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DEVELOPMENT OF AUTOMATED WELDING PROCESS FOR FIELD FABRICATION OF THICK WALLED PRESSURE VESSELS

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MASTER

TASK I: (W R&D)

INTRODUCTION

A Review of Currently Available Welding Processes and Project Planning.

RESULTS FROM PRIOR QUARTERS

A thorough Project Planning review of the entire program was made to incorporate new development and technological updates to enhance the program.

An extensive Process Review of technical literature as specifically applied to this program examined current state-of-the-art of all heavy section welding processes and the accompanying welding metallurgy. A review paper was written of an analysis that included all aspects of each welding process.

DISCUSSION OF CURRENT ACTIVITIES

This task is complete.

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TASK II: (W R&D)

INTRODUCTION

The task's objective is the laboratory adaptation of the GTAW-HW narrow groove process to the vertical and horizontal welds of this program's materials. The process parameters developed in this adaptation also provide qualification data.

RESULTS FROM PRIOR QUARTERS

Sub-tasks such as R&D Facility Rearrangement, Materials Procurement, Torch and Shield Adaptation, Process Mechanical Control and NDT Evaluation are complete. These sub-tasks essentially verified prior conclusions.

Joint Design and Filler Wire Optimization, from the laboratory standpoint, are complete.

The recommended prep is a machined "U" groove of 6° included angle and 7/16 diameter bottom - the land thickness is dependent upon accessibility of the joint root backface for backchip and/or backweld or whether the joint requires guaranteed fusion without backchip.

Filler Wire Optimization has not been entirely satisfactory in that the physical properties of the deposit of commercial wire grades when used with this process appreciably overshoot the attainable physical properties of heavy section plate.

Special chemistry wire heats not only have long lead times but also long turnaround times for a chemical change. As a result, an acceptable but not ideal wire has been evaluated as the best commercial compromise. An idealistic wire heat to be delivered in May 1981 will be included in Task III (Full Section Process Refinement) work.

Sub-tasks Repair Techniques and Horizontal Parameters (4" qualification) will be completed under Task III for time expediency.

Although sub-task Vertical Parameters (down) has been completed and is now being tested, further work to evaluate Vertical (up) will be done under Task III.

DISCUSSION OF CURRENT ACTIVITIES

Westinghouse R&D reports the following laboratory results under Process Mechanical Control:

"It is recalled from the 8th Quarterly Progress report that in light of the back-gouging technique adapted in welding the SA 387 baseplates, the criteria for judging acceptable root parameters became:

(1) The ability to bridge over joint gaps and/or land mismatches.

(2) Deposit quality conducive to subsequent welding. Namely, the root pass should possess volumetric and surface quality which when welded over, will not cause welding difficulties and defects in the following welding passes.

(3) The deposit made with the root parameters must have sufficient "bulk" to sustain and conduct the arc force and heat inputs imposed by the following welding passes.

Involvement with the root pass parametric study soon made it clear that the capability to handle the possible variety of adverse root conditions cannot be derived from one set of welding parameters. Tables I through III show three sets of welding parameters developed for the vertical (3G) position. They were termed conservative, intermediate, and liberal sets.

The "conservative" set of root welding parameters was developed on a root conditional simulator for welding a 0.150 in. thick land. Due to the limited heat inputs and small deposit's cross-sectional area associated with these parameters, they are distinguished by their ability to handle extremely adverse root conditions. From Figure I through IV, the parameters are shown to be in obedience to the established criteria. With a competent welding operator, these parameters can be applied in a single pass to all abutting lands thicker than 0.100 in. For 0.150 in. lands or thicker, the parameters bridged over 0.100 in. root gap and 0.060 in. root gap combined with 0.105 in. land mismatch. On a land 0.100 in. thick, root gaps and/or land mismatches up to 0.125 in. and 0.100 in. were handled by multipass deposition with the conservative parametric set.

TABLE I

CONSERVATIVE ROOT WELDING PARAMETERS IN THE VERTICAL (3G) POSITION

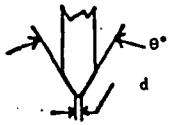
I_{DC}	171 amperes
V_{DC}	12.1 volts
S	10 ipm
W.F.R.	18 ipm
I_{AC}	13 amperes
Electrode Apparent Stick-Out	1 in.
Wire Stick-Out	1/2 in.
Preheat	250°F
	30°
	0.040 in.
Oscillation Frequency	220 c/min.
Gas Main Flow	80 CFH He 50 CFH Ar
Tip No.	7

TABLE II

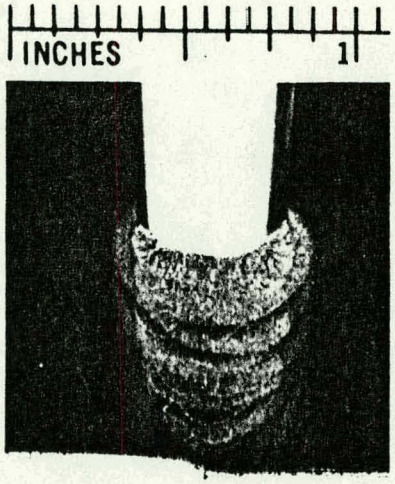
LIBERAL ROOT WELDING PARAMETERS IN THE VERTICAL (3G) POSITION

I_{DC}	230 amperes
V_{DC}	13 volts
S	8.5 ipm
W.F.R.	64 ipm
I_{AC}	52 amperes
Electrode Apparent Stick-Out	1 in.
Wire Stick-Out	1/2 in.
Preheat	250°F
θ°	22°
d	0.060 in.
Oscillation Frequency	220 c/min.
Gas Flow	80 CFH He 50 CFH Ar
Tip No.	7

TABLE III

INTERMEDIATE ROOT WELDING PARAMETERS IN THE VERTICAL (3G) POSITION

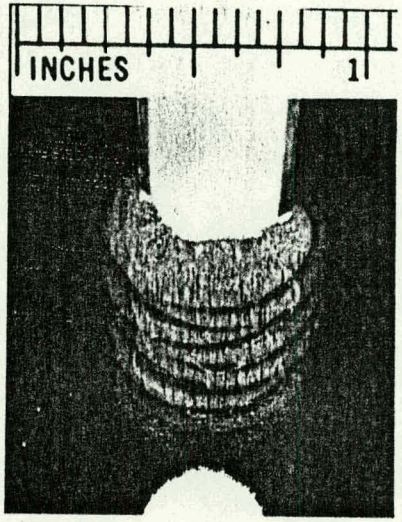
I_{DC}	250 amperes
V_{DC}	12.5 volts
S	10 ipm
W.F.R.	54 ipm
I_{AC}	37 amperes
Electrode Apparent Stick-Out	1 in.
Wire Stick-Out	1/2 in.
Preheat	250°F
θ°	22°
d	0.060 in.
Oscillation Frequency	220 c/min.
Gas Flow	80 CFH He 50 CFH Ar
Tip No.	7



Weld Location: Center
Root Gap: None
Misalignment: None

Cross section of weldment whose .100" thick root was bridged over with conservative parameter settings.

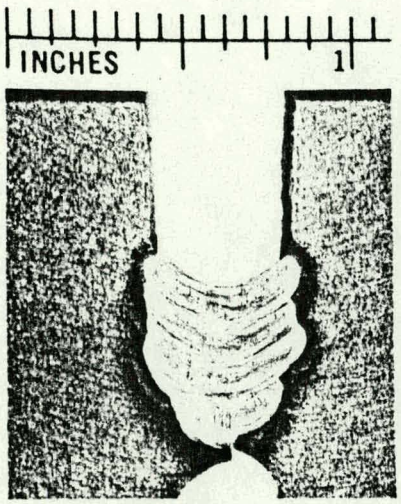
FIGURE I



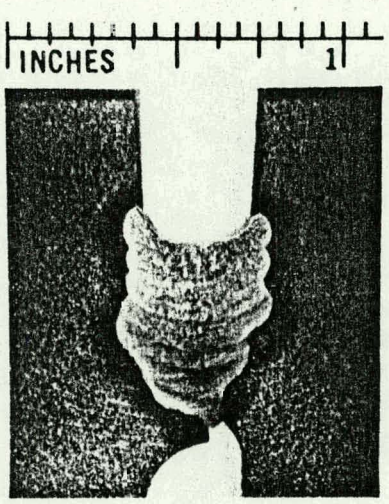
Weld Location: Center
Root Gap: None
Misalignment: None

Cross section of weldment whose .150" thick root was bridged over with conservative parameter settings.

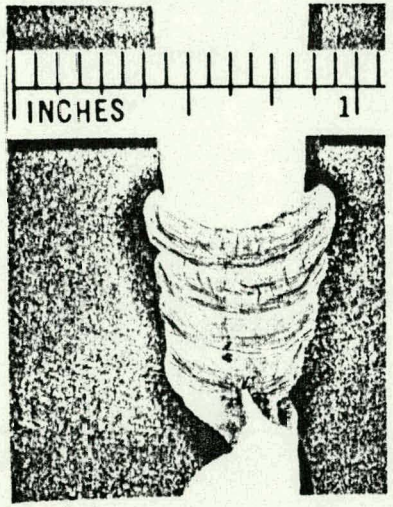
FIGURE II



Weld Location: Start
Root Gap: None
Misalignment: .012 in.



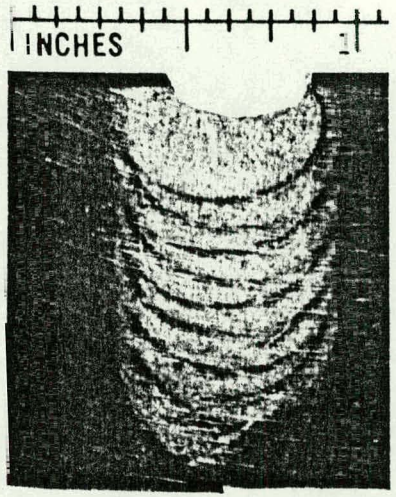
Weld Location: Center
Root Gap: .050 in.
Misalignment: .050 in.



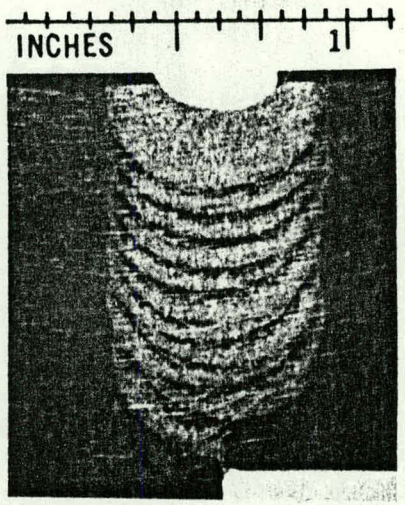
Weld Location: End
Root Gap: .111 in.
Misalignment: .091 in.

Cross sections of weldment whose .100" land was bridged over with conservative parameter settings.

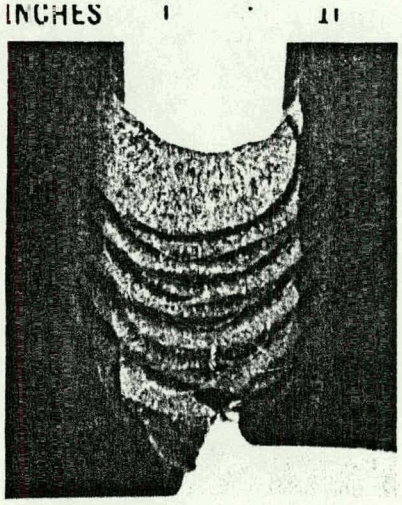
FIGURE III



Weld Location: Start
Root Gap: .014 in.
Misalignment: .016 in.



Weld Location: Center
Root Gap: .078 in.
Misalignment: .087 in.



Weld Location: End
Root Gap: .146 in.
Misalignment: .159 in.

Cross sections of weldment whose .150" land was bridged over with conservative parameter settings.

FIGURE IV

The root gap combined with a land mismatch impose the most extreme condition. Based upon the data and a 30% reduction of each bridgeable misalignment, it is safe to conclude that with a 0.150 in. land or thicker, a single pass made with the "conservative" parametric set would bridge over 0.042 in. root gap and 0.074 in. land mismatch. It is not recommended to machine lands thinner than 0.150 in.

The conservative set of root welding parameters is disadvantaged in its lack of operator-appeal and unattractive bead appearance. The present (R&D Lab) Merrick welding system is not designed to operate within these ranges. Consistent wire feed rate and I_{AC} wire preheating current are difficult to maintain while the system's pendant does not display below 35 amperes preheating current (I_{AC}).

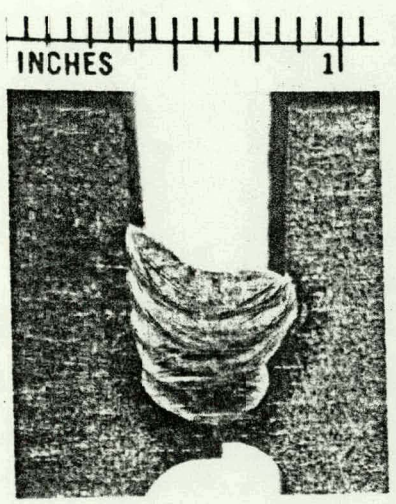
The liberal set of parameters are more adaptable to the present welding system and favored by the welding operator. Figures V through VI illustrate the bridgeability of a single pass made over a progressive root gap/land mismatch combined misalignment. These passes were made over a 0.150 in. land thickness. The same set of parameters was too troublesome on a 0.100 in. land thickness mock-up with a combined misalignment. As a result, an intermediate set of root welding parameters was developed.

Realizing that combined misalignment is the most extreme condition to be encountered about the root, from the data it can be deduced that for a 0.150 in. land, or thicker, a single pass with the "liberal" parameters would bridge over 0.105 in. root gap and 0.105 in. land mismatch.

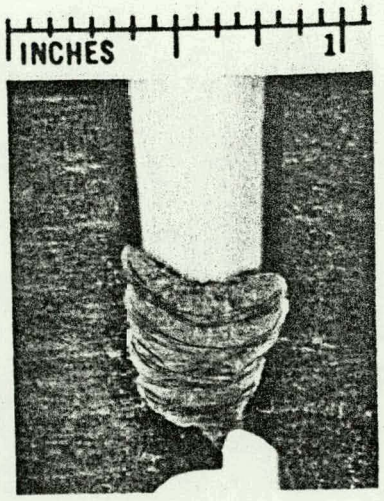
The intermediate root welding parameters are an option given to the operator and field welding engineer when root conditions dictate the need to choose between the conservative and liberal parametric sets.

To summarize:

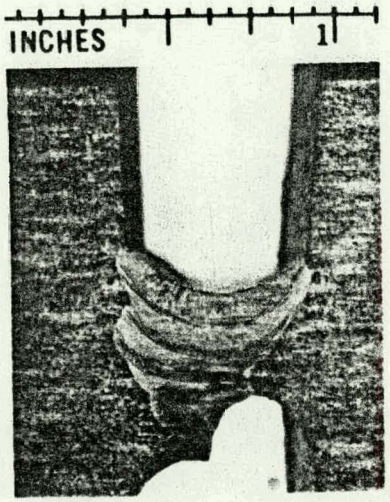
- The usage of lands thicker than 0.150 in. is highly recommended.
- The preference in a descending order will be employment of the liberal, intermediate and/or conservative root welding parameters. Note, however, that the final choice for any root



Weld Location: Start
Root Gap: .012 in.
Misalignment: .012 in.



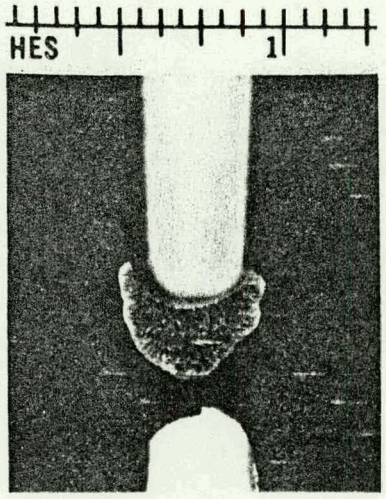
Weld Location: Center
Root Gap: .075 in.
Misalignment: .075 in.



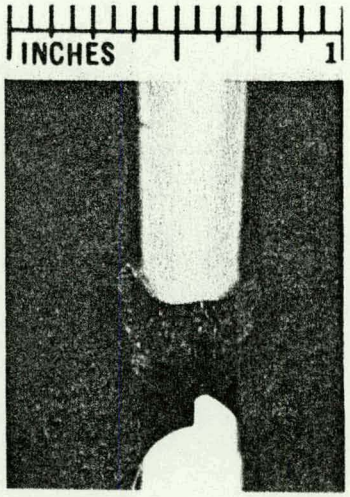
Weld Location: End
Root Gap: .137 in.
Misalignment: .137 in.

Cross sections of weldment whose .150" land was bridged over with liberal parameter settings.

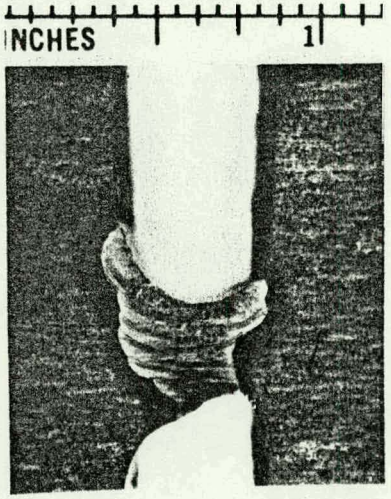
FIGURE V



Weld Location: Start
Root Gap: .012 in.
Misalignment: .012 in.



Weld Location: Center
Root Gap: .075 in.
Misalignment: .075 in.



Weld Location: End
Root Gap: .137 in.
Misalignment: .137 in.

Cross sections of weldment whose .100" land was bridged over with intermediate parameter settings.

FIGURE VI

condition should be made by consultation between the welding operator and the field welding engineer.

. In very extreme root conditions (e.g., large root gap), the conservative parametric set combined with the liberal parametric set can be applied by multi-pass bead deposition."

Sub-Task Joint Design Evaluation conclusions:

". A joint land thickness of 0.150 in. is the minimum recommended.

. Based upon the root welding parametric sets established in the vertical (3G) welding position, application of pulsing does not appear advantageous anymore.

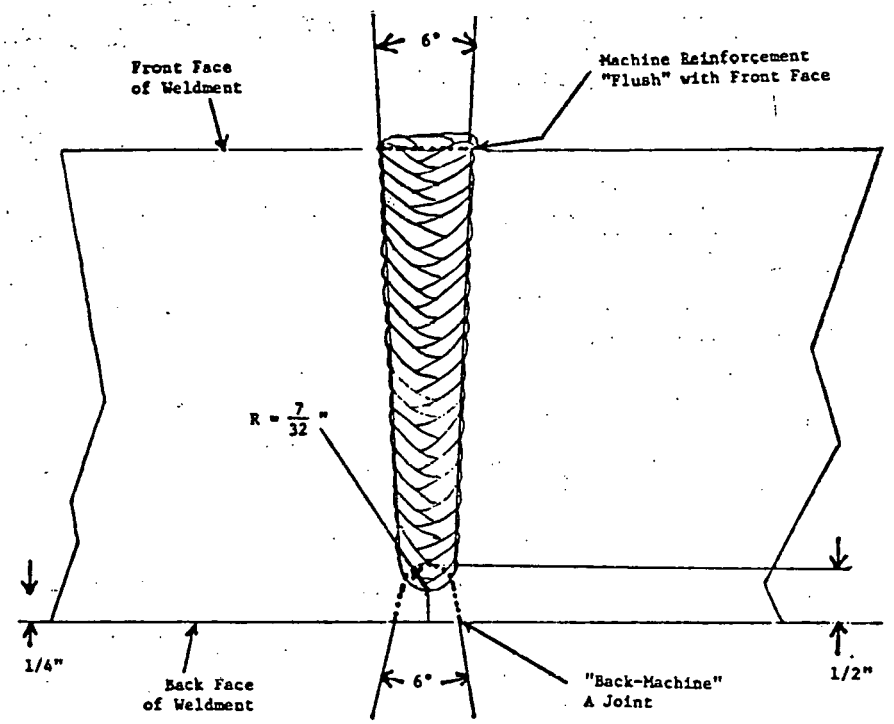
. Because of the back-gouging technique adapted in welding the SA 387 baseplates, 100% root fusion without backchip was not pursued."

Under Sub-Task Vertical Position Parameters/Non-Destructive Evaluation, the following was reported:

"After strongback removal, back-machining a joint from the back face of the weldment (Figure VII), dye penetrant inspection and machining the weld's reinforcement flush with the front face of the weldment (Figure VII), the back joint was welded.

Table IV gives the welding parameters used in welding the back joint in the pedigree baseplates. Strict adherence to those conditions is insufficient to assume a successful welding operation. The judgment of a skilled operator is an integral part of this effort.

After the back-weld was completed, the weld's reinforcement was machined flush with the back face of the weldment (Figure VII), and the weldment was postweld stress-relieved and submitted for radiographic inspection. Once the weldment and radiographs are returned to the R&D Center, Mr. Claude Galyen will review them and supervise the final ultrasonic inspection of the assembly. Mr. Galyen is an NDE Level III inspector contracted by the Tampa Plant. Following the non-destructive tests, specimens for mechanical testing will be removed."



Machining steps on the qualifying weldment.

FIGURE VII

TABLE IV

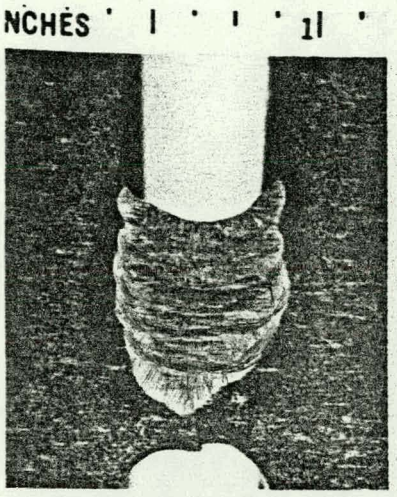
MASTER COLLECTION OF WELDING CONDITIONS

Run No	Start Date	Completion Date	Process	Polarity	Tungsten Dia. In.	Gas Composition	Preheat Temp. °F	Interpass Temp. °F	Welding Position	Baseplates Type	Baseplates Code Certified	Baseplates Practice Non-Certified	Wire Type	Wire German (BOHLER)	Wire Japan (KOBE)	Wire U.S.A.	Wire In.	Baseplates Thickness In.	Joint Type 1-Sided	Joint Type 2-Sided	Incl. Angle	Root Radius In.	Land Thickness In.	Operator
7 [illegible]	11-15-80	10-15-80	NGHWT	STR	3/16 .. [illegible] TO 1/4	75% He 25% Ar	~250	~250	3G ↓	SA 387	2 1/4 Cr 1 Mo				[illegible] 9F05W1 (2621)		.0456	4	✓		6°	7/32	—	[illegible]

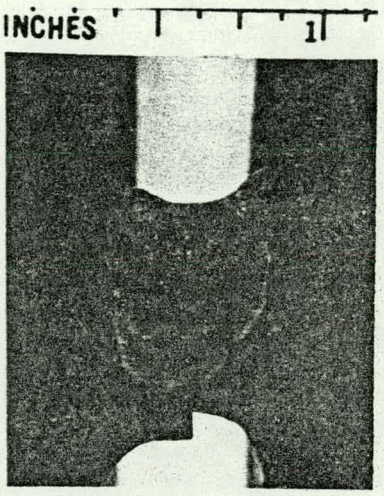
Pass No.	Wall Favored ① Top/Right	Wall Favored ① None	Wall Favored ① Bottom/Left	Joint Side ② F	Joint Side ② B	Joint Side ② O	Apparent Stick-out In.	D.C. Amps.	D.C. Volts	Travel Speed IPM	WFR IPM	A.C. Amps.	A.C. Volts	Wire Stick-out In.
1		X			X	X	5/8	400	13.5	13	100	137	1.9	1/4
2	X						5/8	400	13.5	13	100	135	1.8	1/4
3			X				5/8	400	13.9	13	102	135	1.9	1/4
4	X						5/8	400	13.5	13	100	135	1.9	1/4
5			X				5/8	400	13.5	13	100	135	1.9	1/4
6	X						5/8	400	13.4	13	100	135	2.2	1/4
7			X				5/8	400	13.4	13	100	134	2.1	1/4
8	X						5/8	400	13.3	13	100	133	2.3	1/4
9			X				5/8	400	13.4	13	100	122	2.3	1/4
10	X						5/8	400	13.4	13	100	133	2.4	1/4
11		X					5/8	400	13.4	13-15	100-90	134	2.1	1/4
12		X					5/8	400	13.3	15	90	133	2.0	1/4
13		X					5/8	400	13.4	15	80	133	2.1	1/4
14		X					5/8	400	13.5	15-16	80-70	134-129	2.2	1/4
15		X					5/8	400	13.4	16-16.5	70	125	2.2	1/4
16			X				5/8	400	13.4	16.5-19	70-45	140-110	1.9	1/4
17	X						5/8	400	13.9	19	35	105	1.8	1/4
18			X				5/8	345	12.9	19	35	105-100	1.8	1/4
19	X						5/8	345	12.9	19-18.5	35	100	1.8	1/4
20			X				5/8	345	12.8	18.5	35	100	1.8	1/4
21	X				↓	↓	5/8	345	12.8	18.5	35	100	1.8	1/4

Pass No.	Oscillation ① Freq. Cycle/Min.	Oscillation ① Displace In.	Dwell Top/Right Sec.	Dwell Bottom/Left Sec.	Torch Attitude ③ Top/Right	Torch Attitude ③ Bottom/Left	Approximate Tip-Wall-Distance Top/Right	Approximate Tip-Wall-Distance Bottom/Left	Tip No. 7	Tip No. 8	Tip No. 9	Tip No. 10	Gas Flow Rate C.F.H.
1	220		0	0	–	–						X	145
2	220				10°							X	145
3	220					10°						X	145
4	220				10°							X	145
5	220					10°						X	145
6	220				10°							X	145
7	220					10°						X	145
8	220				7°							X	145
9	220					7°						X	145
10	220				7°							X	145
11	220				–	–						X	145
12	220				–	–						X	145
13	220				–	–						X	145
14	220				–	–						X	145
15	220				–	–						X	145
16	220				–	–						X	145
17	220				–	–						X	145
18	220				–	–						X	145
19	220				–	–						X	145
20	220				–	–						X	145
21	220		↓	↓	–	–						X	145

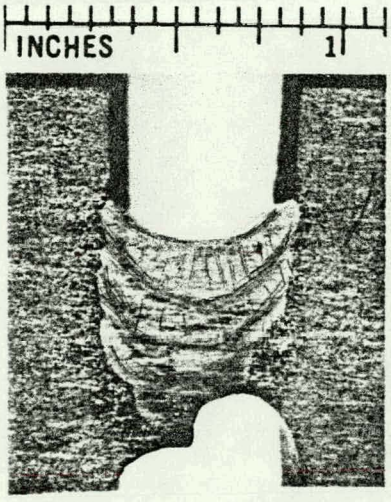
Pass No.	Bead Evaluation: Feathering None	Feathering Some	Feathering Extensive	Appearance ④ Poor	Appearance ④ Fair	Appearance ④ Good	Surface Defects Open Porosity	Surface Defects Slag Imbedments
1						✓		
2						✓		
3						✓		
4						✓		
5						✓		
6						✓		
7						✓		
8						✓		
9						✓		
10						✓		
11						✓	MADE ADJUSTMENTS DURING PASS	
12						✓	PARTIAL PASS ([illegible] OF WELD)	
13						✓		
14						✓		
15						✓		
16	NO ANGLE ON TORCH BUT RAN ALONG LEFT WELD SEAM							[illegible]
17	90 CPH [illegible] 55 CPH [illegible] THIS & ALL OTHER PASSES					✓	[illegible]	[illegible]
18	PARTIAL DOWN LEFT SEAM [illegible]					✓		VERY CLEAN
19						✓		VERY CLEAN
20						✓		"
21						✓		"



Weld Location: Start
Root Gap: .017 in.
Misalignment: .017 in.



Weld Location: Center
Root Gap: .083 in.
Misalignment: .083 in.



Weld Location: End
Root Gap: .172 in.
Misalignment: .172 in.

Cross sections of weldment whose .150" land was bridged over with liberal parameter settings.

FIGURE VIII

TASK III: (WTP)

INTRODUCTION

Perform 8" thick field demonstration/qualification welds in the vertical and horizontal positions.

RESULTS FROM PRIOR QUARTERS

Sub-tasks Material Procurement and Plan for Demonstration Facility have been completed.

All program material was ordered and delivered to a detailed specification. This specification guaranteed compliance to all contact and code requirements.

Planning for the demonstration facility included development of equipment concept sketches and functional specifications. The equipment was designed to encompass essentially all components and functions of the demonstration weld.

Sub-tasks Demonstration Facility, PWHT Facility Proof Test, and Filler Wire Procurement are either nearing completion or have specifications and purchase orders issued.

DISCUSSION OF CURRENT ACTIVITIES

Sub-task Demonstration Facility has had two design reviews of the equipment under design and fabrication--both of these at the vendor's facility. Continuing input to the design is being made.

Sub-task PWHT Facility Proof Test has specifications written that have been sent out on an RFQ. Quotations are presently coming in.

Under sub-task Filler Wire Procurement, a new chemistry concept of filler wire design has been specified and ordered. Limited quantity will be delivered in May 1981.

Limited activity is progressing in sub-tasks Full Section Parameters Refinement and in Field Site Preparation prior to the delivery of the equipment involved in each of these.

Initial evaluation of full section parameters are being made by simulating 8" to 12" thick grooves fabricated from 4" plate. The size of these assemblies are kept light so that they can be handled on the existing WTP Weld Laboratory bench model welder.

All required services of sub-task Field Site Preparation have been provided or scheduled with the exception of verification of PWHT power requirements.

TASK IV: (WTP)
WELDING PROCEDURE HANDBOOK

INTRODUCTION

The handbook will include, for each of the weld positions, the final recommended procedure and parameters. Base material, weld wire and gas specifications as well as PWHT and NDT procedures referenced in the weld procedure will be provided. There will also be included an equipment operating instruction and troubleshooting manual.

RESULTS FROM PRIOR QUARTERS

Base material and shield gas specifications as well as NDT procedures (UT and RT) are complete.

DISCUSSION OF CURRENT ACTIVITIES

No final activity is currently being done--only intermediate steps previously discussed under the various sub-tasks.