OF COMPLIANCE**

ENERGY STEEL and SUPPLY Co.
2715 Paldan
Auburn Hills, MI 48057

WELDING SERVICES
MANUFACTURING DIVISION
3276 MARJAN DRIVE
ATLANTA, GA 30340

Your Order Number	Our Order Number	Date
207866	WELSE004377 01	4/21/89

Item#	Prod#	Qty	Description	Grade-Spec.	Heat Number
1	C0050	1	PLATE 7-1/4X12X30	ASME SA302 GB	21629

This is to certify that the material furnished for your order and described above, has been reviewed and complies to requirements of the applicable material specifications, and meets all requirements of your purchase order.

>>>

Energy Steel & Supply Co.

Kelly A. Dratt

Quality Assurance Specialist

Welding Services Inc. ☐
Welding Services Inc. Mfg. Div. ☐

3276 Marjan Drive
Atlanta, Georgia 30340
Telephone (404) 452-0005

Accounts Payable
(404) 455-0929

PURCHASE ORDER NO.
0207866

990
ENERGY STEEL & SUPPLY CO.
2715 PALDEN DRIVE
AUBURN HILLS,
MICHIGAN
48057-0000

SHIP TO
WELDING SERVICES, INC.
SHIPPING & RECEIEVING
3202 MARJAN DRIVE
ATLANTA, GEORGIA
30340-0000

TE	TERMS	F.O.B.	SHIP VIA	JOB / PROJECT	P. R. NO.	TAXABLE YES / NO	WSI / WSI MFG
	NET 30 DAYS	S/P	AIR BEST	INDIAN POINT II/CON ED.	13735		

TY.	WHSE	WSI MFG PART NO. G/L CODE	SPEC/VENDOR PART NO.	DESCRIPTION	PRICE	UNIT	EXT.	JOB/PHASE N
..00	I5	401-01-00	SA302/GR.B	SA302/GR B STEEL PLATE, 7-1/4" X 12" X 30".	3,900.000	EA	3,900.000	69041-1-1
.00	I5	Q.A. APPROVAL 400-02-00	Q.A. APPROVAL	Q.A. APPROVAL/DATE: 4-22-89 SIGNED: [signature]	.000	EA	.000	69041-1-1
.00	I5	CERTS/TEST REP. 400-02-00	CERTS/TEST REP.	CERTS/MATERIAL TEST REPORTS REQUIRED	.000	EA	.000	69041-1-1

IRMATION TO	REQ/DEPT.	QA Approval YES	QA Approval NO	C of C Req'd YES	C of C Req'd NO	QA Insp. Req. YES	QA Insp. Req. NO
EMING	BURKHALTER						

TOTALS → 3,900.000

PURCHASING DEPT.

ATTACHMENT 2

RELIEF REQUEST 29

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
INDIAN POINT UNIT NO. 2
DOCKET NO. 50-247
NOVEMBER, 1989