Met-Ed / GPU

Metropolitan Edison Company
Post Office Box 480
Middletown, Pennsylvania 17057
717 944-4041

October 19, 1979
GQL 1310

Director of Nuclear Reactor
Regulation
Attention: R. W. Reid, Chief
Operation Reactor Branch No. 4
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Sir:

REFERENCES: A. IE Bulletin No. 79-17 dated July 26, 1979
B. GQL 1059 dated August 15, 1979
C. GQL 1141 dated September 5, 1979

SUBJECT: THREE MILE ISLAND NUCLEAR STATION UNIT 1 (TMI-1)
OPERATING LICENSE NO. DPR-50
DOCKET 50-289
IGSCC INVESTIGATION

Background

References B and C provide status of inspection results at the time to IE Bulletin No. 79-17 dated July 26, 1979. Attached herein (Attachment 1) is an updated status report of the now completed phase I and II ultrasonic inspection. Met-Ed feels confident that through our screening procedure, we have identified all welds which have significant IGSCC. In fact, and as we have pointed out on several occasions, there is a high probability that the 42 reported indications include several "heat affect areas" without evidence of IGSCC. The latter would result from indications emanating from the actual weldments.

Also included in Attachment 2 is a mapping of the reported indications.

Discussion

The purpose of this letter is to request NRC approval for the metallurgical repair proceaure and selection of materials specification used for the replacement. It is requested that a response be provided to the above no later than November 15, 1979 as the replacement materials ordered will by then be in-house.

Enclosed for your review and approval are the following attachments:

A001
S. 1/1

1220 298

7910250 248

Attachment 3 - Gas Tungsten Arc - Shielded Metal Arc Welding of Stainless Steel in Borated Water Systems

Attachment 4 - Catalytic Welding Procedure Specification No. SP-4200-55(N) 102A

Attachment 5 - Evaluation of I.D. Buttering Techniqueto Minimize Weld HAZ Cracking, Lab No. 56052

It is our intention to perform repairs to IGSCC affected areas using the methodology as described in Attachment 3 in conjunction with Attachment 4 Welding Procedure Specification SP-4200-55(N)102A.

The I.D. buttering process will be utilized in situations where an existing 304 SS is to be connected to a 304L stainless steel replacement section, and used only on the 304 SS side. In cases where the weld joint will be 304L to 304L, the buttering process will not be employed.

As we have discussed with your staff on October 3, 1979, we anticipate providing you in the near future, our anticipated surveillance program for monitoring IGSCC in the future.

A final report on this subject will be issued by November 30, 1979.

Very truly yours,

J. G. Herbein
Vice President
Nuclear-Operations

JGH:NCK:ks
Attachments

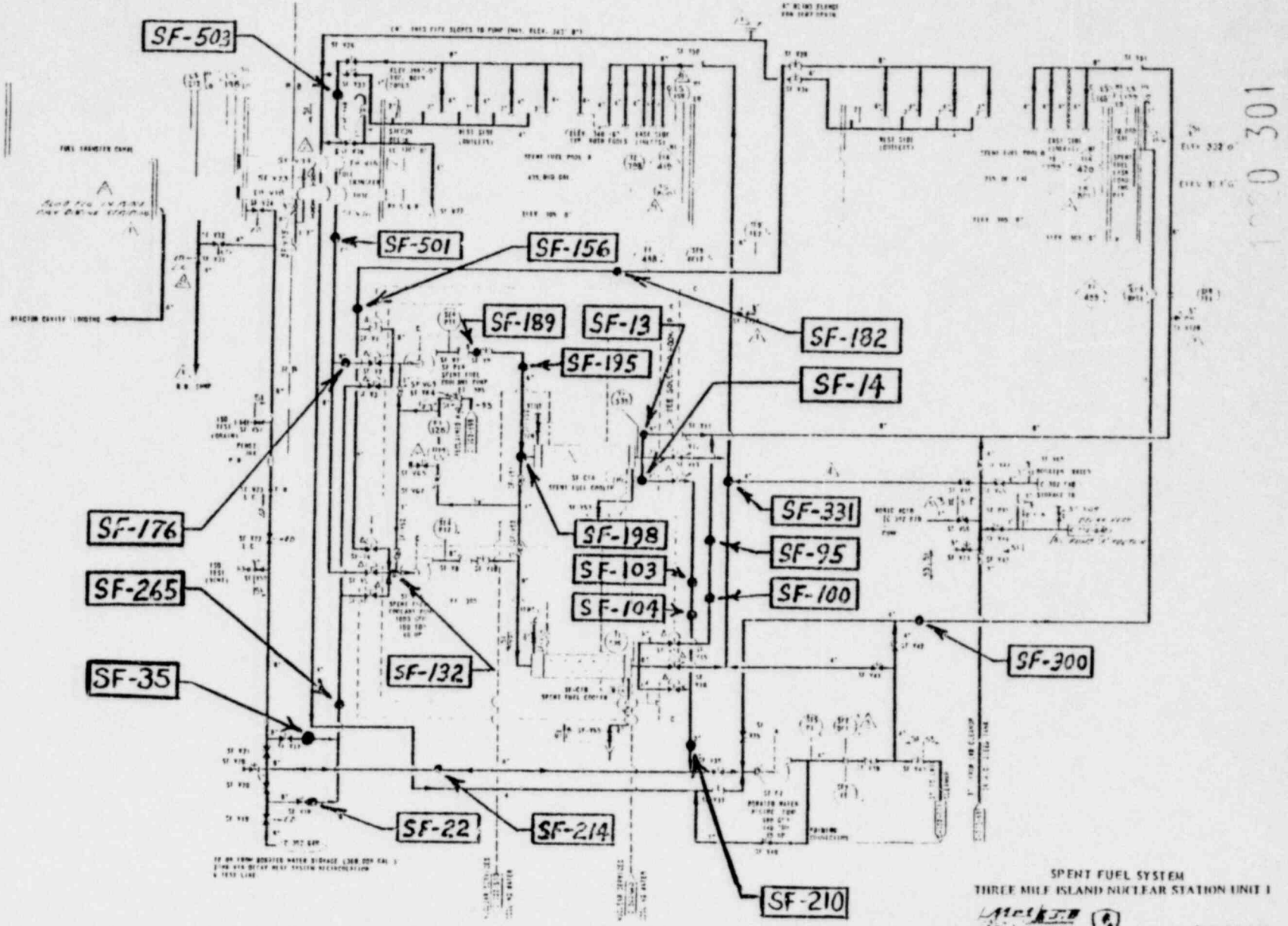
1220 299

ATTACHMENT #1

RESULTS OF UT INSPECTION

System	Total Welds	Welds Inspected	UT Indications	Screened Indications/Leaks	% Screened Indications
Spent Fuel	566	566	149	22	3.9
Decay Heat	408	408	104	11	2.7
Building Spray	241	241	64	8	3.3
Make-Up	1051	697	96	1	.14
Core Flood	31	31	0	0	0
Reactor Coolant Surge	11	11	0	0	0
Reactor Coolant Spray	28	28	1	0	0

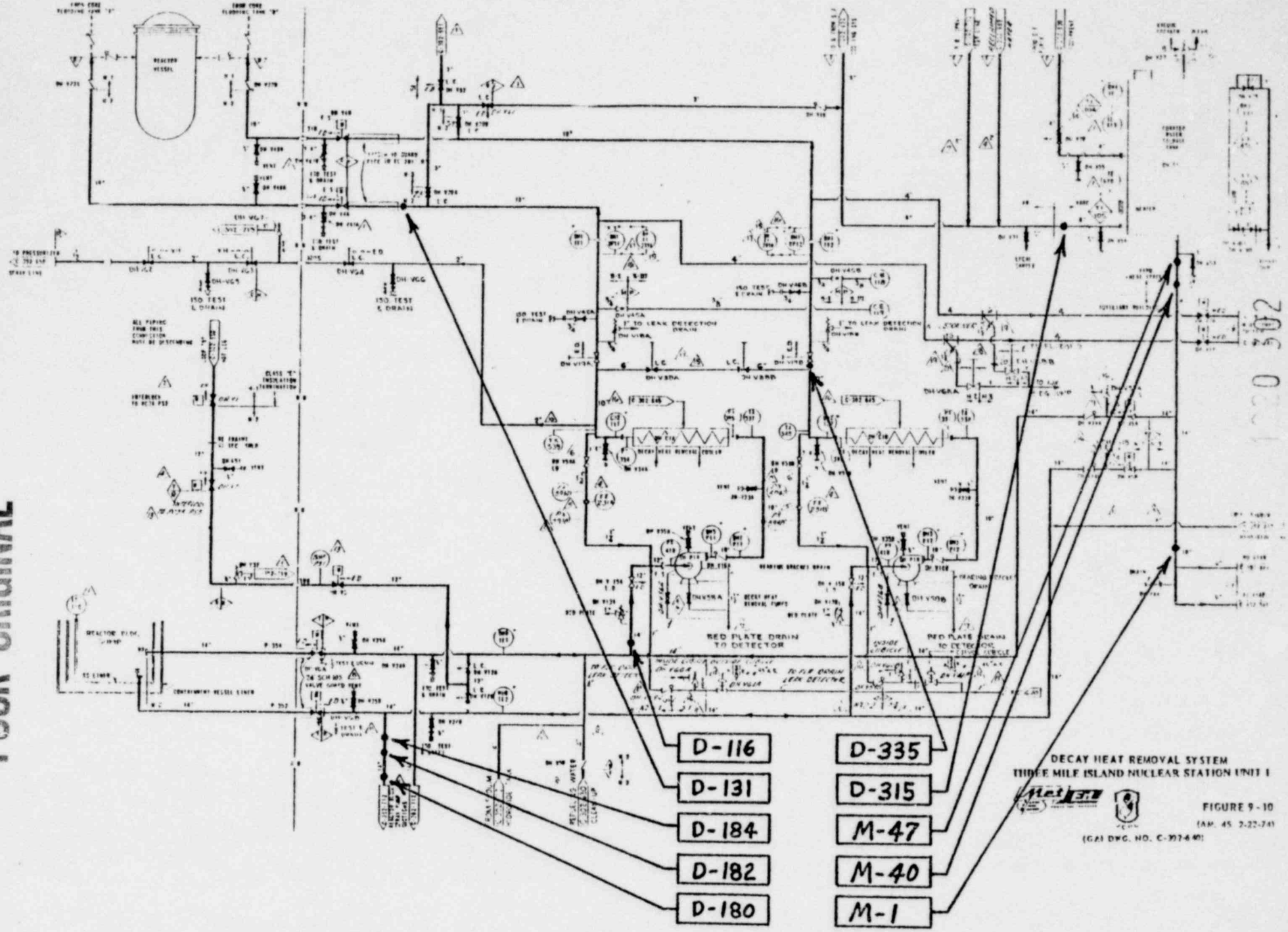
ATTACHMENT #2



SPENT FUEL SYSTEM
THREE MILE ISLAND NUCLEAR STATION UNIT 1

FIGURE 9-9
(AM. 25 4-10-72)

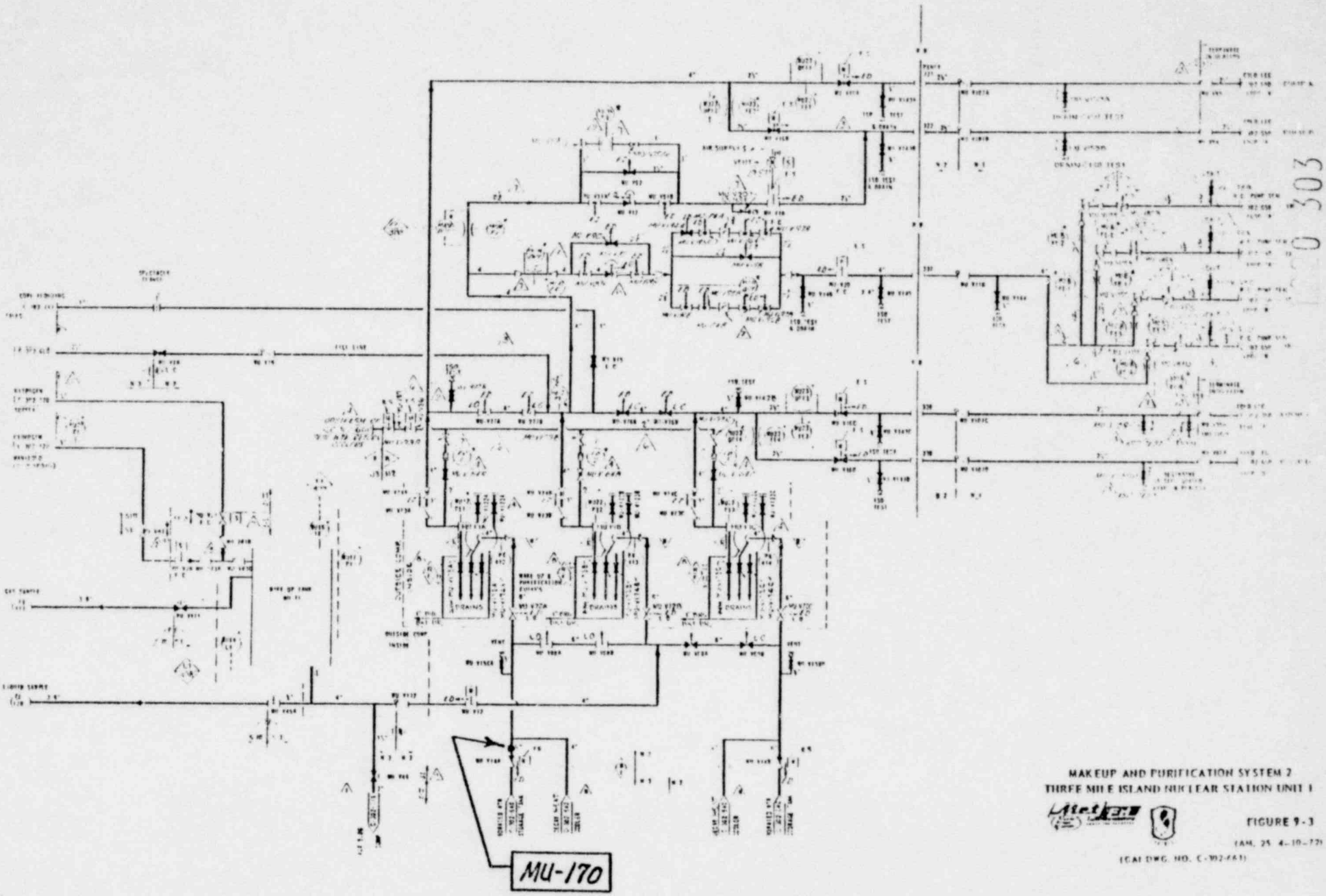
(GAI DWG NO. C-302-430)



DECAY HEAT REMOVAL SYSTEM
THREE MILE ISLAND NUCLEAR STATION UNIT 1

FIGURE 9-10
(AMD. 45, 2-22-74)
(GAI DWG. NO. C-302-640)

POOR ORIGINAL



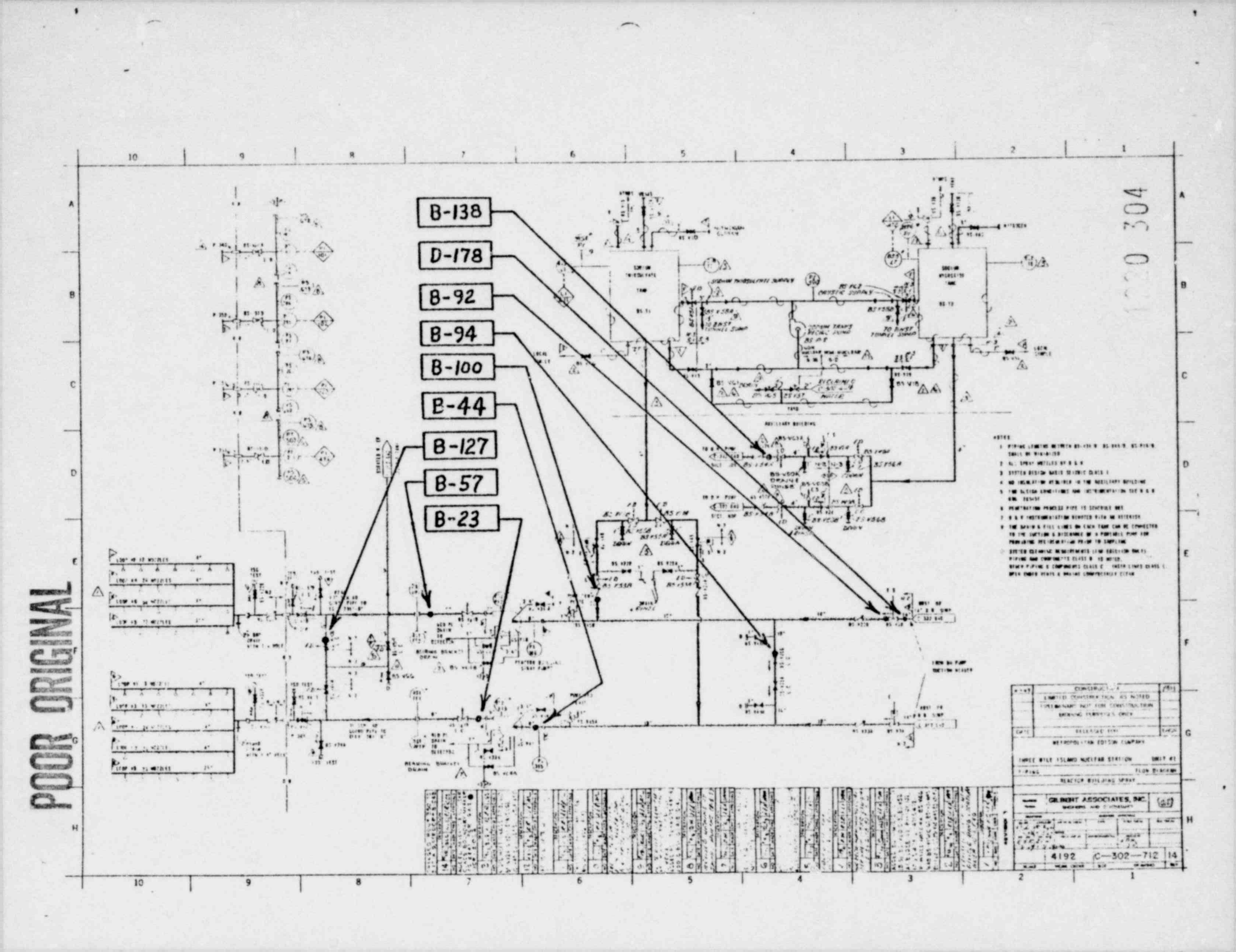
MAKEUP AND PURIFICATION SYSTEM 2
THREE MILE ISLAND NUCLEAR STATION UNIT 1

FIGURE 9-3

(AM. 25 4-10-72)

(GAI DWG. NO. C-302-641)

0303



ATTACHMENT #3

GAS TUNGSTEN ARC - SHIELDED

METAL ARC WELDING OF STAINLESS STEEL

IN BORATED WATER PIPING SYSTEMS

1. Scope

This welding procedure shall be utilized when making welds and weld repairs on the 304 SS and 304L SS piping in the following systems:

A. Spent Fuel

B. Decay Heat

C. Building Spray

D. Make-Up

E. Core Flood

Included in this procedure are the requirements specifically related to producing a corrosion resistant I.D. weld overlay (I.D. Buttering) on the ends of existing 304 SS pipes as recommended in NUREG-0313. Also, as recommended in this document, wherever possible, replacement stainless steel piping material will contain .035% Carbon max.

2. Welding Procedure Specification (WPS)

The basic WPS defining the essential variables to be utilized for this repair are contained in Catalytic WPS No. SP-4200-SS(N)-102A. Non-essential variables specifically tailored for this repair are defined herein. The basic weld procedure specification shall have been qualified in accordance with the requirements of ASME:Section IX and Regulatory Guide 1.31.

3. I.D. Weld Clad (Buttering)

When butt weld joints are to be made between replacement 304L SS piping and the original 304 SS piping in the system the 304SS pipe ends shall be prepared in the following manner:

3. I.D. Weld Clad (Buttering) (Continued)

A. If the pipe end has been thermally cut, a minimum of 1/8" of metal must be removed from the cut and to eliminate the heat-affected-zone (HAZ) from the cutting operation.

B. Clean the pipe end per WPS 4200-SS(N)-102A.

C. Weld clad the I.D. surface of the pipe end to a width of 3/8" + 1/8" - 0 with a single layer of SFA-5.9 Class ER 308L filler metal with 5 FN minimum ferrite, using the GTAW process. (See sketch I).

D. Maximum joulian heat input as established during the I.D. weld clad qualification (GPU Lab No. 56052 rev. 1) shall be 17,100 joules/inch utilizing the following electrical characteristics:

Arc Voltage - 8 - 12 volts

Current - 80 - 95 amps

Travel Speed - 4 in./min.

E. Maximum interpass temperature shall be 100° F.

F. After the I.D. weld cladding is complete the pipe end shall be ground back ≈1/8" to assure the weld clad becomes integral with the weld root. The butt weld joint geometry shall then be prepared by maching or grinding. Joint geometry shall be a 37-1/2° ± 2-1/2° single bevel with a 3/32" ± 1/32" land.

NOTE: Grinding shall not be performed on the weld clad or pipe internal surfaces except in the immediate vicinity of the weld root to facilitate joint fit up and then only light grinding is permitted to remove high spots. Maximum I.D. mismatch on fit up shall be 1/16".

4. Butt Weld Procedure

A. Butt welding shall be in accordance with Catalytic WPS 4200-SS(N)-102A.

4. Butt Weld Procedure (Continued)

B. The root and first pass shall be deposited by the GTAW process utilizing SFA-5.9 Class ER 308L filler metal with a minimum of 5 FN ferrite. Argon gas backing shall be utilized during the first two passes.

C. The weld shall be completed utilizing the SMAW process with SFA-5.4 Class E308L-16 electrodes with a minimum of 5 FN ferrite.

D. Maximum heat input during the welding shall be 35,000 joules/in. with a 300°F max. interpass temperature.

E. Electrical characteristics shall be as follows:

	GTAW	SMAW
Voltage	10 - 12 volts	20 - 23 volts
Current	75 - 95 amps	80 - 100 amps
Travel Speed	2 - 4 in./min.	4 - 6 in./min.

5. Quality Control

A. The quality control inspector shall verify the following:

1) Correct materials, including filler metals, are being utilized.

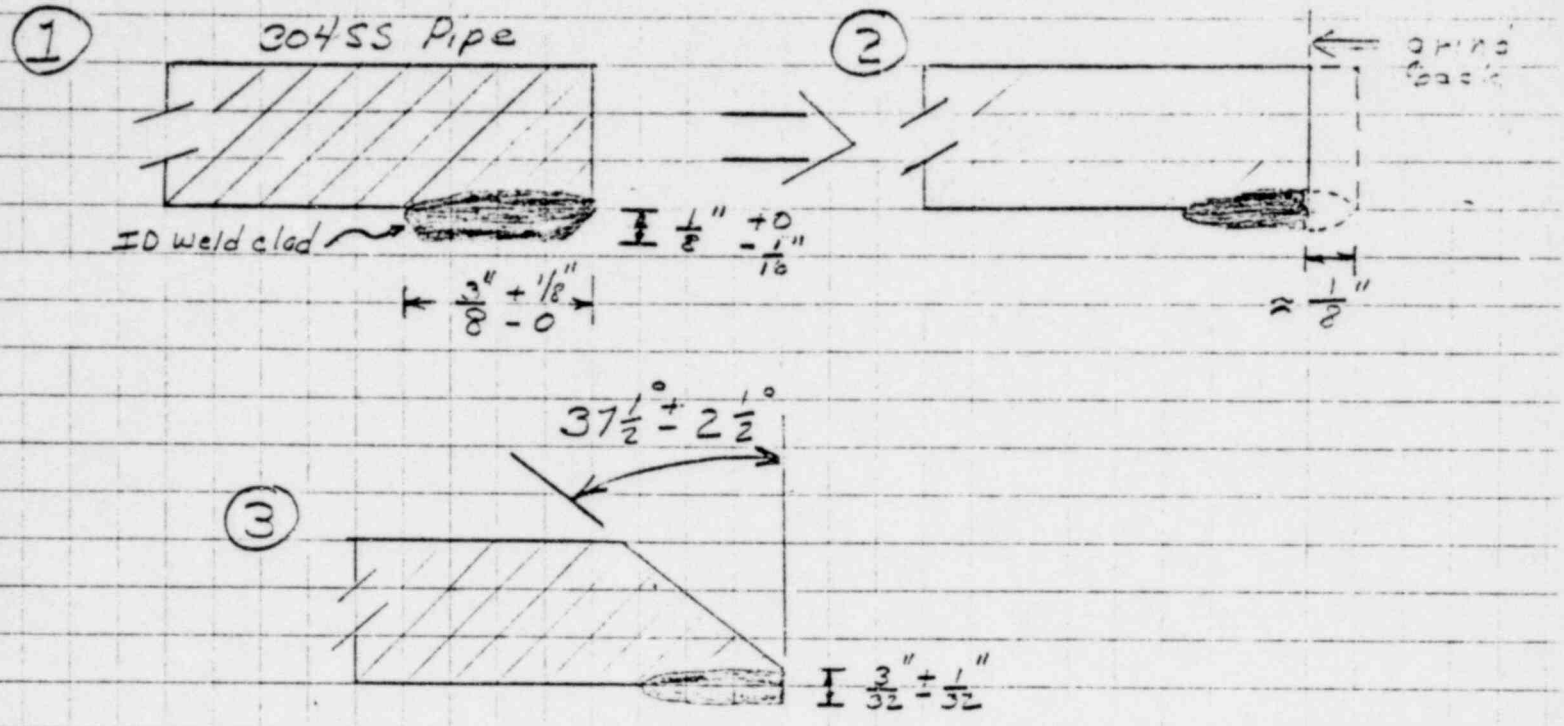
2) I.D. weld clad and joint geometry dimensions are correct.

3) Joint fit up has correct dimensions and aligmment.

B. Quality Control shall also perform spot checks to assure proper electrical characteristics and interpass temperatures are being utilized during welding.

C. Quality Control shall perform final visual inspection per the applicable quality control procedures.

Sketch I



ATTACHMENT #4

CATALYTIC, INC.
ENGINEERING DEPARTMENT

08008 3745P

PLANT: THREE MILE ISLAND CATALYTIC CONTRACT NO. 36590

CLIENT: GPU/METROPOLITAN EDISON SPECIFICATION NO. SP-4200-SS(N)-102A

LOCATION: MIDDLETOWN, PA.

SPECIFICATION

for

GAS TUNGSTEN ARC - SHIELDED METAL ARC WELDING OF STAINLESS STEEL

CONSISTING OF

Reference Attachments:

SP-4200-SS(N)-102A

Item Number	Description

Approved _____ Date _____

Approved _____ Date _____

Approved CLIENT _____ Date _____

Prepared By CATALYTIC _____

CATALYTIC

0 309

Amendment	Approved	Date	Approved	Date	Approved	Approved	Approved	Approved	Date
0					KCT				8/15
	CLIENT				CATALYTIC, INC.				

	CATALYTIC, INC. Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102	Sheet 1 of 11
	GAS TUNGSTEN ARC-SHIELDED METAL ARC WELDING OF STAINLESS STEEL. SPEC.NO. SP-4200-SS(N)-102A	Rev. 00
		Date: 7/30/79

EFFECTIVE PAGE LIST

PAGE NO.	AMENDMENT NO.	EFFECTIVE DATE
1	0	7/30/79
2	0	7/30/79
3	0	7/30/79
4	0	7/30/79
5	0	7/30/79
6	0	7/30/79
7	0	7/30/79
8	0	7/30/79
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21	0	7/30/79
22	0	7/30/79

	CATALYTIC, INC. Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102	Sheet ii of ii
	GAS TUNGSTEN ARC-SHIELDED METAL ARC WELDING OF STAINLESS STEEL. SPEC.NO. SP-4200-SS(N)-102A	Rev 0
		Date 7/30/79

RECORD OR REVISIONS

0	New issue. Amended SP-4200-SS(N)-102, Rev. 7, to meet Three Mile Island job specification.

	CATALYTIC, INC. Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102	Sheet 1 of 22
	GAS TUNGSTEN ARC-SHIELDED METAL ARC WELDING OF STAINLESS STEEL. SPEC.NO. SP-4200-SS(N)-102A	Rev. 0
		Date: 7/30/79

1.00 SCOPE

1.01 This specification is suitable for welding in accordance with the requirements of the ASME Code Section III. This specification is also suitable for welding to ANSI B 31.1, B 31.3 and B 31.7, current edition of all Codes, as of amendment date shown on cover page.

1.02 Welding shall be performed in accordance with the requirements of this specification. Any deviations from this specification shall be documented and approved with an Engineering Design Change Notice authorizing the change.

1.03 This specification shall be used by Catalytic personnel only.

2.00 PROCEDURE QUALIFICATION

2.01 This specification has been qualified in accordance with the requirements of ASME Code Sections III and IX. The qualification tests have also included passing an intergranual corrosion susceptibility test in accordance with ASTM A-262-70 Practice E.

3.00 WELDER QUALIFICATION

3.01 Welders shall be qualified in the positions required for production welds in accordance with the requirements of ASME Code Sections III and IX. Radiographic inspection may be substituted for the guided bend tests at the option of the Catalytic Field Superintendent. When radiographic inspection will be used on production welds, qualification of welders by radiographic inspection should be considered. In the event the welder is qualified by bend tests, the first production weld made shall be inspected.

4.00 GENERAL

4.01 All joints shall be assembled in accordance with the drawings. Jigs, positioners, fixtures and dams shall be employed to the maximum extent practicable to establish and maintain alignment and joint dimensions of the parts. The installation of temporary attachments must be in accordance with applicable Code rules.

4.02 Tack welds shall be made by qualified welders in accordance with this specification. Tack welds to be incorporated into the weld shall have their starting and stopping ends taper ground or similarly prepared.

4.03 Weld bead deposition sequence shown in the procedure specifications shall be followed in the order and location of bead placement. However, there are circumstances where the exact number of beads or layers shown in the procedure specification cannot be maintained. In such circumstances, the number of beads may be varied from that shown.

4.04 Finished butt welds shall not have undercutting greater than 1/32" deep. The height of reinforcement on each face of the weld shall not exceed the following thickness tabulation, considering the thickness of the thinner component being joined and measured from the higher of the two abutting surfaces.

	B31.7 and Sec. III-Piping		B31.1	B31.1 350°F to 750°F	B31.1	B31.3
	Face	(a) Root	< 350°F		≥750°F	
Up to 1/8" incl.	3/32"	3/32"	3/16"	3/32"	1/16"	1/16"
>1/8 to 3/16" incl.	1/18"	3/32"	3/16"	1/8"	1/16"	1/16"
>3/16 to 1/4" incl.	5/32"	1/8"	3/16"	5/32"	1/16"	1/16"
>1/4 to 1/2" incl.	5/32"	1/8"	3/16"	5/32"	1/16"	1/8"
>1/2 to 1" incl.	3/16"	5/32"	3/16"	3/16"	3/32"	5/32"
>1 to 2" incl.	1/4"	5/32"	1/4"	1/4"	1/8"	3/16"
>2"	1/4" *	5/32"	1/4" *	1/4" *	5/32"	3/16"

(a) Root of single welded joints only. Use face dimension for double welded joints.

* Or 1/8 x the width of the weld in inches.

Notes: 1. For Section III vessels, pumps, and valves, refer to Code for allowable reinforcement.

4.05 Concavity on the root side of a single welded circumferential butt weld is permitted when the resulting thickness of the weld is at least equal to the thickness of the thinner of the two members being joined, except that when applied to B31.7, a maximum of 1/32" weld reinforcement may be considered toward the thickness requirements. The contour of the concavity shall be smooth without sharp edges.

4.06 Arc-strikes and weld starts shall not be mad purposely on the base metal outside the weld groove or outside the fillet or socket weld.

4.07 When inadvertent arc-strikes are made on the base metal surface outside the weld groove or area, the arc-strikes shall be removed by grinding or filing and the area shall be examined by the liquid penetrant method.

4.08 If the weld surface requires grinding to meet the required surface condition, care shall be taken to avoid reducing the weld or base material below the required thickness.

4.09 Welding materials for performance qualification testing do not require Certification of Compliance.

4.10 Peening shall not be allowed.

5.00 CLEANING AND JOINT PREPARATION

5.01 Prior to welding, all consumable inserts, pipe ends, weld grooves or surfaces to be welded shall be cleaned of all oil, grease, scale and foreign materials.

5.02 Welding surfaces shall be swabbed with a clean cloth soaked in a suitable solvent such as Acetone or Solvesso Xylol or an approved equal for at least 2 inches back from the weld area on both the inside and outside of the material being joined.

5.03 Weld end preparations shall be made by machining, grinding, metal powder cutting or plasma cutting.

5.04 When metal powder cutting or plasma cutting is used, a 350 F maximum interpass temperature shall be maintained; all remaining slag, scale or oxides shall be removed by grinding or machining to bright metal to a depth of approximately 1/32 inch below the burned surface.

5.05 For cleaning or backg ging, the grinding wheels shall be rubber or resin bonded, aluminum oxide or silicon carbide. Brushing shall be with a stainless steel brush which has not been previously used on carbon steel. Contamination with chlorides, other halides and carbon shall be avoided.

6.00 FIT-UP

6.01 Alignment of inside surfaces of pipe and components shall be in accordance with the Code. Should component tolerances such as diameter, wall thickness, or out-of-roundness, result in inside diameter variations which do not meet these requirements, the inside diameter shall be counterbored, sized, or ground within limits of the Code to produce an acceptable bore.

6.02 Butt, socket and fillet joint supports may be friction type clamps or welded type.

6.03 Welded support clamps shall be removed by grinding only. The base metal shall be inspected by liquid penetrant test methods after removal of the temporary attachment.

6.04 Consumable inserts shall be used only when specified on the drawings.

6.05 When proper fit-up is achieved, the insert shall be tack welded in place to both pipe ends.

7.00 WELDING

7.01.1 Welding by the Gas Tungsten Arc process shall be started with high frequency starting devices whenever possible.

7.01.2 Welding grade Argon Gas of a minimum of 99.995 percent purity (Minus 60°F Dew Point or better) shall be used for backing and as an inert cover gas.

7.01.3 Backing gas shall be used on all pipe welds except socket welds and fillet welds. Backing gas shall be maintained during the root pass and subsequent layers until 3/16 inch of weld metal has been deposited.

7.01.4 The backing gas procedure shall consist of sufficient gas flow rate and waiting time to reduce the oxygen content to a maximum of one percent as measured by an oxygen analyzer or by the following table:

Pipe Size in Inches	Gas Flow Rate Cu. Ft. Per Hr.	Waiting Time Per Ft. of Pipe Length Between Dams
1	10	15 Sec.
2	10	1 Min.
3	10	2 Min.
4	30	1 Min.
5	30	2 Min.

(Continued)

7.01.4 (Continued)

Pipe Size in Inches	Gas Flow Rate Cu. Ft. Per Hr.	Waiting Time Per Ft. of Pipe Length Between Dams
6	30	2-1/2 Min.
8	30	4-1/2 Min.
10	30	6-1/2 Min.
12	30	10 Min.

7.01.5 Dams shall be used to restrict the purged volume to the immediate weld area. The dams may consist of existing valves or temporary dams made from wood, metal, plastic, cardboard or paper and sealed with pressure sensitive tape. No combustible dams shall be placed within 6 inches of a weld. Dams shall be accessible for complete removal after welding, including the residue from the sealing tape. Water soluble paper dams and paste may be used.

7.01.6 Whenever welding is stopped during the Gas Tungsten Arc process, the cover gas shall be directed on the weld after arc extinction until the normal color of the metal is observed.

7.02 Shielded Metal Arc Welding

7.02.1 All slag, flux or surface porosity shall be removed from any weld and there shall be no foreign material present when the next bead of weld metal is deposited.

7.02.2 For vertical (5G) welding with pipe in the horizontal fixed position, welding shall be started at or near the bottom of the joint and proceed upward. Care should be taken to stagger the starts and stops of successive weld passes so that no two adjacent weld beads, either in the same layer or the next layer, start or end in the same location.

7.02.3 For horizontal welding (2G), or with pipe running vertically, weld shall be deposited in succeeding stringer beads, starting at the bottom of the groove and proceeding evenly on both sides toward the top, using staggered starts and stops to prevent weld beads that begin or end in the same location.

7.02.4 Retainers shall not be used.

8.00 PREHEAT CHECK

8.01 The preheat temperature shall be checked by use of temperature indicating crayons, thermocouple pyrometers, or other suitable methods to assure that the required preheat temperature is obtained prior to and uniformly maintained during the welding operation.

9.00 REPAIR WELDING

9.01 Welds and adjacent base metal having defects that are in excess of those permitted by applicable acceptance standards shall be repaired employing the techniques of Section 14.00. When applicable, conformance to the Code restrictions for repair welding shall be complied with.

9.02 Base metal defects may be repaired using this procedure employing the techniques of 14.00 when the applicable Code permits such repair. All limitations imposed by the applicable Code for repair welding shall be complied with.

10.00 NON-DESTRUCTIVE EXAMINATION

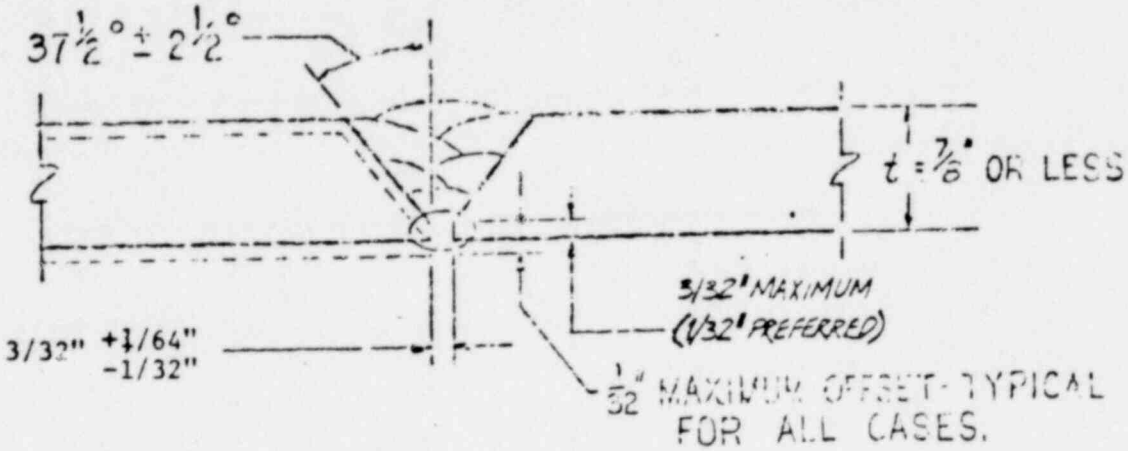
10.01 Each pass of all welds shall be visually checked by the welder.

10.02 Non-destructive examination will be identified on the Weld Index and NDE Chart, work order, or job specification.

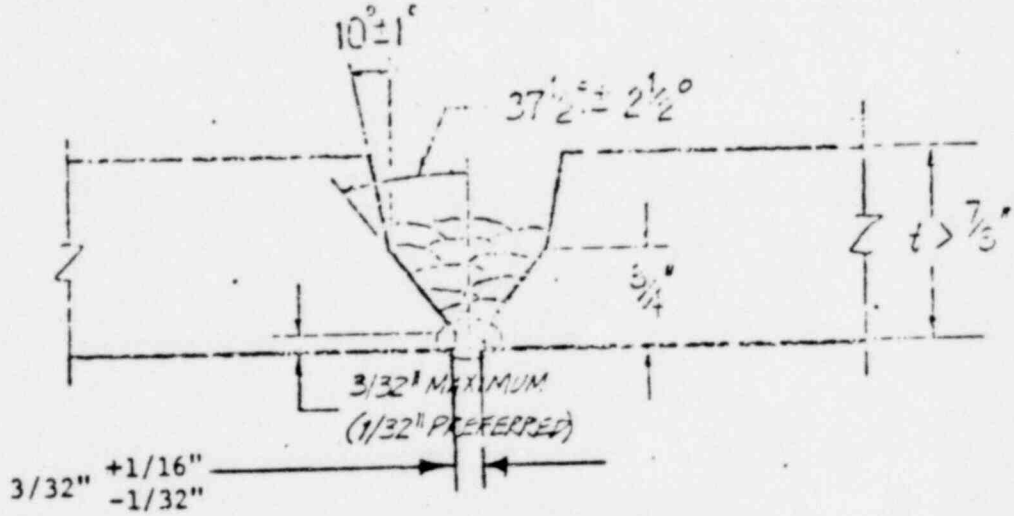
10.03 The surface condition of the finished welds shall be suitable for the proper interpretation of the required non-destructive examination.

11.00 JOINT PREPARATION

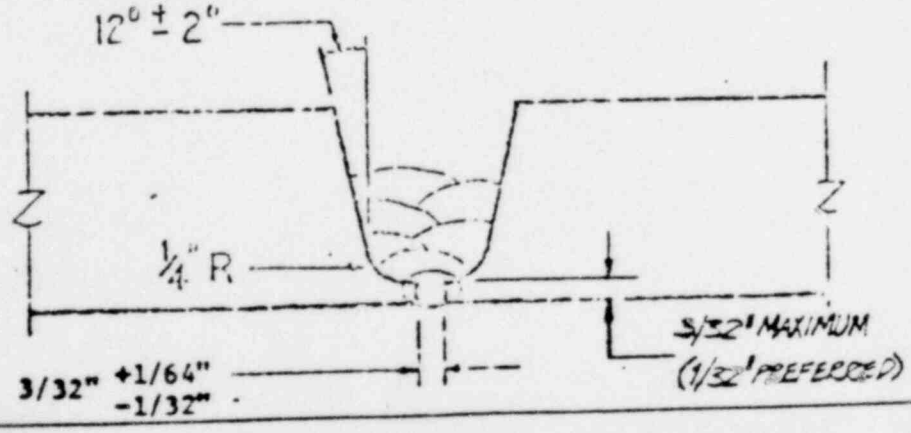
11.01 Butt Weld Joint



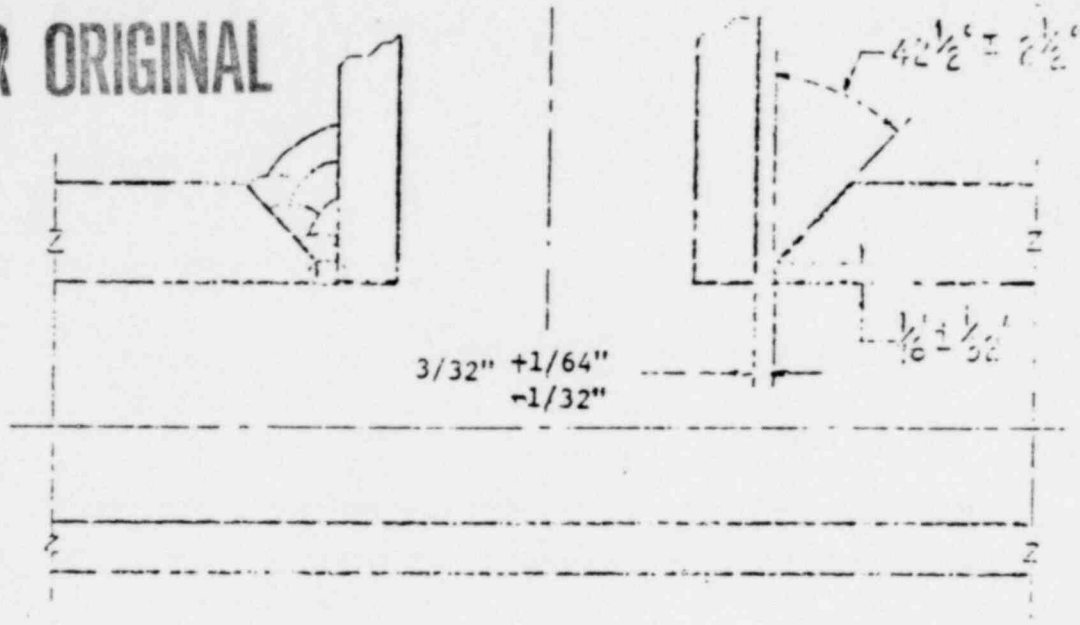
11.02 Butt Weld Joint



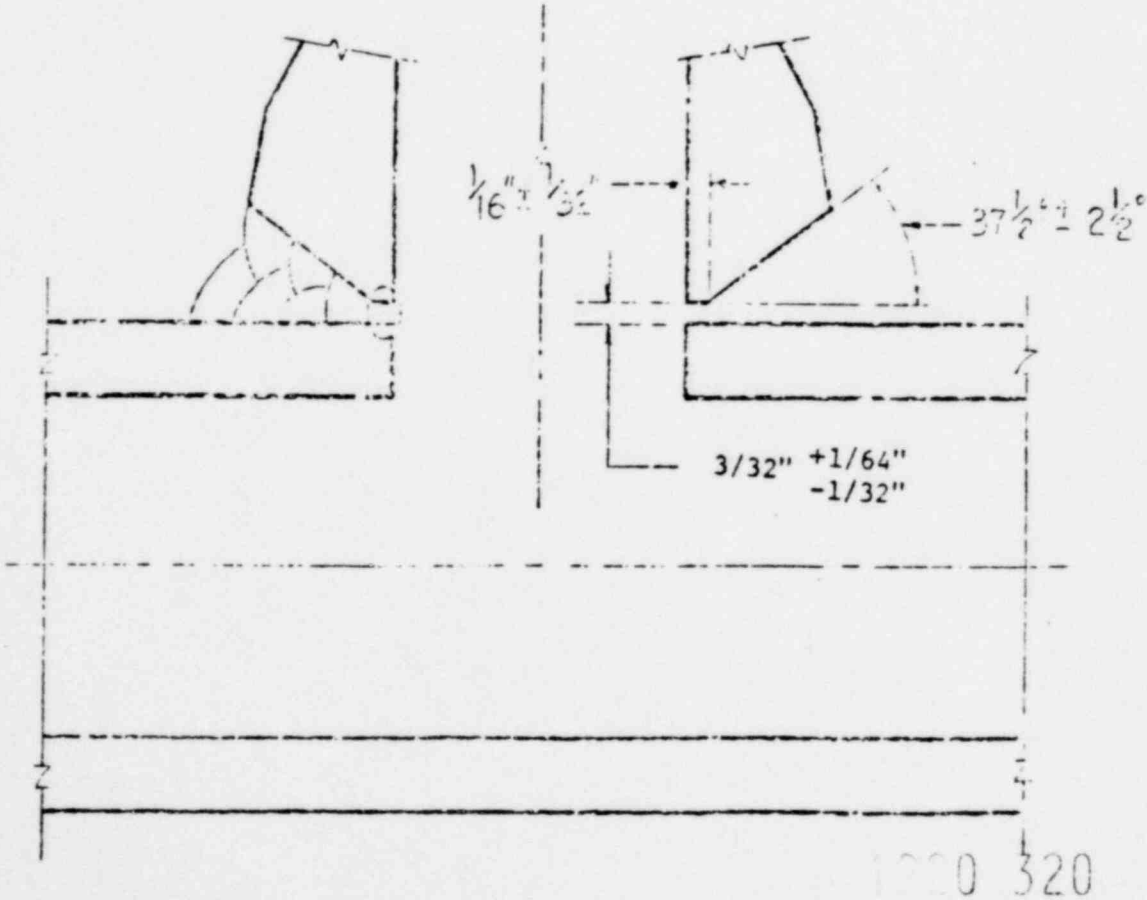
11.03 Butt Weld Joint (Alternate)
Use Only Where Shown on Drawings



11.04 Branch Connection Joint

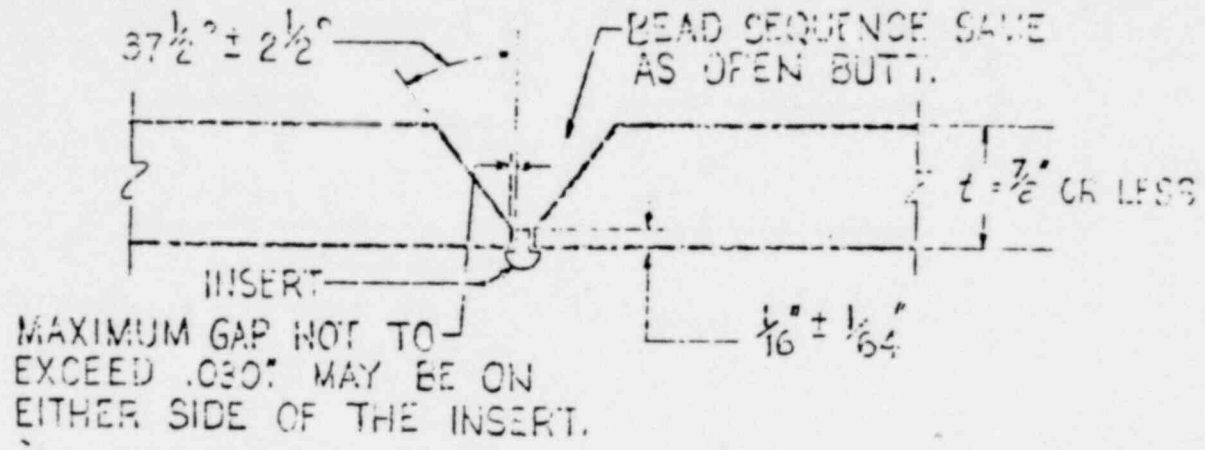


11.05 Weldolet Joint



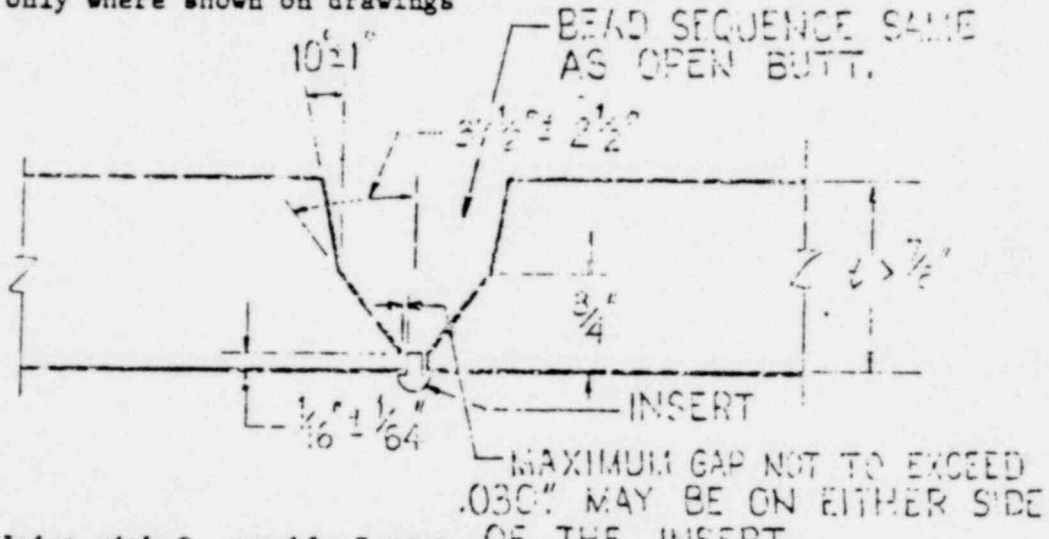
11.06 **Butt Joint with Consumable Insert**

Use only where shown on drawings



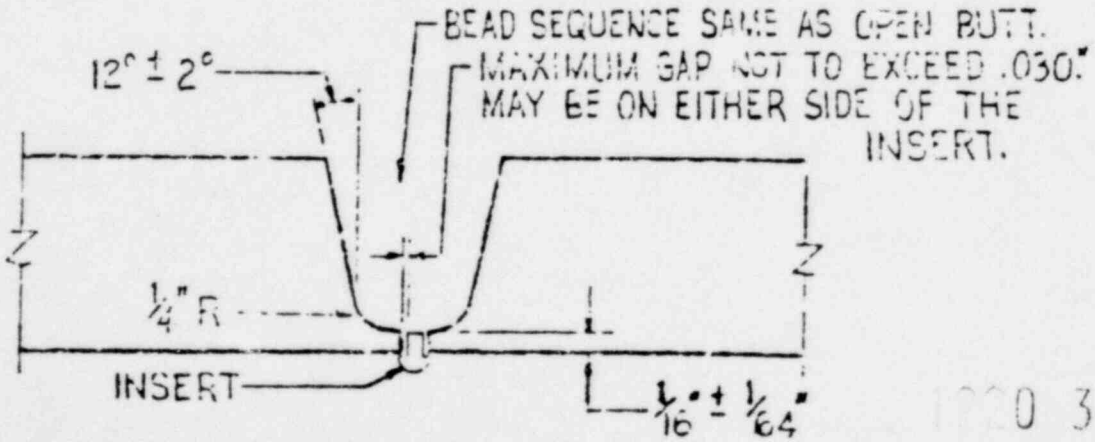
11.07 **Butt Joint with Consumable Insert**

Use only where shown on drawings

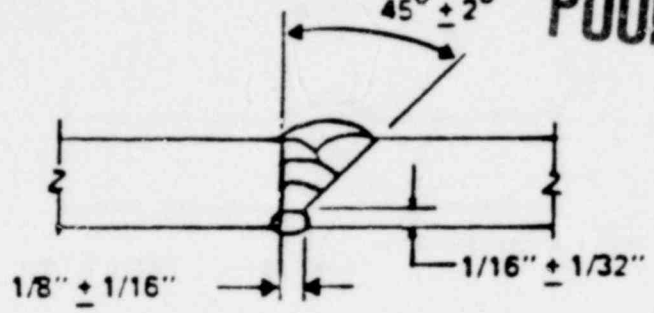


11.08 **Butt Joint with Consumable Insert (Alternate)**

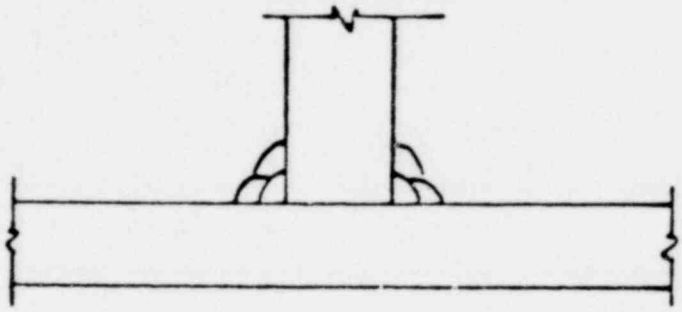
Use only where shown on drawings.



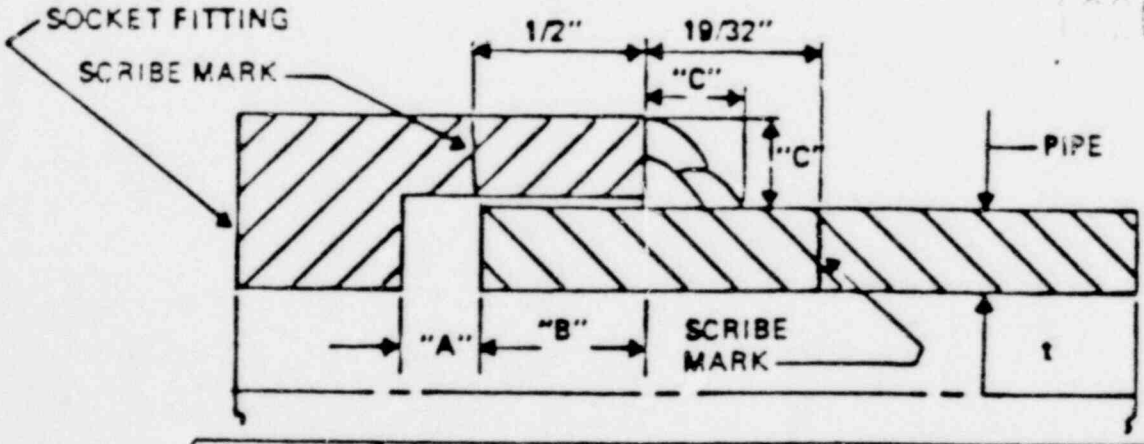
11.09 BEVEL JOINT



11.10 FILLET WELD JOINT



11.11 SOCKET WELD JOINT (For other than socket weld "fitting") i.e. flanges, see Code.
"C" min. = 1½" t - B 31.1, B 31.3.
"C" min. = 1.09 t - All other codes.



Pipe Size	Bottoming Clearance "A"	Engagement Distance "B"
1/8"to ¼"	3/32" min.	1/4" min.
3/4"to 1½"	3/32" min.	3/8" min.
to 2"	3/32" min.	1/2" min.

Insert pipe to bottom of fitting, scribe 1/2" from fitting, withdraw 3/32".

28087 1076P

	CATALYTIC, INC Centre Square West 1500 Market Street, Phiiadelphia, Pennsylvania 19102	Sheet 12 of 22
	GAS TUNGSTEN ARC-SHIELDED METAL ARC WELDING OF STAINLESS STEEL SPEC.NO. SP-4200-SS(N)-102A	Rev. 0
		Date 7/30/79

12.00 WELDING DETAILS

BASE MATERIAL: Stainless Steel
Welded to: Stainless Steel
* ASME Section IX: P 8 to P 8
* Procedure Qualified for Weld Thickness of 1/16" Min to 2.00" Max.
* WELDING PROCESS: GTAW & SMAW
Weld Position All
Weld Progression Up
* Shielding Gas: Welding Gr. Argon (99.995%)
Backing Gas: Welding Gr. Argon (99.995%)
WELDING MATERIAL: ASME SFA 5.9 & 5.4
* ASME Section IX: F 6 & 5 A 8
Type: ER-XXX & E-XXX - 15/16 with 5-15 Ferrite Number
* :See Schedule

HEAT TREATMENT:
* Preheat Temp. 50°F Min
* Interpass Temp. 350°F Max
* Postweld Holding Temp: NA
Postweld Holding Time: NA
Maintenance of Preheat after Welding:
[X] May be Dropped
[ ] Drop after Holding, hours

WELD JOINT:

Butt	Para.	11.01-11.03
Fillet		11.10 *
Socket		11.11 *
Branch		11.04
Weldolet		11.05
Bevel		11.09

*May use either process for entire weld.

Base Material	Weld Material
304	308
304L	308L
316	316
316L	316L
321	321 Wire 347 Electrode
347	347

ADDITIONAL REQUIREMENTS: 3/16" maximum thickness per layer.

WELDING PROCESS:	GTAW	SMAW	SMAW	SMAW
PORTION OF JOINT:	Root	Fill (3)	Fill (3)	Fill (3)
Pass Number	1 & 2	3 to complete	3 to complete	3 to complete
Current (amps)	75 - 150	60 - 90	90 - 120	120 - 160
Current Type/ Polarity (5)	DCSP	DCRP	DCRP	DCRP
Torch Gas (C.F.H.)	14 -20	NA	NA	NA
Backing Gas (C.F.H.) (1)	3 - 6	NA	NA	NA
Cup Size (I.D.-in.) (6)	1/4-1/2	NA	NA	NA
Bare Wire Diameter (in)	1/16 - 1/8	NA	NA	NA
Electrode Diameter (in)	1/16-1/8 (4)	3/32	1/8	5/32
Tungsten Elec. Ext. (in)	3/8 max.	NA	NA	NA
Voltage (Volts)	10 - 14	20 - 25	20 - 25	21 - 26
Travel Speed (in/min.)	Approx. 4	6 - 12	6 - 12	6 - 12
Welding Technique	String	- - - - - - -	String & Weave (2) - - -	
Interpass Cleaning	Wire brush	- - - - - - -	Grind and wire brushing - -	
Backgouging	- - - - - -	- - - - - - -	Grinding and Wire Brushing -	

NOTES: (1) Gas back for first 3/16 inch of weld thickness.
(2) Weave of up to 2½ times nominal core wire diameter is allowed.
(3) Fill pass may use either column singly or in combination.
(4) 3/32 preferred. (5) No pulse. (6) No trailer.

APPLICATION:

* Essential Variables Requiring Requalification.

28082 1076P

CATALYTIC, INC.
Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102

Sheet 13 of 22
Rev. 0
Date 7/30/79

GAS TUNGSTEN ARC-SHIELDED METAL ARC WELDING OF STAINLESS STEEL
SPEC.NO. SP-4200-SS(N)-102A

13.00 WELDING DETAILS (EB DESIGN)

BASE MATERIAL: Stainless Steel
Welded to: Stainless Steel
ASME Section IX: P 8 to P 8
Procedure Qualified for Weld Thickness of 1/16" Min to 0.644" Max.
WELDING PROCESS: GTAW & SMAW
Weld Position All
Weld Progression Up
Shielding Gas: Welding Gr. Argon (99.995%)
Backing Gas: Welding Gr. Argon (99.995%)
WELDING MATERIAL: ASME SFA 5.9 & 5.4
ASME Section IX: F 6 & 5 A 8
Type: ER-XXX & E-XXX-15/16 with 5-15 Ferrite Number - See Schedule
Consumable Insert: E.G. to SFA 5.9 ER-XXX - See Schedule

HEAT TREATMENT:
Preheat Temp. 50°F Min.
Interpass Temp. 350°F Max
Postweld Holding Temp: NA
Postweld Holding Time: NA
Maintenance of Preheat after Welding:
☒ May be Dropped
☐ Drop after Holding, hours

WELD JOINT:

Butt - Paragraph 11.06-11.08.

Base Material	Weld Material
304	308
304L	308L
316	316
316L	316L
321	321 Wire
	347 Electrode
347	347

ADDITIONAL REQUIREMENTS: 3/16" maximum thickness per layer.

WELDING PROCESS:	GTAW	GTAW	SMAW	SMAW	SMAW
PORTION OF JOINT:	Root	1st layer	Fill (3)	Fill (3)	Fill (3)
Pass Number	1	2	3 to compl.	3 to compl.	3 to complete
Current (amps)	75 - 150	75 - 150	60 - 90	90 - 120	120 - 160
Current Type/ Polarity (5)	DCSP	DCSP	DCRP	DCRP	DCRP
Torch Gas (C.F.H.)	14 -20	14 -20	NA	NA	NA
Backing Gas (C.F.H.) (1)	3 - 6	3 - 6	NA	NA	NA
Cup Size (I.D.-in.)(6)	1/4-1/2	1/4-1/2	NA	NA	NA
Bare Wire Diameter (in)	NA	1/16-1/8	NA	NA	NA
Electrode Diameter (in)	1/16-1/8(4)	1/16-1/8 (4)	3/32	1/8	5/32
Tungsten Elec. Ext. (in)	3/8 Max	1/4 Max	NA	NA	NA
Voltage (Volts)	10 - 14	10 - 14	20-25	20 - 25	21 - 26
Travel Speed (in/min.)	Approx 4	Approx 4	6-12	6 - 12	6 - 12
Welding Technique	String	String	String and weave (2)	- - -	- - -
Interpass Cleaning	Wire Brush		Grind and Wire Brush	- - -	- - -
Backgouging	- - - - Grind and Wire Brush - - - -		- - - - - - - -	- - - - - -	

NOTES: (1) For first 3/16 inch of weld thickness.
(2) Weave of 2-1/2 times diameter of core wire allowed.
(3) Fill pass may use either column singly or in combination.
(4) 3/32 preferred. (5) No pulse. (6) No trailer.

APPLICATION:

* Essential Variables Requiring Requalification.

CATALYTIC, INC.
Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102

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GAS TUNGSTEN ARC-SHIELDED METAL ARC WELDING OF STAINLESS STEEL

SPEC.NO. SP-4200-SS(N)-102A

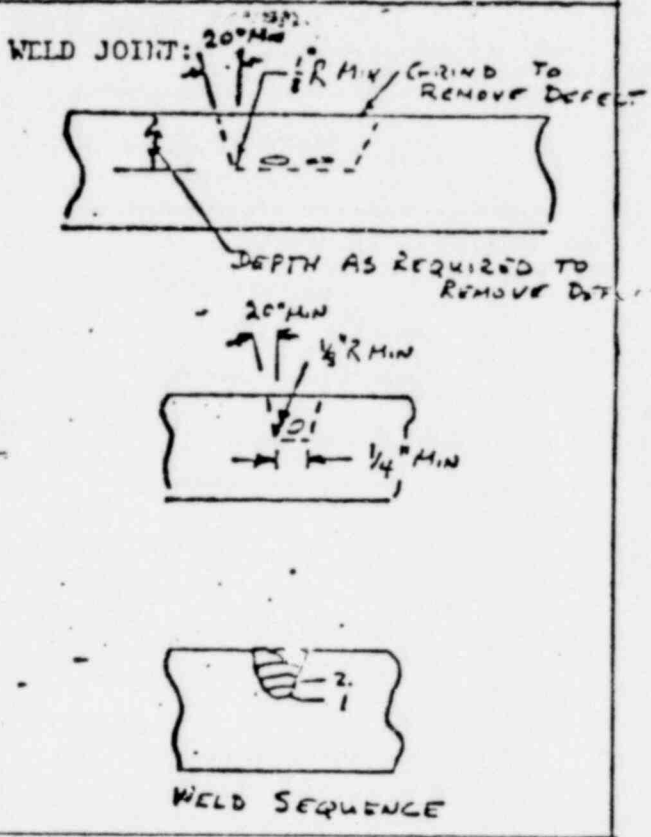
Rev. 0

Date: 7/30/79

14.00 REPAIR DETAILS

BASE MATERIAL: Stainless Steel
Welded to:
ASME Section IX: P 8
* Procedure Qualified for Weld Thickness of Min to Max.
* WELDING PROCESS: GTAW - SMAW
Weld Position All
Weld Progression
* Shielding Gas: Welding Grade Argon (99.995%)
Backing Gas:
WELDING MATERIAL: ASME SFA 5.9 & 5.4
* ASME Section IX: F 6 & 4 A #8
* Type: ER-XXX & E-XXX- 15, . with 5-15 Ferrite Number. See Schedule Para. 11.00, 12.00.

HEAT TREATMENT:
* Preheat Temp. 50°F Min
* Interpass Temp. 350°F Max
* Postweld Holding Temp: None
Postweld Holding Time: NA
Maintenance of Preheat after Welding:
[X] May be Dropped
[ ] Drop after Holding, hours



ADDITIONAL REQUIREMENTS: Liquid penetrant inspect ground preparation to insure all defects removed prior to welding. 3/16" maximum thickness per layer.

WELDING PROCESS: (1)	GTAW	SMAW	SMAW	
POSITION OF JOINT:	All	All	Fill	
Pass Number	All	All (2)	2nd to complete	(2)
Current (amps)	75 - 150	60 - 90	110 - 140	
Current Type/ Polarity (5)	DCSP	DCRP	DCRP	
Torch Gas (C.F.H.)	14 -20	NA	NA	
Cup Size (I.D.-in.) (6)	1/4-1/2	NA	NA	
Bare Wire Diameter (in)	1/16-1/8	NA	NA	
Electrode Diameter (in)	1/16-1/8 (4)	3/32	1/8	
Tungsten Elec. Ext. (in)	1/4" Max	NA	NA	
Voltage (Volts)	10 - 14	20 - 24	20 - 24	
Travel Speed (in/min.)	Approx 3	Approx 6	Approx 6	
Welding Technique	Weave (3)	Weave (3)	Weave (3)	
Interpass Cleaning	Brushing	Chip and Brush		

NOTES: (1) Welding process used to be same as used for weld being repaired.
(2) Fill pass (SMAW) may use either column singly or in combination.
(3) Weave up to 2½ times nominal core wire diameter.
(4) 3/32 preferred. (5) No pulse. (6) No trailer.

APPLICATION:

* Essential Variables Requiring Requalification.

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CATALYTIC, INC.
Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102

RECORD OF PROCEDURE AND PERFORMANCE QUALIFICATION TESTS

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Date: 7/30/79

Description of Welding Process

GAS TUNGSTEN ARC PORTION

Welding Specification No.
SP-4200-NS(N)-102A

JOINTS (QW-402)

Paragraph 10.01

Groove Design Used

BASE METALS (QW-403)

Material Spec. SA 213
Type or Grade Type 304
P No. 8 to P No. 8
Thickness 0.322
Diameter 8" Schedule 40
Other Qualifies 1/16 to .644"

FILLER METALS (QW-404)

Weld Metal Analysis A No. 8
Size of Electrode 3/32
Filler Metal F. No. 6
SFA Specification 5.9
AWS Classification ER 308
Other

POSITION (QW-405)

Position of Groove 2G
Weld Progression (Uphill, Downhill)
Other

PREHEAT (QW-406)

Preheat Temp. 50°F Min
Interpass Temp. 350°F Max
Other

POSTWELD HEAT TREATMENT (QW-407)

Temperature NA
Time
Other

GAS (QW-408)

Type of Gas or Gases Argon
Composition of Gas Mixture 99.995%
Other

ELECTRICAL CHARACTERISTICS (QW-409)

Current Direct
Polarity Straight
Amps. 75-200 Volts 10-17
Travel Speed 4"/Min
Other

TECHNIQUE (QW-410)

String or Weave Bead String
Oscillation
Multipass or Single Pass Multipass per side
Single or Multiple Electrodes Single

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Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102

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RECORD OF PROCEDURE AND PERFORMANCE QUALIFICATION TESTS

Welding Specification No. SP-4200-SS(N)-102 A

TENSILE TEST (QW-150)

SPECIMEN NO.	WIDTH	THICKNESS	AREA	ULTIMATE TOTAL LOAD LB.	ULTIMATE UNIT STRESS PSI	CHARACTER OF FAILURE & LOCATION
T-1	0.750	0.238	0.178	15,120	84,945	Weld
T-4	0.750	0.239	0.179	14,770	82,515	Weld

GUIDED BEND TESTS (QW-160)

TYPE AND FIGURE NO.	RESULT	TYPE AND FIGURE NO.	RESULT
2 Face	1 Tear - 3/32"	3 - Root	1 Tear - 1/32"
5 Face	2 Tears- 3/32", 7/64"	6 - Root	No Tears

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

Type of Test ASTM A262-70 Practice E Susceptibility to Intergranular Attack

Deposit Analysis

Other No Intergranular Attack Noted - Toledo Testing Lab #401178

FILLET WELD TEST (QW-180)

Result - Satisfactory _____ (Yes, No) Penetration into Parent Metal _____ (Yes, No)

Type and Character of Failure _____ Macro-Results _____

Welder's Name Philip Van Dyne Clock No. SS #300-28-6748 Stamp No. BUG

Tests conducted by Toledo Testing Lab., Inc Laboratory Test No. 401168

Original Signed ~~xxx~~ by: Gerald Herrig

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

Original Spec. No. SP-4200-SS(N)-100.03

Signed CATALYTIC, INC. (Manufacturer)

Date 6/21/76 Original Signed By R. Oakes, Jr.

27008/01-107SP

CATALYTIC, INC.
Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102

RECORD OF PROCEDURE AND PERFORMANCE QUALIFICATION TESTS

Rev. 0

Date 7/30/79

Description of Welding Process

GAS TUNGSTEN ARC PORTION

Welding Specification No.
SP-4200-SS(N)-102A

JOINTS (QW-402)

Paragraph 10.06

Groove Design Used

BASE METALS (QW-403)

Material Spec. SA 213

Type or Grade Type 304

P No. 8 to P No. 8

Thickness .322

Diameter 8" Schedule 40

Other Qualifies 1/16 to .644"

FILLER METALS (QW-404)

Weld Metal Analysis A No. 8

Size of Electrode 3/32

Filler Metal F. No. 6

SFA Specification 5.9

AWS Classification ER 308

Other Insert ER 308 Type A

POSITION (QW-405)

Position of Groove 2G

Weld Progression _____ (Uphill, Downhill)

Other _____

PREHEAT (QW-406)

Preheat Temp. 50°F Min

Interpass Temp. 350°F Max

Other _____

POSTWELD HEAT TREATMENT (QW-407)

Temperature NA

Time _____

Other _____

GAS (QW-408)

Type of Gas or Gases Argon

Composition of Gas Mixture 99.9%

Other _____

ELECTRICAL CHARACTERISTICS (QW-409)

Current Direct

Polarity Straight

Amps. 75-200 Volts 10-17

Travel Speed 4"/Min

Other _____

TECHNIQUE (QW-410)

String or Weave Bead String

Oscillation _____

Multipass or Single Pass Multipass per side

Single or Multiple Electrodes Single

CATALYTIC, INC.
Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102

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Rev. 0

Date: 7/30/79

RECORD OF PROCEDURE AND PERFORMANCE QUALIFICATION TESTS

Welding Specification No. SP-4200-SS(N)-102 A

TENSILE TEST (QW-150)

SPECIMEN NO.	WIDTH	THICKNESS	AREA	ULTIMATE TOTAL LOAD LB.	ULTIMATE UNIT STRESS PSI	CHARACTER OF FAILURE & LOCATION
T-1	0.750	0.228	0.171	14,925	87,280	Weld
T-4	0.751	0.221	0.166	13,650	82,230	Weld

GUIDED BEND TESTS (QW 160)

TYPE AND FIGURE NO.	RESULT	TYPE AND FIGURE NO.	RESULT
2 - Face	No tears	3 - Root	1 Tear - 1/64"
5 - Face	No tears	6 - Root	No Tears

TOUGHNESS TESTS (QW-170)

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

Type of Test ASTM A 262-70 Practice E - Susceptibility to Intergranular Attack

Deposit Analysis

Other No Intergranular Attack Noted - Toledo Testing Labs #401178

FILLET WELD TEST (QW-180)

Result - Satisfactory _____ (Yes, No) Penetration into Parent Metal _____ (Yes, No)

Type and Character of Failure _____ Macro-Results _____

Welder's Name Philip Van Dyne S. S. #300-28-6748 Stamp No BUC

Tests conducted by Toledo Testing Lab., Inc Laboratory Test No. 401169

Original Signed By: Gerald Herrig

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

ORIGINAL SPEC. NO. SP-4200-SS(N)-100.01

Signed CATALYTIC, INC.
(Manufacturer)

Date 6/21/76 Original Signed By R. H. Oakes, Jr.

27008/01-107SP

CATALYTIC, INC.
Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102

RECORD OF PROCEDURE AND PERFORMANCE QUALIFICATION TESTS

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Description of Welding Process
SHIELDED METAL ARC PORTION

Welding Specification No.
SP-4200-SS(N)-102A

JOINTS (QW-402)

Paragraph 10.01

Groove Design Used

BASE METALS (QW-403)

Material Spec. SA 213
Type or Grade Type 304
P No. 8 to P No. 8
Thickness 0.332"
Diameter 8" D Schedule 40
Other Qualifies 1/16" to .664

FILLER METALS (QW-404)

Weld Metal Analysis A No. 8
Size of Electrode 1/8" Dia.
Filler Metal F. No. 5
SFA Specification 5.4
AWS Classification E 308-16
Other

POSITION (QW-405)

Position of Groove 2G
Weld Progression (Uphill, Downhill)
Other

PREHEAT (QW-406)

Preheat Temp. 50°F Min
Interpass Temp. 350°F Max
Other

POSTWELD HEAT TREATMENT (QW-407)

Temperature NA
Time
Other

GAS (QW-408)

Type of Gas or Gases NA
Composition of Gas Mixture
Other

ELECTRICAL CHARACTERISTICS (QW-409)

Current Direct
Polarity Reverse
Amps. 90-120 Volts 20-24
Travel Speed 4"/Min
Other

TECHNIQUE (QW-410)

String or Weave Bead String
Oscillation
Multipass or Single Pass Multipass per side
Single or Multiple Electrodes Single

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CATALYTIC, INC.
Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102

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RECORD OF PROCEDURE AND PERFORMANCE QUALIFICATION TESTS

Welding Specification No. SP-4200-SS(N)-102A

TENSILE TEST (QW 150)

SPECIMEN NO.	WIDTH	THICKNESS	AREA	ULTIMATE TOTAL LOAD LB.	ULTIMATE UNIT STRESS PSI	CHARACTER OF FAILURE & LOCATION
T-1	0.746	0.271	0.202	16,735	82,845	Base Metal
T-4	0.750	0.289	0.217	18,960	87,370	Base Metal

GUIDED BEND TESTS (QW 160)

TYPE AND FIGURE NO.	RESULT	TYPE AND FIGURE NO.	RESULT
2 Face	No Tears	3 Root	No Tears
5 Face	No Tears	6 Root	No Tears

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

Type of Test ASTM A-262-70 Practice E Susceptibility to Intergranular Attack

Deposit Analysis _____

Other No Intergranular Attack Noted - Toledo Testing Lab #401178

FILLET WELD TEST (QW-180)

0 331

Result - Satisfactory _____ Penetration into Parent Metal _____
Yes, No Yes, No

Type and Character of Failure _____ Macro-Results _____

Welder's Name Phillip Van Dyne SS #300-28-6748 Stamp No BUG

Tests conducted by Toledo Testing Lab., Inc Laboratory Test No. 401018

Original Signed By Gerald Herrig

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

Original Spec. No. SP-4200-SS(N)-100.05

Signed CATALYTIC, INC.
(Manufacturer)

Date 6/21/76 Original Signed By R. H. Oakes, Jr.

K Tam

37008/01-107SP

CATALYTIC, INC.
Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102

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Date: 7/30/79

RECORD OF PROCEDURE AND PERFORMANCE QUALIFICATION TESTS

Description of Welding Process
Manual Gas Tungsten Arc and
Shielded Metal Arc

Welding Specification No. SP-4200-SS(N)-102 A

JOINTS (QW-402)

Paragraph 10.02

Groove Design Used

BASE METALS (QW-403)

Material Spec. SA 240

Type or Grade Type 304

P No. 8 to P No. 8

Thickness 1"

Diameter Plate

Other Qualifies 3/16" to 2" range

FILLER METALS (QW-404)

Weld Metal Analysis A No. 8

Size of Electrode GTAW 3/32", SMAW 5/32"

Filler Metal F. No. 6 and 5

SFA Specification SFA5.9 & SFA5.4

AWS Classification ER 308 & E 308-16

Other

POSITION (QW-405)

Position of Groove 3G

Weld Progression Uphill
(Uphill, Downhill)

Other

PREHEAT (QW-406)

Preheat Temp. 50°F Min.

Interpass Temp. 350°F Max.

Other

POSTWELD HEAT TREATMENT (QW-407)

Temperature N/A

Time

Other

GAS (QW-408)

Type of Gas or Gases Argon

Composition of Gas Mixture 99.995%

Other Backing - Argon 99.995%

ELECTRICAL CHARACTERISTICS (QW-409)

Current Direct

Polarity GTAW Straight SMAW Reverse

Amps. GTAW-75-150 SMAW-90-160 Volts GTAW-10-14 SMAW-20-26

Travel Speed GTAW-4"/Min., SMAW-6-12"/Min

Other

TECHNIQUE (QW-410)

String or Weave Bead String

Oscillation NA

Multipass or Single Pass Multipass
per side

Single or Multiple Electrodes Single

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CATALYTIC, INC.
Centre Square West, 1500 Market Street, Philadelphia, Pennsylvania 19102

Sheet 22 of 22

Rev. 0

Date: 7/30/79

RECORD OF PROCEDURE AND PERFORMANCE QUALIFICATION TESTS

Welding Specification No. SP-4200-SS(N)-102 A

TENSILE TEST (QW-150)

SPECIMEN NO.	WIDTH	THICKNESS	AREA	ULTIMATE TOTAL LOAD LB.	ULTIMATE UNIT STRESS PSI	CHARACTER OF FAILURE & LOCATION
1	.496	.257	0.13	11,850	91,150	Ductile-HAZ
2	.498	.247	0.12	12,000	100,000	Ductile-Base Metal

GUIDED BEND TESTS (QW 160)

	TYPE AND FIGURE NO.	RESULT	TYPE AND FIGURE NO.	RESULT
Side	QW462.2(a)	Satisfactory	Side-QW462	2(a) Satisfactory
"	QW462.2(a)	Satisfactory		
"	QW462.2(a)	Satisfactory		

TOUGHNESS TESTS (QW-170)

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

Type of Test ASTM A-262-70, Practice E, Susceptibility to Intergranular Attack.

~~Deposit~~ Analysis Satisfactory using microexamination

Other

FILLET WELD TEST (QW-180)

Result – Satisfactory N/A Penetration into Parent Metal N/A

Type and Character of Failure Yes, No N/A Macro-Results Yes, No N/A

Welder's Name Ralph Tayman Clock No 67006 Stamp No 67006

Tests conducted by Value Engineering Lab. Laboratory Test No. VEL-296-77

Orig. signed per J. S. Hubacher

J. S. Hubacher, P.E. Assistant Laboratory Director

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

Signed Catalytic, Inc. (Manufacturer)

Date 25 January 1977 By KC Tabor

ATTACHMENT #5

Inter-Office Memorandum

Date: September 27, 1979

GPU Service

Subject: Evaluation of I.D. Buttering Technique to Minimize Weld HAZ Cracking, Lab No. 56052 (REVISION #1)

To: N. C. KAZANAS Location: Reading

In order to qualify a field welding procedure for joining 304L SS to 304 SS which would minimize the potential for intergranular stress corrosion cracking (IGSCC) in the 304 SS weld heat-affected-zone (HAZ), a sample was prepared for evaluation utilizing a proposed I.D. buttering technique. This sample consisted of two sections of 8" schedule 40 piping; one section 304 SS (HT.334165), the other section 304L SS (HT.83602000).

To one-half of the I.D. circumference of the 304 SS pipe a layer of ER308L SS (HT.760133) approximately 1/8" thick was deposited by the GTAW process to a width of approximately 1/2" (Figures 1 & 2). This deposit was applied at 8-10 volts, 80-95 amps. After this weld deposit had been applied, the joint geometry was then machined at this clad end. This section of pipe was then butt welded to the 304L SS pipe. The root pass was made by the GTAW process at 90 amps with argon gas backing. This pass was allowed to cool to ambient temperature at which time a second pass was made at 95 amps. When the interpass temperature had reached 120°F (this was the actual reading -- the spec required 300°F max. interpass temp.) a final cover pass was made by the SMAW process at 85-90 amps. Half this circumferential weld deposit was made with a weave bead and half with stringer beads (see sketch). This was done to assess the cover pass weld technique's effect on sensitization.

Metallurgical Evaluation

To evaluate the suitability of this welding procedure to minimize the propensity for IGSCC it was decided that the HAZ structures would be evaluated by the oxalic acid etch test (A262 prac. A) for the degree of sensitization. Metallographic specimens were prepared transverse to the butt weld from the four quadrants of the pipe. These specimens included the weld and both HAZ's. After the specimens were etched, the HAZ areas showing the highest degree of sensitization on the I.D. were photomicrographed.

Conclusion

The degree of sensitization in the HAZ adjacent to the I.D. weld clad is significantly less than that which has been observed to be associated with the current pipe cracking. Based on this observation, it appears that I.D. weld clad, deposited with good control on heat input, will be beneficial in minimizing the potential for IGSCC and therefore should be utilized when joining new spools of 304L SS to existing 304 SS pipe ends.

No difference in degree of sensitization at the I.D. was observed between the weave or stringer bead cover pass.

0 334

As would be expected, the 304L SS (.016% C) heat-affected-zones showed no evidence of sensitization, further supporting this material's use in the borated water environment.

F. SCOTT GIACOBBE

FSG:brk

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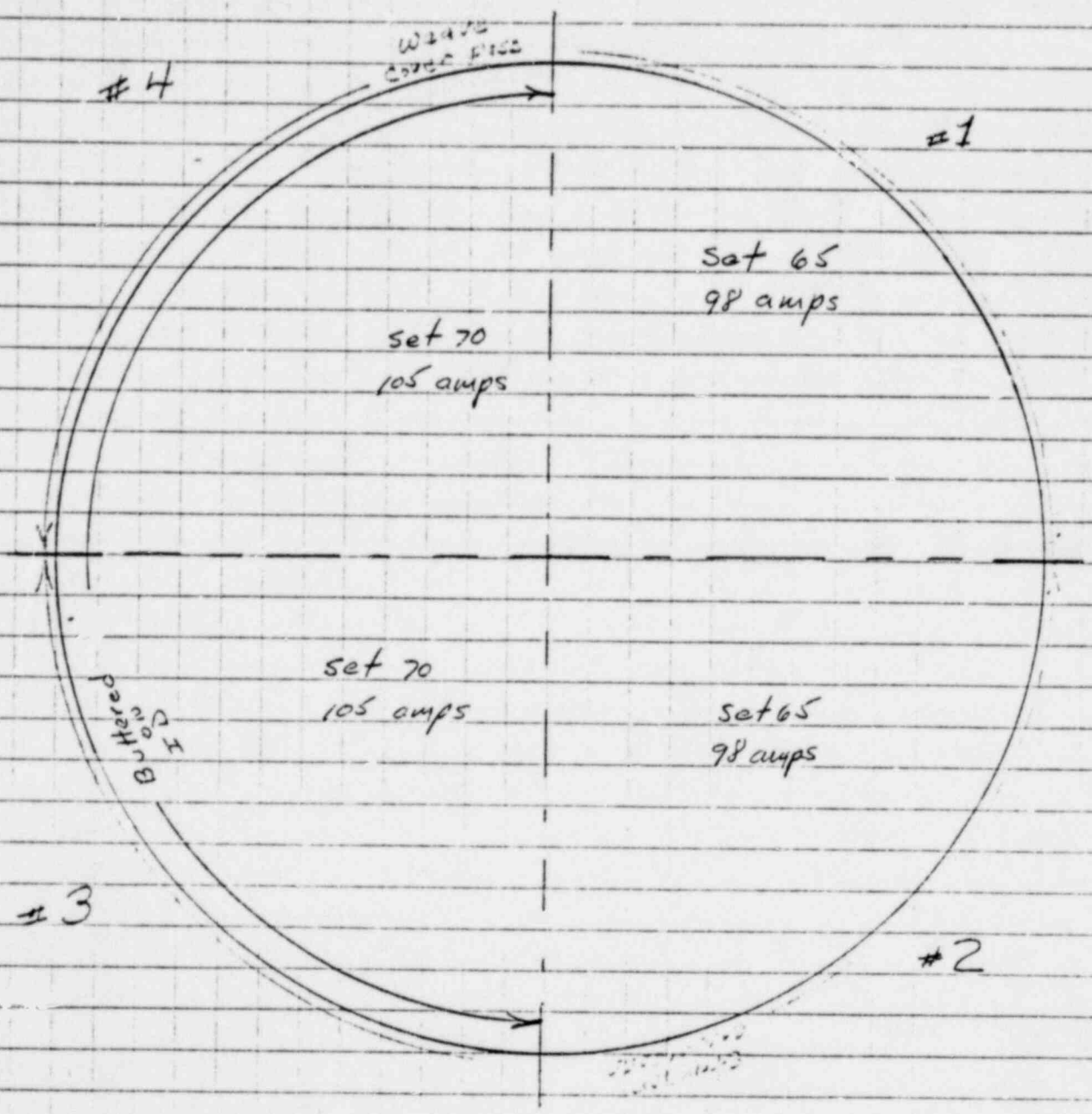

304 SS - 304L SS Butt Weld
GTAW Root SMAW Fill

0 336

CHEMISTRY

	HT. No. 334165	HT. No. 83602000
C	.080	.016
Mn	1.72	1.87
P	.028	.025
S	.014	.005
Si	.52	.45
Cr	18.46	18.45
Ni	8.60	10.10

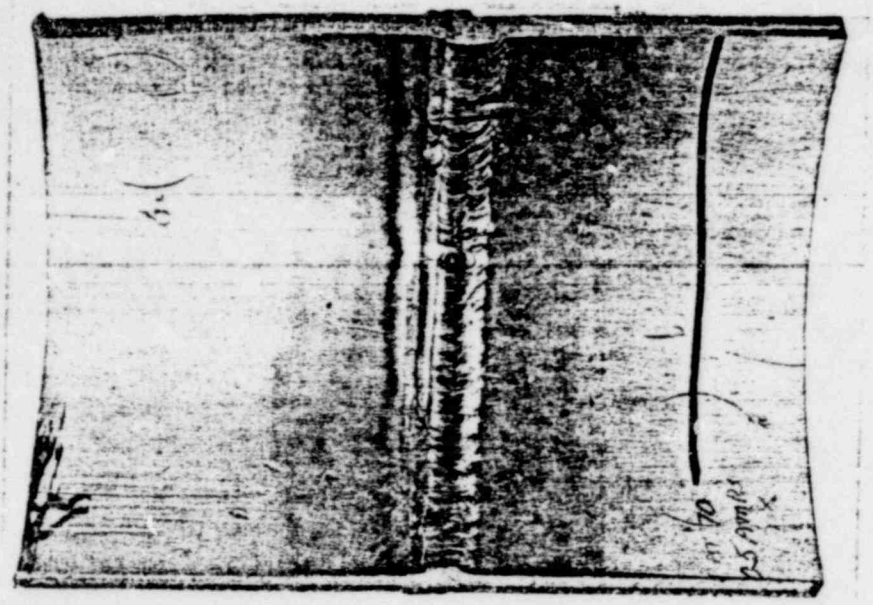

FIGURE I

Weld clad on ID surface on the 304 SS pipe end

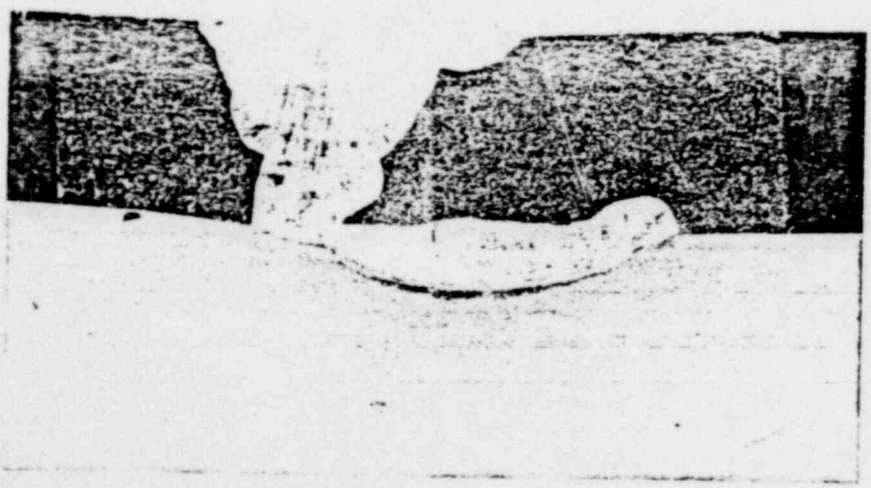

FIGURE 2

Photo showing butt weld plus I.D. weld clad

FIGURE 3

Sample #3
Mag 500X
Etch: Oxalic Acid
HAZ adjacent to
I.D. weld clad.
Step structure,
no ditching

FIGURE 4

Sample #3
Mag 500X
Etch: Oxalic Acid
304 L SS HAZ on
I.D. surface.
Step structure,
no ditching

FIGURE 5

Sample #4
Mag 500X
Etch: Oxalic Acid
HAZ adjacent to
I.D. Weld clad.
Step structure,
no ditching

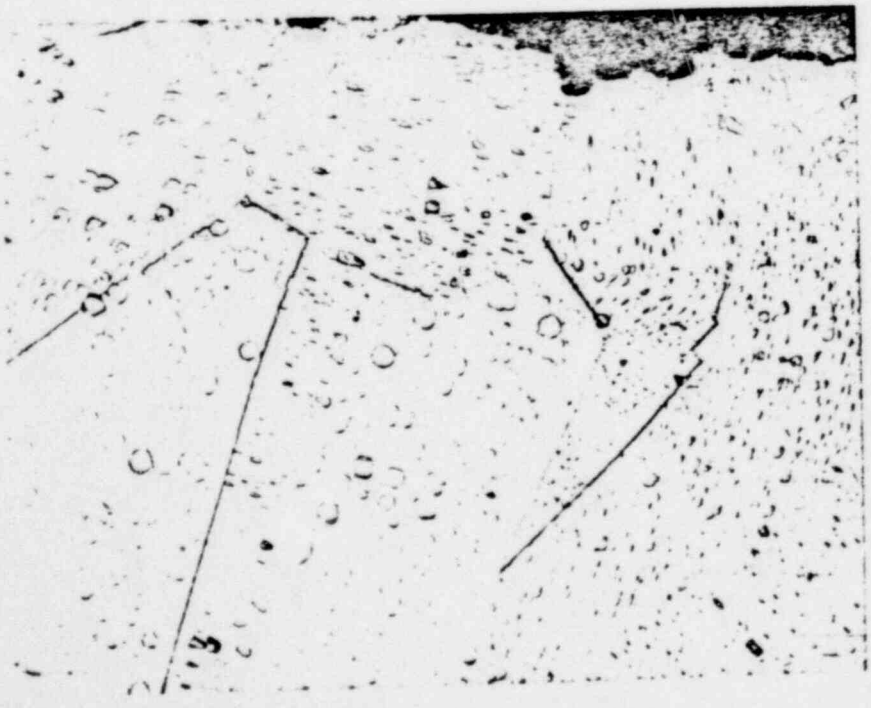

FIGURE 6

Sample #4
Mag 500X
Etch: Oxalic Acid
304 L SS HAZ on
I.D. surface.
Step structure,
no ditching

FIGURE 7

Sample #1
Mag 500X
Etch: Oxalic Acid
304 SS HAZ at I.D. surface. Step structure plus some ditching

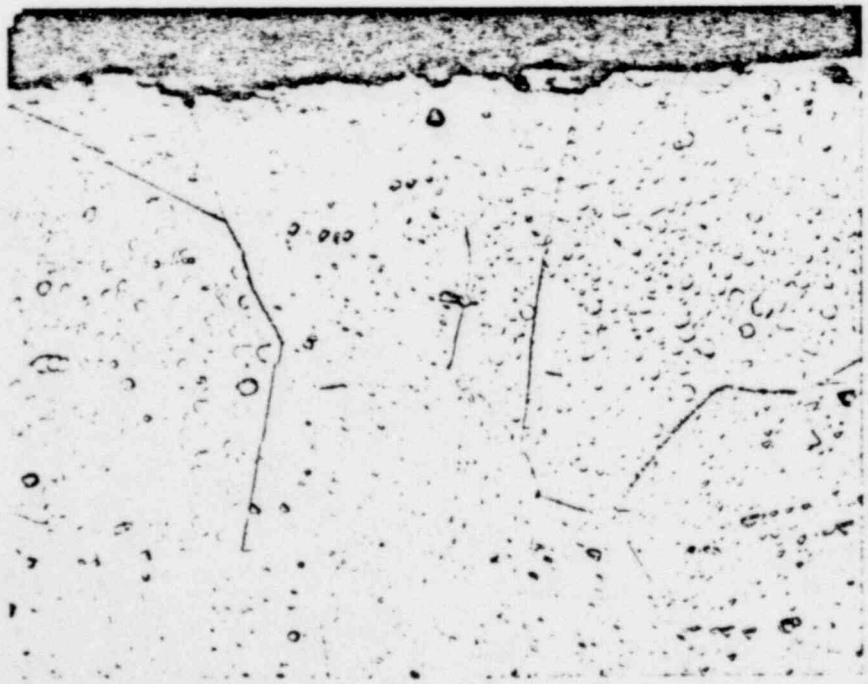

FIGURE 8

Sample #1
Mag 500X
Etch: Oxalic Acid
304 L SS HAZ at I.D. surface.
Step structure, no ditching

FIGURE 9

Sample #2
Mag 500X
Etch: Oxalic Acid
304 SS HAZ at I.D. surface. Step structure plus some ditching

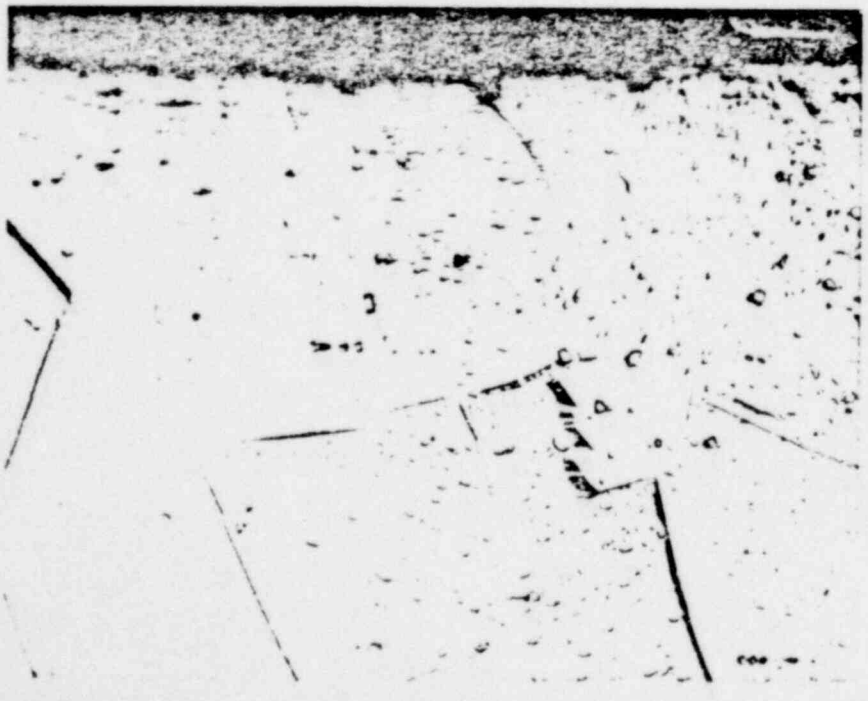

FIGURE 10

Sample #2
Mag 500X
Etch: Oxalic Acid
304 L SS HAZ at I.D. surface.
Step structure, no ditching