Title

CONTRACT NO. DE-AC05-78OR13511
DEVELOPMENT OF AUTOMATED WELDING PROCESS FOR
FIELD FABRICATION OF THICK-WALLED PRESSURE VESSELS

DOE/ET/13511--T7

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WESTINGHOUSE ELECTRIC CORPORATION
NUCLEAR EQUIPMENT DIVISION
TAMPA, FL 33616

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 on an analysis that included all aspects of each welding process.

DISCUSSION OF CURRENT ACTIVITIES

This task is complete.

MGW

DISCLAIMER

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 turnaroundtimes for a chemical change. As a result, an acceptable but not ideal wire has been evaluated as the best commecial compromise. An idealistic wire heat delivered in July 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.

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

"This test plate has been welded, UT'd, x-rayed, PWHT'd and destructive tested. The test results are recorded in this report attachment "TQ 339"--the Westinghouse Tampa format for the Section IX required PQR. This PQR documents all contract and code required data for sub-task 2.12, 4" thick 3G-down, procedure qualification.

DISCUSSION OF CURRENT ACTIVITIES

No further work on these sub-tasks under Task II is intended with the exception of the Final Task Report.

TASK III: (WTP)

INTRODUCTION

Peform 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 contract and code requirements.

Planning for the demonstration facility include 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 Tests, and Filler Wire Procurement are either nearing completion or have specifications and purchase order issued.

Sub-tasks Demonstration Facility has had the welding equipment completed, proof tested at the vendor and delivered to Tampa in July. However, modifications required as a result of structural problems has delayed operation of the equipment. This equipment will be operational approximately August 1.

The contract for sub-task PWHT Facility Proof Test has been awarded to a vendor. His PWHT specification has been written and approved. His equipment is on site for the demonstration welds.

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 July 1981.

All required services of sub-task Field Site Preparation have been provided.

DISCUSSION OF CURRENT ACTIVITIES

The welding equipment of the sub-task Demonstration Facility is being modified, reassembled and checked out.

Destructive testing of the 4" 2G qualification plate is almost complete.

A 3G-up 4" qualification plate has been welded PWHT'd, UT'd and x-rayed. Destructive testing has just started.

TASK IV: (WTP)
WELDING PROCEDURE HANDBOOK

INTRODUCTION

The handbood 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, shield gas and PWHT specifications, as well as NDT procedures (UT and RT) are complete.

DISCUSSION OF CURRENT ACTIVITIES

The Operator's Manual (including operating instructions and trouble shooting) is drafted and under review.

The first of five intended PQR's (TQ 339) is attached to this report.

The Process Specification draft is near completion.

WELDING PROCEDURE QUALIFICATION RECORD

GAS TUNGSTEN ARC-HOT WIRE WELDING OF 2¼CR-1MO STEEL

R. Nelson

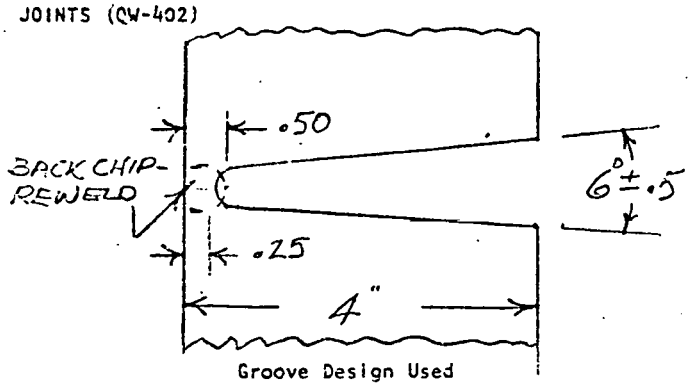
CHANGED

WPS NO. NPT 101

WELDING PROCESS(ES) GTAW-HW

TYPES Automatic
(Manual, Automatic, Semi-Automatic)

JOINTS (QW-402)



Groove Design Used

BASE METALS (QW-403)

Material Spec. SA 387

Type or Grade 22, CL. 2

P No. 5, Gp1 to P No. 5, Gp1

Thickness 4"

Thickness Range this test qualifies 3/16" - 8"

(W) Specification 2652A59

FILLER METALS (QW-404)

Weld Metal Analysis A No. 4

Size of Electrode Tungsten-3/16", Wire-.045"

Filler Metal F No. 6

SFA Specification A5.28

(W) Specification 2654A05

AWS Classification ER90S-B (Modified)

Other Trade designation--KOBE MGS-2GM
Heat #9F0561. WFS = 40/137 ipn

FLUX

Flux Trade Name or Composition N/A

(W) Specification -

AWS Classification -

Other -

POSITION (QW-405)

Position of Groove 3G

Weld Progression Downhill
(Uphill, Downhill)

Other

PREHEAT (QW-406)

Preheat Temp. 200-300°F

Interpass Temp 200-300°F (During Welding)

Other 200-500°F (No welding underway)

GAS (QW-408) (Front) DC Torch--36/109CFH He/Ar
(Backchip)

Type of Gas or Gases DC Torch -50/80-CF He/Ar

Composition of Gas Mixture 75% He--25% Ar

(W) Specification 2652A67

Gas Nozzle Size W #7

POSTWELD HEAT TREATMENT (QW-407)

Temperature 1275°F ± 25

Time 24 Hours

Other 75°F/hr. Heating/cooling rate

TECHNIQUE (QW-410)

String or Weave Bead weave

Back-chip/reweld Yes, (1/2" depth)

Multipass or Single Pass Multipass
(per side)

Single or Multiple Electrodes Single

Travel Speed 10-19 ipm

Oscillation:

Frequency 220 cpm

Displacement 1/8" (total)

Dwell (bot.edge, bot.bead) None

ELECTRICAL CHARACTERISTICS (QW-409)

Current DC-Tungsten; AC-Wire

Polarity DCSP (Tungsten electrode)

Amps. (DC) 275/400 (AC) 66/133

Volts (DC) 12.5/13.5 (AC) 0.7/2.3

Other

WELDING PROCEDURE QUALIFICATION RECORD
GAS TUNGSTEN ARC-HOT WIRE WELDING OF 2¼CR-1MO STEEL

ISSUE 1
8/4/81

R.Nelson

CHANGED

TENSILE TEST (QW-150)

SPECIMEN NO.	DIMENSIONS WIDTH	DIMENSIONS THICKNESS	AREA	ULTIMATE TOTAL LOAD, LB	ULTIMATE UNIT STRESS, PSI	CHARACTER OF FAILURE AND LOCATION
#4 - Tranverse					81,685	Ductile-base
#14 - Tranverse	See attached table				80,120	" "
#6 - Long					86,030	Ductile-weld
#16 - Long					84,048	" "

GUIDED BEND TESTS (QW-160)

TYPE AND FIGURE NO.	RESULT	TYPE AND FIGURE NO.	RESULT
QW462.2A #2	Acceptable	WQ462.2A #11	Acceptable
" #8	"	" #18	"

TOUGHNESS TESTS (QW-170)

SPECIMEN NO.	DROPWEIGHT TEST TEMP. * BREAK	DROPWEIGHT TEST TEMP. * NO BREAK
#10 (weld)	-	+60°F
#10 (haz)	-	"
#13 (weld)	-	"
#13 (haz)	-	"
* Contract requirement		

SPECIMEN NO.	NOTCH LOCATION	NOTCH TYPE	TEST TEMP.	IMPACT VALUES	LATERAL EXP. % SHEAR	LATERAL EXP. MILS
3-1	Weld	45°V	+60°F	130	70	.84
3-2	Weld	"	"	109	55	.071
3-3	Haz	"	"	239	100	.091
9-1	Weld	"	"	133	70	.083
9-2	Weld	"	"	125	70	.085
9-3	Haz	"	"	227	100	.072
12-1	Weld	"	"	116	55	.086
12-2	Weld	"	"	100	45	.075
12-3	Haz	"	"	234	100	.081

RT_{NDT} = --- °F

Chemical Analysis

C--.082
Mn--1.010
P--.011
S--.008
Cr--2.290
Si--.480
Ni--.010
Mo--1.050

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 G. J. Fechko, R. D. O'Brokta Clock No. _____ Stamp No. _____

Who by virtue of these tests meets welder performance requirements.

Test Conducted by Materials & Joining W R & D Lab Laboratory-Test No. TQ 339 Per I. Stol

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 WESTINGHOUSE ELECTRIC CORPORATION (Manufacturer)

Date 7/30/81 By _____

Westinghouse Electric Corporation
Tampa Division Nuclear Energy Systems
Tampa, Florida, U. S. A.

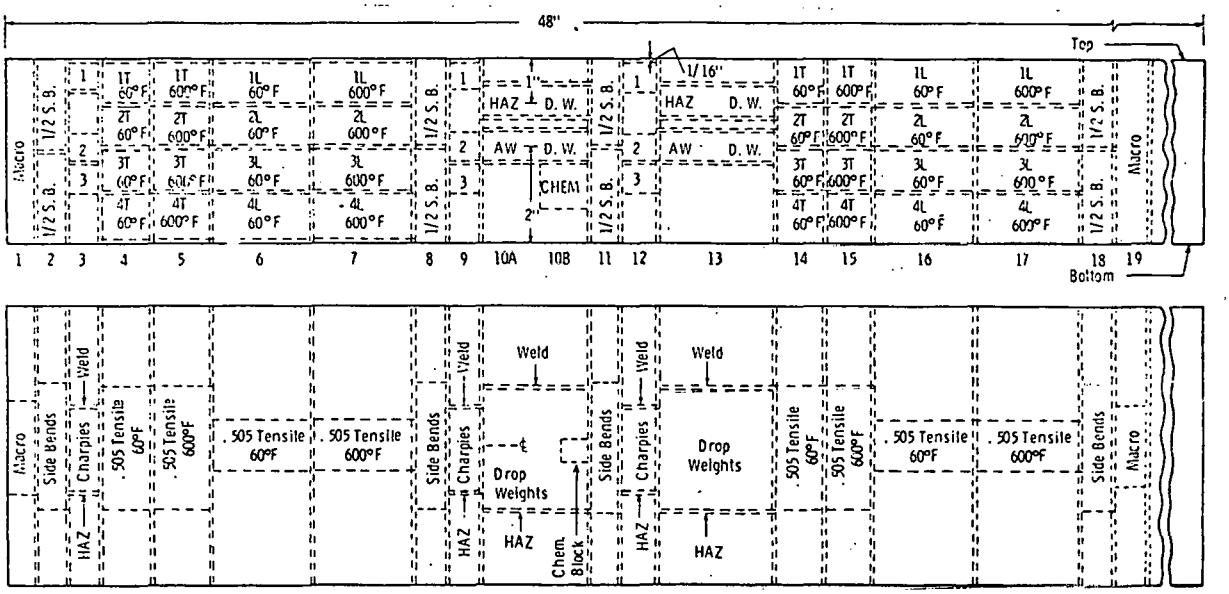
INSPECTION AND TESTING

A. Nondestructive Examination

1. Postwelding radiography (Tasks 2.8 and 2.12) - result, acceptable.
2. UT examination following deposition of every few weld passes and after PWHT of completed joint (Tasks 2.8 and 2.12) - result, acceptable.
3. Dye-penetrant inspection of back-joint machined into "front" weld deposit - result, acceptable.

B. Destructive Testing

1. Eight transverse tensile specimens, tested at 60°F - result, acceptable.
2. Eight longitudinal tensile specimens, tested at 60°F - results, acceptable.
3. Eight transverse tensile specimens, tested at 600°F for information only.
4. Eight longitudinal tensile specimens, tested at 600°F for information only.
5. Two drop weight specimens, notched about the weld and tested at 60°F - results, acceptable.
6. Two drop weight specimens, notched about the HAZ and tested at 60°F - results, acceptable.
7. Six Charpy V-notch specimens, notched in the weld and tested at 60°F - results, acceptable.
8. Three Charpy V-notch specimens, notched in the HAZ and tested at 60°F - results, acceptable.
9. Chemistry of weld was determined.
10. Cross-sectional macrograph.



Sampling layout for weld procedure qualification.

WELDING PROCEDURE QUALIFICATION RECORD

Tensile Test (QW-150)*

Specimen No.	Temp. °F	Dia. In.	Area In.^{2}	Ultimate Total Load, Lb.	Ultimate Unit Stress, psi	Yield, psi .2% Offset	Elongation % in 2 In.	Reduction of Area,%	Failure Type
4-1T	60	0.505	0.200	16,370	81,730	58,910	28.6	76.3	Ductile/Base
4-2T	60	0.504	0.199	16,250	81,450	59,150	25.0	76.2	"
4-3T	60	0.505	0.200	16,360	81,680	59,660	26.2	79.3	"
4-4T	60	0.505	0.200	16,400	81,880	59,410	27.4	77.1	"
14-1T	60	0.504	0.199	15,790	79,150	55,140	27.6	76.6	"
14-2T	60	0.505	0.200	16,040	80,080	56,520	28.5	78.2	"
14-3T	60	0.504	0.199	16,100	80,700	57,540	27.8	76.6	"
14-4T	60	0.504	0.199	16,070	80,550	57,390	28.7	76.9	"
6-1L	60	0.503	0.198	17,010	84,580	68,620	25.7	68.9	Ductile/Weld
6-2L	60	0.504	0.199	17,140	85,910	71,180	26.7	71.7	"
6-3L	60	0.503	0.198	17,150	86,660	71,850	26.1	71.5	"
6-4L	60	0.502	0.198	17,280	86,970	71,970	25.8	71.2	"
16-1L	60	0.503	0.198	16,350	82,280	64,670	29.6	72.0	"
16-2L	60	0.504	0.199	16,780	84,110	68,670	27.3	72.4	"
16-3L	60	0.503	0.199	16,790	84,500	68,690	26.5	71.2	"
16-4L	60	0.502	0.198	16,880	85,300	69,730	26.9	73.2	"

SIXTEEN ADDITIONAL TENSILES, NOT CODE REQUIRED,
TAKEN FOR INFORMATION ONLY

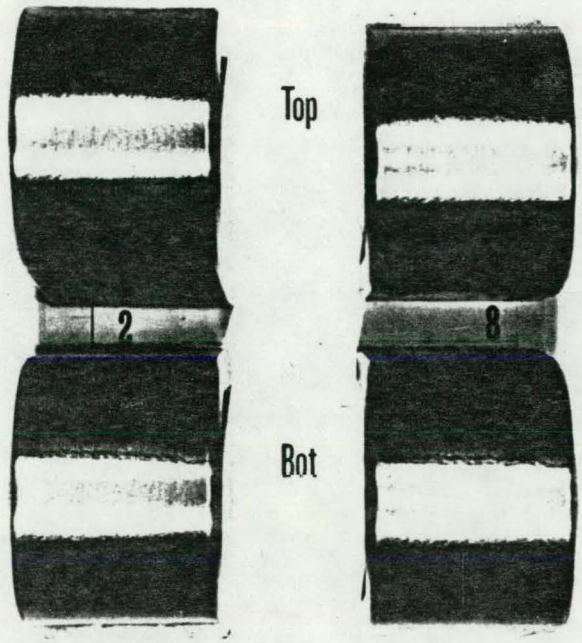
Tensile Test (QW-150)*

Specimen No.	Temp. °F	Dia. In.	Area In.^{2}	Ultimate Total Load, Lb.	Ultimate Unit Stress, psi	Yield, psi .2% Offset	Elongation % in 2 In.	Reduction of Area,%	Failure Type
5-1T	600	0.506	0.200	13,330	67,280	49,230	21.1	76.0	Ductile/Base
5-2T	600	0.505	0.200	13,400	66,900	49,930	21.5	77.8	"
5-3T	600	0.505	0.200	13,390	66,850	49,930	20.8	76.3	"
5-4T	600	0.505	0.200	13,610	67,950	49,930	22.5	75.5	"
15-1T	600	0.505	0.200	13,020	65,000	46,180	22.8	75.9	"
15-2T	600	0.504	0.199	13,230	66,320	47,620	21.5	71.3	"
15-3T	600	0.504	0.199	13,180	66,070	48,120	21.4	75.8	"
15-4T	600	0.503	0.198	13,150	66,180	48,060	22.4	75.3	"
7-1L	600	0.503	0.198	14,030	70,610	57,120	21.1	68.1	Ductile/Weld
7-2L	600	0.504	0.199	14,240	71,380	59,150	20.8	69.1	"
7-3L	600	0.501	0.197	14,410	73,100	59,860	19.3	65.3	"
7-4L	600	0.502	0.198	14,450	73,020	60,030	21.0	68.9	"
17-1L	600	0.504	0.199	14,040	70,380	56,140	21.4	71.7	"
17-2L	600	0.502	0.198	14,120	71,350	58,810	20.5	71.1	"
17-3L	600	0.506	0.200	14,340	71,310	58,730	21.0	67.2	"
17-4L	600	0.503	0.198	14,370	72,320	59,490	21.1	69.5	"

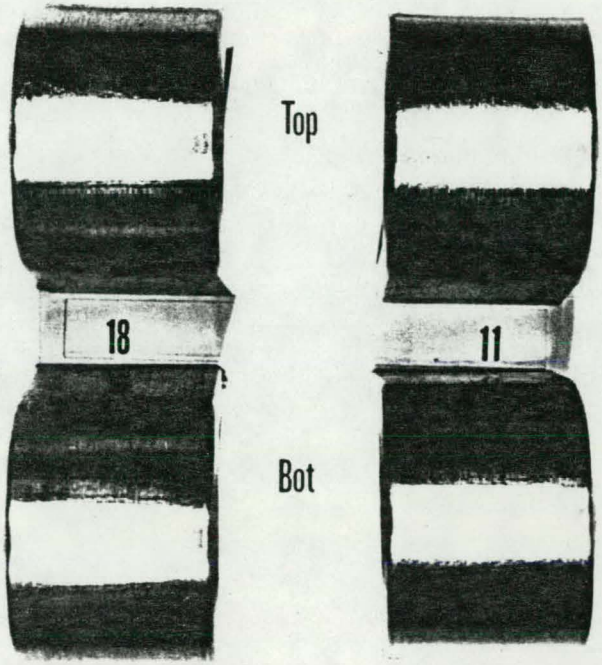
WELDING PROCEDURE QUALIFICATION RECORD
GAS TUNGSTEN ARC-HOT WIRE WELDING OF 2¼CR-1MO STEEL

Issue
3/4/81

R.Nelson
Changed



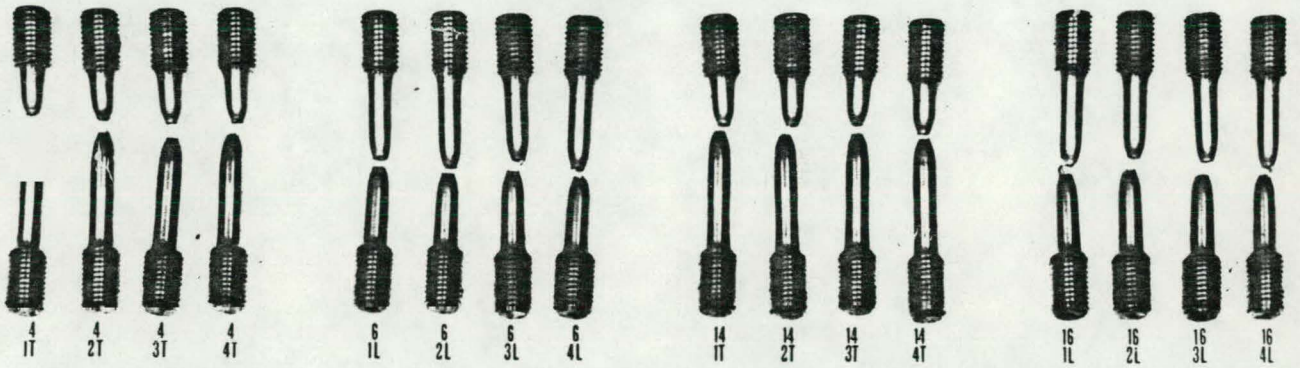
Side Bend Specimens



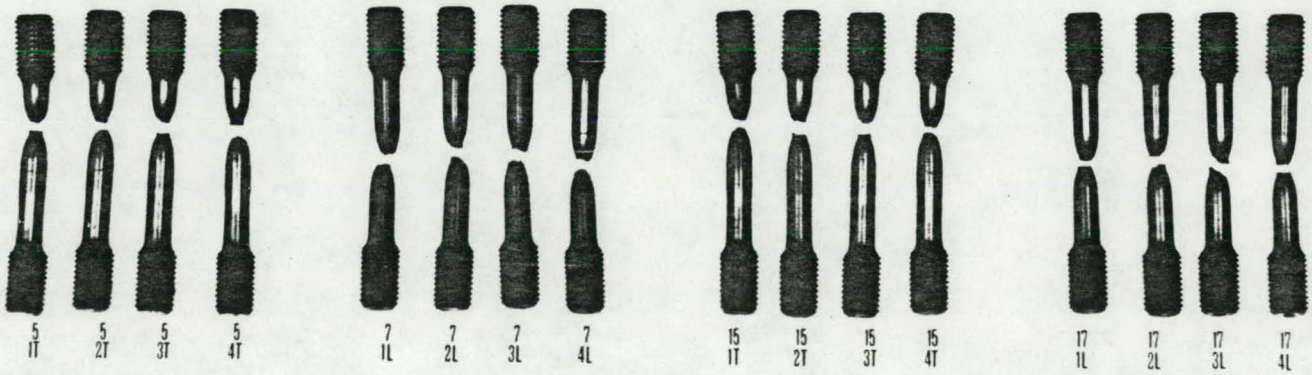
Side Bend Specimens

TENSILE SPECIMENS

60°F



600°F

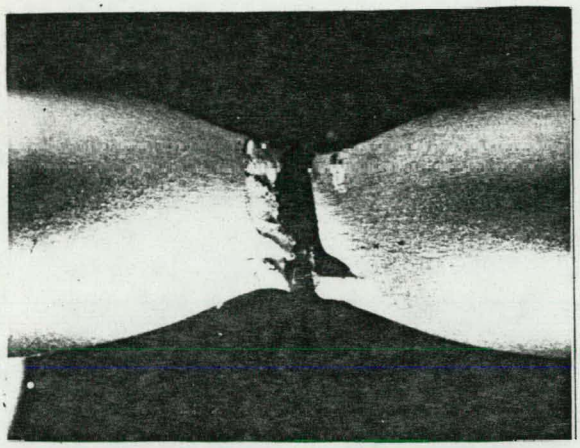


L - LONGITUDINAL SPECIMEN (ALL WELD METAL)
T - TRANSVERSE SPECIMEN

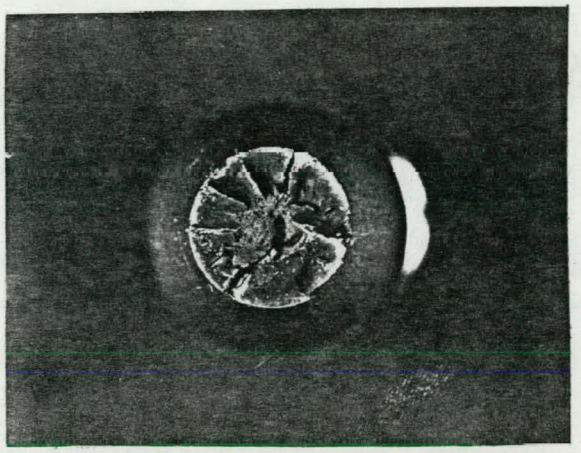
WELDING PROCEDURE QUALIFICATION RECORD

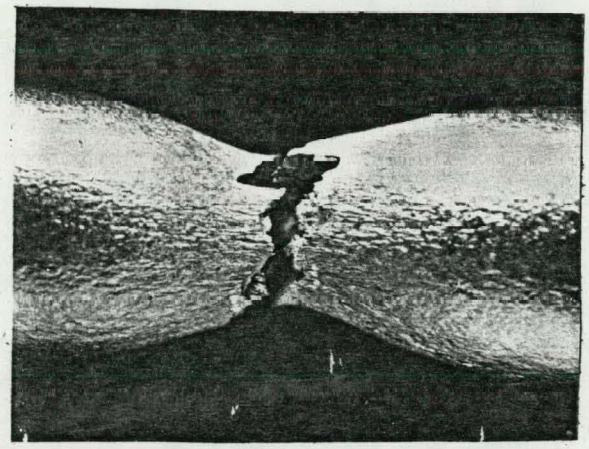
GAS TUNGSTEN ARC-HOT WIRE WELDING OF 2¼CR-1MO STEEL

TYPICAL TENSILE FAILURES

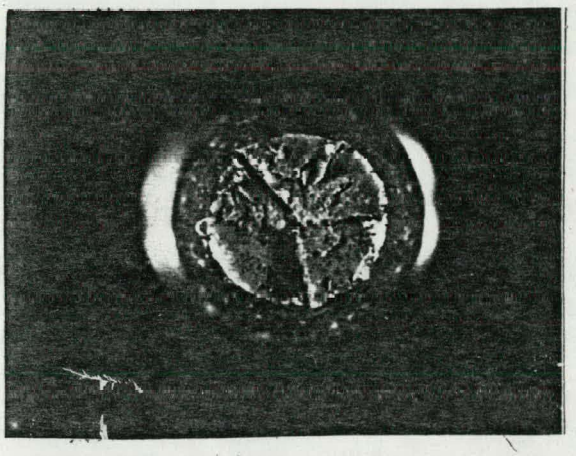


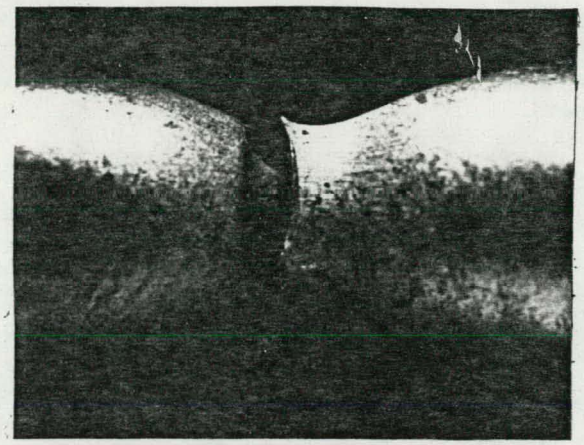
60°F--TRANVERSE



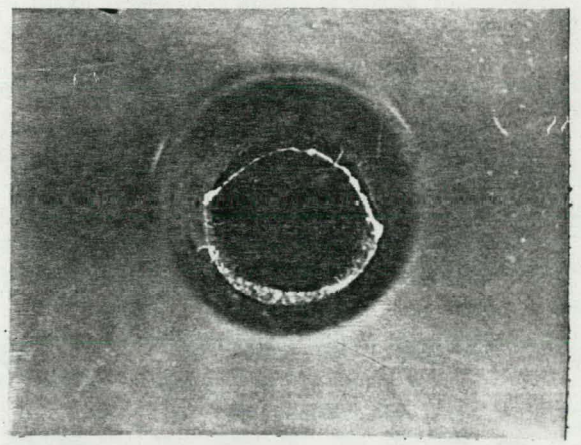


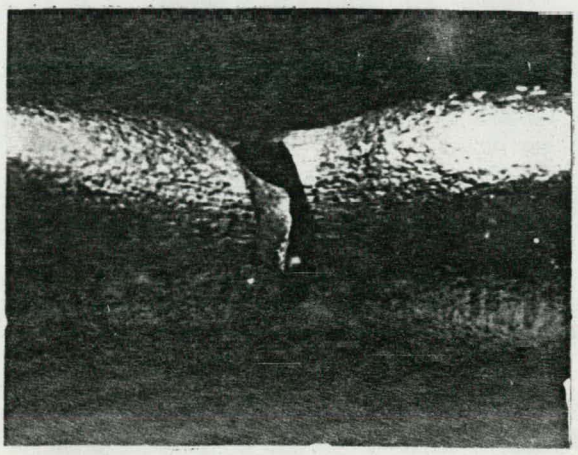
60°F--LONG.



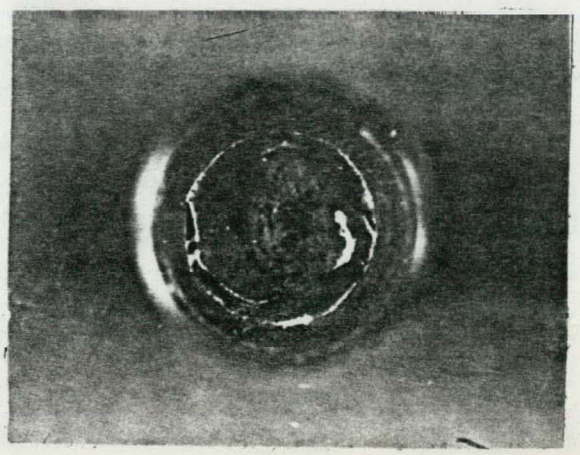


600°F--TRANVERSE





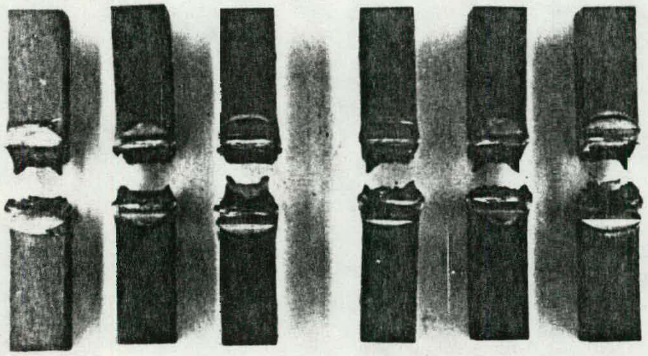
600°F--LONG.



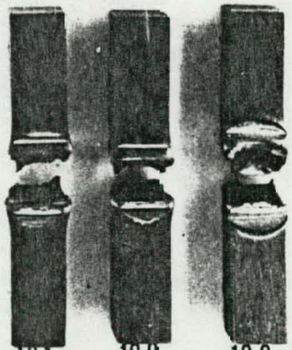
WELDING PROCEDURE QUALIFICATION RECORD

GAS TUNGSTEN ARC-HOT WIRE WELDING OF 2¼CR-1MO STEEL

IMPACT SPECIMENS



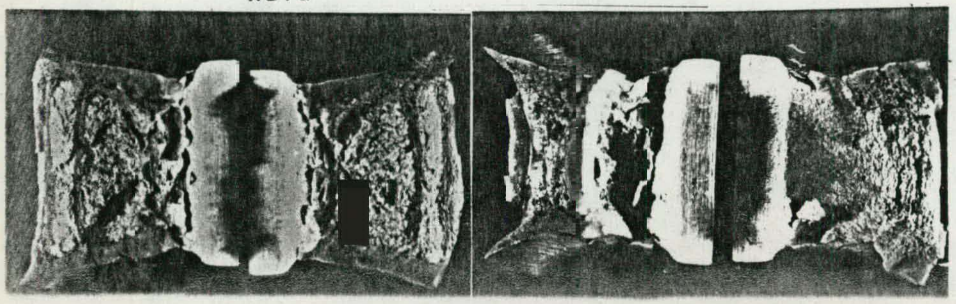
3-1 weld | 3-2 weld | 3-3 haz | 9-1 weld | 9-2 weld | 9-3 haz



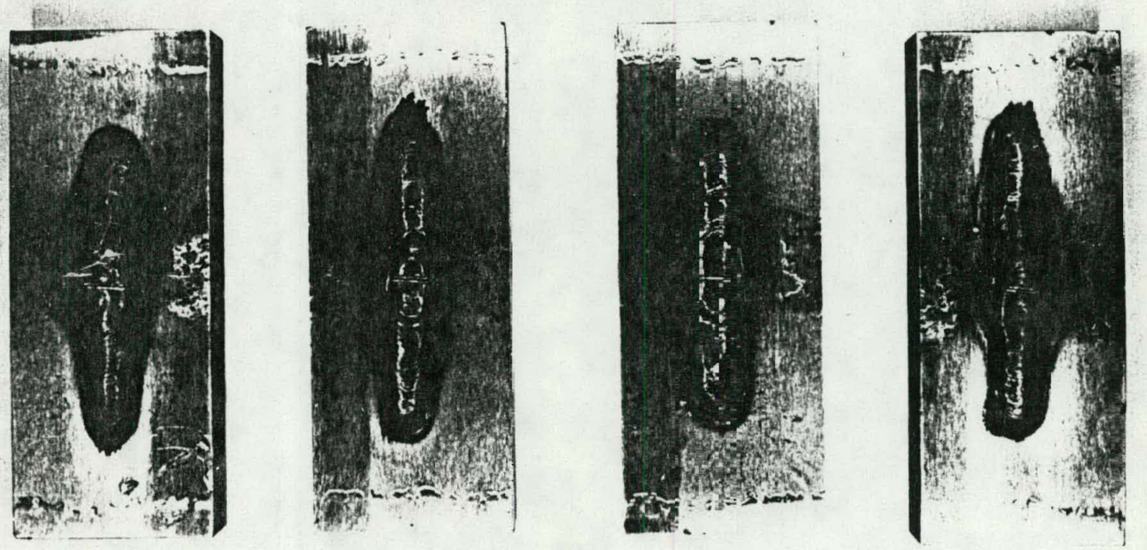
12-1 weld | 12-2 weld | 12-3 haz

TYPICAL

Weld | Haz



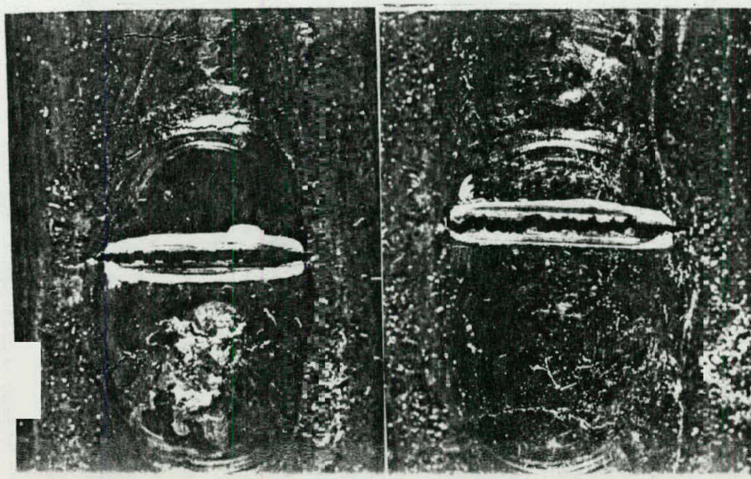
DROP WEIGHT SPECIMENS



10A WELD | 10A HAZ | 13 WELD | 13 HAZ

TYPICAL

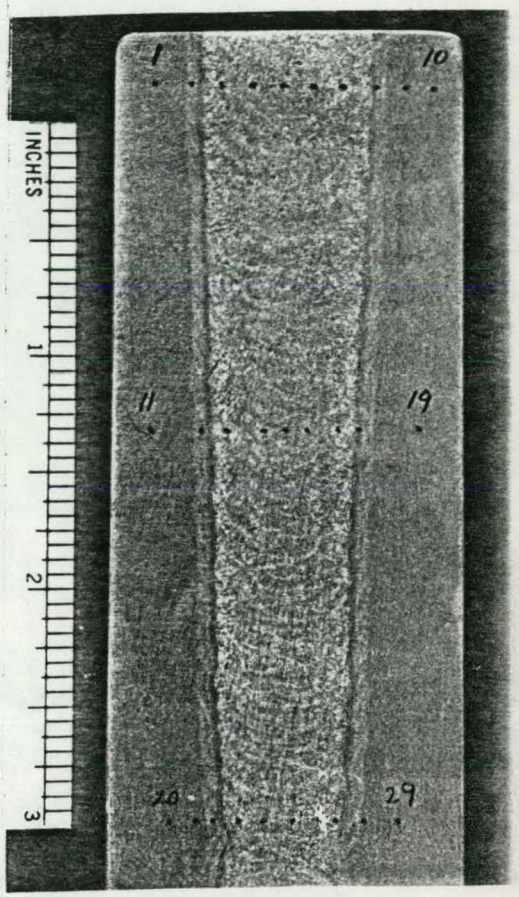
Weld | Haz



WELDING PROCEDURE QUALIFICATION RECORD
GAS TUNGSTEN ARC-HOT WIRE WELDING OF 2¼CR-1MO STEEL

VICKERS HARDNESSES MADE ON A CROSS SECTION
OF THE QUALIFYING WELD (10 Kg LOAD, 2/3 OBJ.)

Location*	Horizontal	Vertical	Average	DPH
TOP				
1. BM	321	321	321	180
2. HAZ	322	322	322	179
3. Weld	298	296	297	210
4. Weld	292	293	292	218
5. Weld	290	297	293	216
6. Weld	298	301	299	207
7. Weld	292	292	292	218
8. HAZ	314	316	315	187
9. BM	321	321	321	180
10. BM	319	321	320	181
MIDDLE				
11. BM	318	321	319	182
12. HAZ	311	311	311	192
13. Weld	295	294	294	215
14. Weld	297	302	299	207
15. Weld	292	293	292	218
16. Weld	303	302.5	303	202
17. Weld	296	300	298	209
18. Weld/HAZ	295	293	294	215
19. BM	312	312	312	191
BOTTOM				
20. BM	319	319	319	182
21. BM	324	322	323	178
22. HAZ	312	312	312	191
23. Weld	293	295	294	215
24. Weld	294	294	294	215
25. Weld	287	289	288	224
26. Weld	292	296	294	215
27. Weld	296	295	295	213
28. BM	323	323	323	178
29. BM	317	317	317	185



*See attached macrograph.

CHEMISTRY:

	BASE	WIRE	DEPOSIT
C	.120	.080	.082
Mn	.550	1.02	1.010
P	.008	.013	.011
S	.003	.008	.008
Si	.220	.51	.480
Ni		.10	.010
Cr	2.260	2.32	2.290
Mo	.340	1.03	1.050
Cu			

MATERIALS IDENTIFICATION

Base
Creusot-Loire Heat No.82353.2
W TO No. 9353
W Specification 26252A59
P. O. No. 545-BTT561B183

Wire
Kobe Heat No. 9F0561
No TO number
SFA 5.28 Class ER90S-B(Modified)
W Specification 2654A05
Trade Designation MGS-2CM
P.O. 545-BTT563B119