MECHANIZED GAS METAL ARC WELDING
OF LIGHT PLATE
FEBRUARY, 1979
Mechanized Gas Metal Arc Welding of Light Plate

Naval Surface Warfare Center CD Code 2230 - Design Integration Tools
Building 192 Room 128-9500 MacArthur Blvd Bethesda, MD 20817-5700

Approved for public release, distribution unlimited

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Standard Form 298 (Rev. 8-98) Prescribed by ANSI Std Z39-18
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FOREWORD

The purpose of this report is to present the results of one of the research and development programs which was initiated by the members of the Ship Production Committee of The Society of Naval Architects and Marine Engineers and financed largely by government funds through the cost sharing contract between the U.S. Maritime Administration and Bethlehem Steel Corporation. The effort of this project was directed to the development of improved methods and hardware applicable to shipyard welding in the U.S. shipyards.

Mr. W. C. Brayton, Bethlehem Steel Corporation, was the Program Manager. Mr. Malcolm T. Gilliland designed and directed the development work at the Gilliland plant at Peachtree City, Georgia.

Special acknowledgement is made to the members of Welding Panel SP-7 of the SNAME Ship Production Committee who served as technical advisors in the preparation of inquires and evaluation of sub-contract proposals.
BACKGROUND

The need for a low-cost, well-engineered, self-contained, unitized and mechanized gas metal arc/flux-core welding system for all-position welding of thin (1/8" - 5/8") steel and also aluminum alloy sheet and plate for shipbuilding applications has never been fulfilled.

One approach to the problem has been to purchase individual components from different vendors and to design and fabricate your own equipment.

The substantial initial expense and the inherent problems with maintenance and vendor responsibility have proved this approach to be impractical.

OBJECTIVE

Develop a prototype mechanized gas metal arc welding machine complete with motorized carriage, torch holders, and related accessories to consistently and reliably weld butts and/or fillet welds on mild steel and aluminum sheets ranging from 0.119 to 0.188 and plates ranging from 0.188 to 0.625.

APPROACH

Because this project encompasses a vast number of possibilities which could require lengthy evaluation and testing periods before the utmost in usable hardware could be available for actual use, we proposed to design and build a standard operating prototype which would incorporate the following features and specifications as an initial phase.
SPECIFICATIONS

1. Mechanized precision tractor to be consistent, reliable, and completely repeatable with welding speeds from 2 to 70 inches per minute.

2. All mechanisms and controls to be made in and self-contained in tractor housing assembly.

3. Track assemblies to be ultra lightweight and easy to roll form if required for operating on curved surfaces.

4. Unit to be portable yet rugged with complete voltage regulation giving constant performance under all conditions; but yet weighing only approximately 40 pounds less welding wire.

5. Wire feeding capability will range from .030 to 3/32" diameters of wire with a controlled speed of ± 1%.

6. Potentiometer for wire speed, travel speed, and oscillation speed will be 10 turns precision instruments.

7. A quick cable disconnect will be supplied to allow wire jogging and inching during setup.

8. Torch will have both vertical and lateral adjustments available prior to and during welding.

9. Torch oscillating mechanism will have both dwell and width controls which may be adjusted before or during the welding operation.

10. Both preflow and postflow of gas shielding media will be provided.

11. Fingertip current and voltage decay capabilities for trailing out weld to prevent crater cracking.

12. Torch shall be adjustable such as to either lead or trail direction of travel 15° in either direction.
SPECIFICATIONS (cont'd.)

13. Start-stop switches will be provided for travel, oscillator mechanism, and wire feed.

14. Forward-reverse switches will be provided for travel.

15. Automatic arc striking capabilities shall be incorporated into all controls so as to make the machine easily adaptable to either constant voltage or constant current power sources, inorder to obtain the optimum conditions required for welding both aluminum and steel.

16. A heavy duty air-cooled welding troth capable of welding currents of 300 amps for Argon and 500 amps for CO2 at 100% duty cycle will be designed and made available on this unit.

ACHIEVEMENT

In February, 1978, a standard operating prototype was designed, manufactured, and tested at the Gilliland plant in Peachtree City, Georgia. The prototype unit was shipped to Todd Pacific Shipyards Corporation, Seattle Division for shipyard evaluation.

Portions of Todd's final report entitled: Shipyard Evaluation of Mechanized Gilliland GMAW/FCAW System for Welding Thin Sheet and Plate, are included in this report.
CONTROL PANEL / FUNCTIONS
Prototype Front Panel, Gilliland Unit
Prototype Gilliland Unit, Mounted for Vertical Welding
MTG-6000 OSCILLATOR CONTROL PANEL FUNCTIONS

1. **POWER ON-OFF-BRAKE TOGGLE SWITCH;**
   - **ON** position: All control circuits are activated.
   - **BRAKE OFF** position: All control circuits deactivated.
   - This position is also used in conjunction with switch 6, to apply braking to travel motor.

2. **VOLTAGE RAISE-LOWER TOGGLE SWITCH;**
   - **A** position: Automatically increases welding voltage as long as switch is held in position.
   - **L** position: Automatically decreases welding voltage as long as switch is held in position.

3. **WELD-INCH TOGGLE SWITCH;**
   - **WELD** position: Activates wire feed and welding voltage circuits.
   - **INCH** position: Deactivates wire feed and welding voltage circuits. To inch wire, depress pushbutton 4. Wire will continue to inch until pushbutton 4 is released.

4. **INCH-PURGE PUSHBUTTON;**
   - With Switch 3 in INCH position, depress inch pushbutton 4 to inch wire. This pushbutton is also used to purge gas lines.

5. **WIRE FEED SPEED CONTROL;**
   - Wire feed speed is increased by turning control knob clockwise and is decreased by turning control knob counterclockwise. This dial will turn approximately 8½ turns with 100 marked increments in each turn. Dial may be locked at any desired setting by moving lock arm to the right. Dial range 0.00 - 8.70.

6. **TRAVEL BRAKE-DELAY-NONE-MOTION TOGGLE SWITCH;**
   - **MOTION** position and with switch 9 in **NORMAL** position:
     - Unit will advance along track without interruption as the gun oscillates back and forth across weld with no dwell time at end of stroke.
   - **MOTION** position and with switch 9 in **DELAY** position:
     - Unit will advance along track as the gun oscillates across weld and will stop and restart when the gun dwells and reverses direction at each end of stroke.
   - **DELAY** position and with switch 9 in **DELAY** position:
     - Unit will advance along track when the gun dwells on each end of stroke and will stop as the gun oscillates across weld.
DELAY position and with switch 9 in NORMAL position:
Unit will remain stopped as gun constantly oscillates
across weld.

NONE position: Travel circuit is deactivated.

BRAKE position and with switch 1 in BRAKE position:
Electro-dynamic braking is applied to travel motor to
prevent unit from "DRIFTING" down track when it is used
to weld vertically. The ON-OFF toggle switch at the
power supply should be left ON for brake operation.

TRAVEL FORWARD-REVERSE TOGGLE SWITCH:
FORWARD position: Unit will advance to RIGHT as you
face control panel.

REVERSE position: Unit will advance to LEFT as you
face control panel.

TRAVEL SPEED CONTROL:
Travel speed is increased by rotating knob clockwise and
is decreased by rotating knob counterclockwise. Dial may
be locked at any desired setting by moving locking arm to
the right. Dial range 0.00 - 8.70. This dial will turn
approximately 8½ turns with 100 marked increments in each turn.

OSCILLATION NORMAL-OFF-DELAY TOGGLE SWITCH:
OFF position: Oscillation circuit deactivates
NORMAL position: Gun will oscillate back and forth across
weld with no dwell time at end of stroke.

DELAY position: Gun will oscillate back and forth across
weld and will dwell for a period of time at each extreme
end of stroke. Dwell time periods are set with dials
14 and 15.

OSCILLATION STROKE, LONG-SHORT:
LONG STROKE position: The gun has a slower rate of speed
as it passes across center of weld. This setting primarily
used when making a wide pass such as a cap pass.

SHORT STROKE position: The gun has a faster rate of speed
as it passes across center of weld. This setting is primarily
used where a relatively narrow pass is required.

OSCILLATION SPEED CONTROL:
Oscillation speed is increased by rotating knob clockwise
and decreased by rotating knob counterclockwise. Dial may
be locked at any desired setting by moving lock arm to the
right dial range; 0.00 - 0.87.
12 OSCILLATION START PUSHBUTTON;
Depress pushbutton for ten seconds or until gun begins to oscillate. This will begin sequence control circuits to start gun oscillation.

13 STROKE AMPLITUDE;
This knob is used to adjust the width that the gun travels as it oscillates across weld. Turn knob clockwise to increase stroke amplitude and turn knob counterclockwise to decrease stroke amplitude.
NOTE: It is normal for knob to rotate when oscillating.

14 OUTSIDE DWELL CONTROL;
This control sets the gun dwell time at the end of the stroke toward the bottom as you face the control panel. Dial range: 0.00 - 0.87.

15 INSIDE DWELL CONTROL;
This control sets the gun dwell time at the end of the stroke toward the top as you face the control panel. Dial range: 0.00 - 0.87.

16 VOLTMETER

17 AMP METER

18 HEATER;
115 volt @ 125 watts maximum receptacle to be used for powering a heater coil inside a wire canister. Primarily for use with critical types of aluminum wire.
TODD SHIP'S REPORT
PURPOSE: The purpose of this report is to cover the evaluation of the mechanized gas metal arc welding (GMAW) flux-cored arc welding (FCAW) system for welding thin (1/8" - 5/8") steel and also aluminum alloy sheet and plate for shipbuilding applications.

This report covers the field production weld testing of the mechanized Gilliland GMAW/FCAW system for all-position welding of thin steel and aluminum alloy sheets and plates used for shipbuilding. For clarity's sake, the basic welding variables are covered under each heading together with test reports, conclusions, and recommendations.

A. EQUIPMENT

In mid-February 1978, the following equipment was received from M. T. Gilliland, Inc. These were as follows:

- One only 500 ampere MTG 6010 welding power source. (Serial #012078)
- One only MTG 6020 automatic control unit.
- One only MTG 6030 automatic oscillating-type welding head.
- One only 150 ft. length stretch cable consisting of electrode cable, control cable, and gas hose complete with quick disconnect fittings.
- Three only ten (10) ft. sections of super lightweight track assembly.
- One only MTG 4005 automatic gun and cable assembly.

1. POWER SOURCE

The welding power source was a Gilliland MTG 6010, 600 ampere constant voltage type machine.

2. CONTROL PANEL

The control panel Figure 1 and its functions are listed below:

1) Power on-off-brake toggle switch
2) Voltage: raise-lower toggle switch
3) Weld/inch toggle switch
4) Inch/pre-purge push button
5) Wire feed speed control potentiometer

TRACTOR TRAVEL

6) Tractor Travel: Break-delay-none-motion toggle switch
7) Tractor Travel: Forward-reverse toggle switch
8) Tractor Travel Speed Control

OSCILLATION

9) Oscillation normal-off-delay toggle switch
10) Oscillation stroke: long-short
3. TRACTOR

From a shipyard application viewpoint, the basic size or envelope of the tractor appears good. The basic tractor dimensions are: 9 inches wide x 11 inches high x 13 inches long and with the wire spool mounted and the torch fully extended: 17 inches wide x 17 inches high x 26 inches long.

Although the Gilliland tractor does have a method to mount the tractor on the middle of the rail length, it certainly does not offer easy-quick-on/disconnect capabilities to mate to the rails. This is a great disadvantage, for example, when preparing for a vertical-up welding set-up from a scaffold.

4. TRAVEL SPEED

Actual travel speed of the Gilliland tractor was plotted against the travel speed potentiometer settings in both the forward (right) and the reverse (left) directions. Figures 2 and 3 respectively show the results. The data indicates that the travel speed is not linear. However, travel speed in the 5-50 inches per minute range is fair. No travel is initiated until the travel speed potentiometer is increased from "0" to almost "I". It is our opinion that this can be improved by using a tachometer generator type arrangement or by using a bull gear system.

5. OSCILLATOR

When using 1/16 inch diameter solid or flux-cored wire with the GMAW or FCAW process, there are many butt and fillet weld joints that cannot be filled in a single pass and require multiple pass deposits for fill. For the flat position, the submerged arc process may be used as an alternative to cut down the numbers of weld passes. But, for all-position GMA & FCA welding (especially vertical-up), torch oscillation has become a necessity for improving welding deposition rates and efficiency.

The oscillator developed by Gilliland is a controlled oscillation device and the number of oscillation patterns that may be generated are limited. Tests with the oscillator revealed the following:
1) The Gilliland oscillator is a compact line weaver with infinitely adjustable amplitude (during operation) of 1/4 inch to 2 inches. Amplitude is the distance normal to the direction of welding between the outermost positions which the electrode tip reaches while oscillating.

2) The outside and inside dwell controls set the gun dwell time at the ends of each stroke. Dwell is the time during which the electrode rests at any point in each oscillating swing or traverse. The oscillation normal-off-delay toggle switch must be in the delay position so that the gun will oscillate back and forth transversely across the weld/joint axis and will dwell for a period of time at each end of the stroke.

3) The frequency of oscillation is increased by rotating the oscillation speed control knob clockwise and decreased by rotating the knob counter-clockwise. Frequency is the completed number of cycles which the oscillating head makes in one minute or other specified time increments.

4) Figure 4 illustrates the oscillator in the constant dwell (0), amplitude mode, but the travel speed increased from left to right.

5) Figure 5 shows the oscillator in the constant amplitude, weaving speed, and dwell modes; but the tractor travel speed was increased gradually.

6) Figure 6 shows the oscillator in the constant amplitude, tractor travel speed, and frequency mode; but the dwell was increased from left to right.

7) Figure 7 shows the oscillator in constant amplitude, weaving speed mode, but the inside and outside dwell increased gradually from left to right.

8) Figure 8 illustrates the oscillator in the constant amplitude and weaving speed mode, but the outside dwell increased only two cycles then subsequently increased the inside dwell to the same magnitude as the outside dwell.

B. PRODUCTION WELDING TESTS

1. BY-80/HY-80 MECHANIZED WELDING PROCEDURE QUALIFICATION

The Gilliland system was used to qualify the mechanized welding procedure qualification tests for gas metal arc welding(GMAW) of HY-80/HY-80 steel hull plating.
Todd Welding Procedure Specification 9761504, "Mechanized Gas Metal Arc Welding (GMAW) of HY-80 to HY-80 Steel and to Carbon Steels" was generated from the qualification test data. This procedure is applicable for materials ranging from 1/8 inch to 1 inch thickness. Solid filler wire of 1/16th inch diameter per MIL-E-23765/2-composition MIL-100S-1 was used. Shielding gas was 98% Argon, 2% Oxygen. This covered welding in the flat and horizontal positions only. The basic welding parameters were as follows:

27-30 Volts
320-380 Amperes
11-20 inches per minute/Travel Speed

The tempering bead technique was utilized and the Joules per inch (heat input) was carefully monitored. See Figures 9 and 10 for the test summary sheets. Also see Figure 11 for mechanized properties test report, Figure 12 for radiographic inspection report, and also Figure 13 for magnetic particle inspection report.

2. NAVY FFG-10 ERECTION UNITS: STEEL

The four longitudinal seam welds in the lower erection unit A2-001, Frames 241-271, were welded with the Gilliland system. The sketch in Figure 14 shows the longitudinal seam weld locations on the hull and also the weld joint configurations and material thicknesses welded. Figures 15 thru 20 are photographs of the Gilliland System being used to flux-cored arc weld the four seam weld joints illustrated in the preceding sketch.

Figure 15 illustrates the Gilliland tractor oscillator, torch, controls, and flux-cored wire (25 lbs. spool) mounted on the Gilliland rails with magnet attachments. These compact magnet assemblies are cleverly swivel mounted for quick on/off convenience.

Figure 16 is a close-up view of the control panel located on the Gilliland tractor.

Figure 17 and 18 shows the tractor unit flux-cored arc welding the seam.

Figure 19 and 20 illustrates the completed welds with the Gilliland unit adjacent to the completed flux-cored arc welding seam joint.

Figures 21, 22 and 23 illustrates the Gilliland machine settings covering the 3 pass flux-cored arc welding on the 1st side. (i.e. root pass, second pass, and fill pass) The second side was arc gouged and manually welded overhead.
C. LABORATORY WELDING EVALUATION

1. VERTICAL-UP WELDING

At this point during the course of this study, it was decided to bring the Gilliland Welding Systems back into the laboratory. This was necessary to determine and establish firm welding machines settings for the vertical-up and overhead positions prior to going back on production application. Oscillation of the welding torch for vertical-up welding appears to be a critical variable when AWS E 70 TG flux cored wire is utilized. Various oscillation patterns were used however the addition of the 2% nickel in this all position wire made the weld puddle extremely fluid in the vertical-up mode.

Figure 24 shows the machine settings established on vertical-up welding: 200-240 amperes; 24-26 volts; and 6-6½ inch travel speed.

Figures 25, 26, 27 and 28 illustrate the Gilliland Welding System in the vertical-up weld test set-up. The flux cored all position filler wire was Chemetron 8000 2Ni, in the 0.045 inch diameter.

2. OVERHEAD WELDING

Figure 29 shows the machine settings established for the overhead welding position. Amperage ranged from 210-230; voltage; 27-30; and travel speeds 10-12 inches per minute. Weld filler wire used was the same as for the vertical-up tests; 0.045 inch diameter Chemetron 8000 2Ni, AWS E 70 TG.

Figures 30, 31 and 32 illustrate the weld test set-up for overhead welding.
ACTUAL FORWARD TRAVEL SPEED, IPM
GILLILAND TRACTOR

FIGURE 2
ACTUAL REVERSE TRAVEL SPEED, IPM
GILLILAND TRACTOR

FIGURE 3
Control Panel Mode:
Power on - ✓

Weld/inch toggle switch: Weld ✓
Inch/pre-purge push button: Pre-Purge □
Wire feed speed control potentiometer □

Tractor Travel: Break-delay □ motion ✓
Tractor Travel: Left □ Right ✓
Tractor Travel Speed Control: 2.40 to 3.25

Oscillation: normal ✓ delay □
Oscillation stroke: long ✓ short □
Oscillation speed control 30
Stroke amplitude OPEN Outside dwell control 0 Inside dwell control 0

FIGURE 4
CONSTANT DWELL (0), AMPLITUDE; BUT TRAVEL SPEED INCREASED FROM LEFT TO RIGHT.
**Control Panel Mode:**
- **Power on:**  
- **Weld/inch toggle switch:** Weld
- **Inch/pre-purge push button:** Pre-Purge  
- **Wire feed speed control potentiometer:**

**Tractor Travel:**
- **Break-delay motion:**
- **Tractor Travel:**
  - Left
  - Right
- **Tractor Travel Speed Control:** 1.70 to 9.98

**Oscillation:**
- **normal delay:**
- **Oscillation stroke:**
  - long  
  - short
- **Oscillation speed control:** 1.40
- **Stroke amplitude:**
  - OPEN
  - Outside dwell control: 1.10
  - Inside dwell control: 1.2

**FIGURE 5**

**CONSTANT AMPLITUDE, WEAVING SPEED AND DWELL**
**BUT TRAVEL SPEED INCREASED GRADUALLY**
Control Panel Mode:
Power on - [V]

Weld/inch toggle switch: Weld [V]
Inch/pre-purge push button: Pre-Purge [ ]
Wire feed speed control potentiometer [ ]

Tractor Travel: Break-delay [V] motion [ ]
Tractor Travel: Left [ ] Right [V]
Tractor Travel Speed Control: [2.40] to 4.28

Oscillation: normal [ ] delay [V]
Oscillation stroke: long [V] short [ ]
Oscillation speed control [ .37]
Stroke amplitude [OPEN] Outside dwell control [ .10] Inside dwell control [ .10]

FIGURE 6
CONSTANT AMPLITUDE, TRAVEL SPEED & FREQUENCY BUT INCREASED DWELL: LEFT TO RIGHT
Control Panel Mode:
Power on - [✓]

Weld/Inch toggle switch: Weld [ ]
Inch/pre-purge push button: Pre-Purge [ ]
Wire feed speed control potentiometer [ ]

Tractor Travel: Break-delay [✓] motion [ ]
Tractor Travel: Left [ ] Right [✓]
Tractor Travel Speed Control: [2.40]

Oscillation: normal [ ] delay [✓]
Oscillation stroke: long [✓] short [ ]
Oscillation speed control [ .30 ]
Stroke amplitude [OPEN] Outside dwell control [ .10 ] Inside dwell control [ .10 ] [ .30 ]

FIGURE 7

CONSTANT AMPLITUDE, WEAVING SPEED; BUT INSIDE & OUTSIDE DWELL INCREASED GRADUALLY LEFT TO RIGHT
CONTROL PANEL MODE:
Power on: ✓

Weld/inch toggle switch: Weld
Inch/pre-purge push button: Pre-Purge
Wire feed speed control potentiometer

Tractor Travel: Break-delay ✓ motion
Tractor Travel: Left Right ✓
Tractor Travel Speed Control: 2.40

Oscillation: normal delay ✓
Oscillation stroke: long ✓ short
Oscillation speed control .50
Stroke amplitude: ✓ Outside dwell control: 0 Inside dwell control: 0

.30 .30

FIGURE 8

CONANT AMPLITUDE, WEAVING SPEED, BUT OUTSIDE DWELL INCREASED ONLY 2 CYCLES
THEN SUBSEQUENTLY INCREASED INSIDE DWELL TO SAME MAGNITUDE AS OUTSIDE DWELL
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<td>WELDER QUALIF.</td>
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<td>BASE METALS</td>
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<td>SPEC./TYPE FILLER METAL</td>
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<td>POSITION OF WELD</td>
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<tr>
<td>JOINT PREPARATION &amp; SIDE NUMBER</td>
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<td>INTERPASS CLEANING</td>
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<td>REPAIRS</td>
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<tr>
<td>PREHEAT TEMPERATURE</td>
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<td>INTERPASS TEMPERATURE</td>
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<tr>
<th>ACTUAL TRAVEL SPEED (I.P.M.)</th>
<th>FILLER METAL DIAMETER</th>
<th>AMPERAGE RANGE</th>
<th>ARC VOLTAGE RANGE</th>
<th>WELDING POSITION</th>
<th>NOTES</th>
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<tbody>
<tr>
<td>11-20</td>
<td>1/16</td>
<td>320-380</td>
<td>27-30</td>
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**Control Panel Mode:**
- Power on: [ ]
- Weld/inch toggle switch: Weld: [X]
- Inch/pre-purge push button: Pre-Purge: [X]
- Wire feed speed control potentiometer: [405]
- Tractor Travel: Break-delay motion: [X]
- Tractor Travel: Left: [X]
- Tractor Travel Speed Control: [284]
- Oscillation delay: [X]
- Oscillation stroke: Long: [ ]
- Oscillation speed control: [ ]
- Stroke amplitude: [ ]
- Outside dwell control: [ ]
- Inside dwell control: [ ]

**WELDING ENGINEER:**
- Approval: [Signature]
- DATE: [ ]

**GILLILAND MACHINE SETTINGS**

**FIGURE 9**
TODD SHIPYARDS CORPORATION
Seattle Division

WELDING PROCEDURE QUALIFICATION TEST SUMMARY

QUALIFICATION JOINT

MATERIALS:
Base Spec. MIL-S-16216, HY-80

Base Inks. 1/2 inch
Filler Spec. MIL-E-23765/2,
Type MIL 100S-1 (Linde 95)
Filler dia. 1/16 inch
Shielding Gas 98% Argon 2% Oxygen
Flux and Size N/A

EQUIPMENT:
Power Supply Gilliland 600 Amp (CP)
Torch or Holder Type Gilliland 400 Amp.
Cup Type & Size 5/8" dia.
Electrode Type & Size N/A

OPERATING PARAMETERS:
Welding Pos. Flat No. Passes 8
Preheat 60°F Min. Interpass Temp 300°F Min.
Current Charac. D.C.R.P. (Spray Transfer
Current Range 320-380 Amps
Voltage Range 27-30 Volts

Wire Feed RPM N/A
Shield Flow 30 C/F
Travel Speed 11-20 IFM
Max. Heat Input j/in 47,127 Joules
Heat Treat None

NDT Tests:
Vis. PT UT MT

DT TESTS: Plate or Spec. Ser. No.

Charpy
Side Bend
Root Bend
Face Bend
Fillet Bend
Fillet Break
Trans. shear
Long shear
Expl. bulge
Other

RESULTS
Vis. No Visible Defects
RT. Acc., Report # 4831 Attached
MT. Acc., Report # 737 Attached

REMARKS: Electrode Control per TWS 975-4003

J. Johnson
WELD OPR.

W. Faller
CLOTH NO.

1/8 to 1 inch

This certifies that the data herein is complete and accurate to best possible knowledge and that testing and evaluation was conducted in accordance with the requirements listed below.

MTL-STD 248C
NAVSHIPS 0900-000-1001
NAVSHIPS 0900-093-9000
NAVSHIPS 0900-003-9000

FIGURE 10
Report to: Todd Shipyards Corporation  
Date: May 18, 1978

Report on: Welds, P.O. PS16738  
Lab. No. E13494

IDENTIFICATION:

TWPS 976-1504 Series 1504-1
Base Material - MIL-S-16216H (Ship) HY-80; 1/2" Thick
Welding Process - GMAW; Welding Position - Flat
Welding Electrode - 1/16" Dia., Type MIL 1005-1 (MIL-E-23765/2A)
Shielding Gas - 98% Argon, 2% Oxygen

TRANVERSE TENSILE TEST:

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BEND TESTS:

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<th>Number</th>
<th>Type of Bend</th>
<th>Location, Nature &amp; Size of Cracks &amp; Tears</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-1</td>
<td>Face</td>
<td>No Flaws - Satisfactory</td>
</tr>
<tr>
<td>F-2</td>
<td>Face</td>
<td>2 Cracks 1/16&quot;, 1 Crack 1/32&quot; - Satisfactory</td>
</tr>
<tr>
<td>R-1</td>
<td>Root</td>
<td>No Flaws - Satisfactory</td>
</tr>
<tr>
<td>R-2</td>
<td>Root</td>
<td>No Flaws - Satisfactory</td>
</tr>
</tbody>
</table>

This is to certify that the above weld procedure qualification test specimens have been tested and found to be acceptable per requirements of MIL-STD-248C and MIL-STD-418C.

Albert O. Wahto, P.E.  
Chief Testing Engineer  
License No. 3004

MECHANIZED PROPERTIES
FCAW HY 80-HY 80

FIGURE 11
<table>
<thead>
<tr>
<th>FILM TYPE(S)</th>
<th>SEQUENCE NO.</th>
<th>THICKNESS (INCHES)</th>
<th>VIEW</th>
<th>ORIG. OF REP.</th>
<th>PONDOSITY</th>
<th>INCLUSIONS</th>
<th>PENTRATION</th>
<th>FUSION</th>
<th>CRACK</th>
<th>UNDERCUT</th>
<th>SURFACE</th>
<th>OTHER</th>
<th>DISPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 B&amp;W X</td>
<td>0-1</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>REJECT</td>
</tr>
</tbody>
</table>

**REMARKS:** SURFACE WITHIN SAFE

**CODE:**
1. ACCEPTABLE
2. BORDERLINE
3. EXCESSIVE

**RADIATION SOURCE:**
X-RAY: KY
IR-192: CURIES

**NO. OF VIEWS:**
4¼ x 17 | 4¼ x 10 1 | 7 x 17

**NO. OF FILM:**
1

**PREPARED BY:**
R. B. (x)

**APPROVED BY:**

**ACCEPTED BY:**

**QA-RT-2**

**FIGURE 12**

**CONTRACT NO.:**

**DATE:** 4-24-79

**HULL:** NA

**JOB NAME:** WELDING PROCEDURE QUALIFICATION - GMW

**JOB NO.:** 6541

**ITEM NO.:** 621.16

**PAGE:** 1 of 1

**MAT'LE HY-80**

**QUANTITY:** 1

**MISSING FIELD:** PROCEUTE 450X
DESCRIPTION OF OBJECT/LOCATION AND TEST RESULTS. Performed NDT inspection using the magnetic particle method on one test plate HY-80 to HY-80 flat setting up a magnetic field in two directions parallel and to the right angle of the weld and 1 in. of the heat affected zone. Indications that were found were removed by grinding re-inspected and found acceptable. See sketch below.
Figure 14
SKETCH—LOWER ERECTION UNIT
FFG-FR. 241-271
FIGURE 15 - GILLILAND TRACTOR, TORCH AND CONTROL WITH 25 POUND FLUX CORED WIRE (LINDE 727) MOUNTED ON GILLILAND RAILS.
FIGURE 16 - CLOSE-UP VIEW OF GILLILAND TRACTOR UNIT.
FIGURE 17 - GILLILAND SYSTEM AT WORK.
FIGURE 18 - GILLILAND SYSTEM AT WORK.
FIGURE 19 - COMPLETED FCAW WELD USING GILLILAND SYSTEM.
FIGURE 20 - COMPLETED FCAW SEAM USING GILLILAND SYSTEM.
**Preheat Temperature:** 60° Min.  
**Interpass Temperature:**

<table>
<thead>
<tr>
<th>Weld Technique</th>
<th>WELD TECHNIQUE IN ACCORDANCE WITH T.W.P.S 976-1516</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Filler Metal Diameter</th>
<th>1/16</th>
<th>1/16</th>
<th>1/16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amperage Range</td>
<td>230-25</td>
<td>200</td>
<td>210-220</td>
</tr>
<tr>
<td>Arc Voltage Range</td>
<td>28</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>Welding Position</td>
<td>FLAT</td>
<td>FLAT</td>
<td>FLAT</td>
</tr>
<tr>
<td>Notes</td>
<td>ROOT PASS</td>
<td>2ND PASS</td>
<td>COVER PASS</td>
</tr>
</tbody>
</table>

Control Panel Mode:
- Power on [✓]
- Weld [✓]
- Inch/pre-purge push button: Pre-Purge [✓]
- Wire feed speed control potentiometer [✓]

Tractor Travel: Break-delay motion [✓]  
Tractor Travel: Left [✓] Right [✓]
Tractor Travel Speed Control: 2.50-2.80

Oscillation: normal delay [✓]
Oscillation stroke: long [✓] short [✓]
Oscillation speed control [✓]
Stroke amplitude [✓]

**GILLILAND MACHINE SETTINGS**

**FIGURE 21**
<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SECTION #2101 - DRW. 1111-05 SHT. 3A - FR241-271</th>
</tr>
</thead>
<tbody>
<tr>
<td>WELDER QUALIF.</td>
<td>MIL-STD-248C</td>
</tr>
<tr>
<td>PROCEDURE QUALIF. STD.</td>
<td>MIL-STD-248C</td>
</tr>
<tr>
<td>PROCEDURE</td>
<td>MIL-STD-248C</td>
</tr>
<tr>
<td>BASE METALS</td>
<td>LOW CARBON STEEL</td>
</tr>
<tr>
<td>PROCESS</td>
<td>FCAW</td>
</tr>
<tr>
<td>SPEC./TYPE</td>
<td>1/16 Inch Diameter</td>
</tr>
<tr>
<td>POWER SOURCE ; MODEL/TYPE</td>
<td>GILLILAND CV600</td>
</tr>
<tr>
<td>FILLER METAL</td>
<td>LINDE 727 E70T-G</td>
</tr>
<tr>
<td>POLARITY</td>
<td>DC RP</td>
</tr>
<tr>
<td>POSITION OF WELD</td>
<td>FLAT</td>
</tr>
<tr>
<td>GAS : FLOW RATE/TYPE</td>
<td>45 C.F.H.</td>
</tr>
<tr>
<td>JOINT PREPARATION &amp; SIDE NUMBER</td>
<td>SINGLE BEVEL SIDE #1</td>
</tr>
<tr>
<td>INTERPASS CLEANING</td>
<td></td>
</tr>
<tr>
<td>REPAIRS</td>
<td></td>
</tr>
<tr>
<td>PREHEAT TEMPERATURE</td>
<td>NA</td>
</tr>
<tr>
<td>INTERPASS TEMPERATURE</td>
<td>NA</td>
</tr>
<tr>
<td>WELD TECHNIQUE</td>
<td>PER TWPS 976-1516</td>
</tr>
<tr>
<td>ACTUAL TRAVEL SPEED (I.P.M.)</td>
<td></td>
</tr>
<tr>
<td>FILLER METAL DIAMETER</td>
<td>1/16</td>
</tr>
<tr>
<td>AMPERAGE RANGE</td>
<td>200</td>
</tr>
<tr>
<td>VOLTAGE RANGE</td>
<td>30</td>
</tr>
<tr>
<td>WELDING POSITION</td>
<td>FLAT 2ND PASS</td>
</tr>
<tr>
<td>NOTES:</td>
<td></td>
</tr>
</tbody>
</table>

Control Panel Mode:

- Power on - [✓]
- Weld [✓]
- Inch/pre-purge push button: Pre-Purge [✓]
- Wire feed speed control potentiometer 1.0

Tractor Travel:
- Break-delay [✓] motion [ ]
- Tractor Travel: Left [✓] Right [ ]
- Tractor Travel Speed Control: [2:2]

Oscillation:
- Normal [ ] delay [✓]
- Oscillation stroke: long [ ] short [ ]
- Oscillation speed control [ ]
- Stroke amplitude [ ] Outside dwell control [10] Inside dwell control [10]

GILLILAND MACHINE SETTINGS

FIGURE 22
# GILLILAND MACHINE SETTINGS

**FIGURE 23**

**DESCRIPTION**

<table>
<thead>
<tr>
<th>WELDER QUALIF.</th>
<th>MIL-STD-248C</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROCEDURE QUALIF. STD.</td>
<td>MIL-STD-248C</td>
</tr>
<tr>
<td>BASE METALS</td>
<td>LOW CARBON STEEL</td>
</tr>
<tr>
<td>SPEC./TYPE</td>
<td>1/16 INCH DIAMETER</td>
</tr>
<tr>
<td>FILLER METAL</td>
<td>LINDE 727 E70T-G</td>
</tr>
<tr>
<td>GAS</td>
<td>FLOW RATE/TYP: 50 G.C.F.H.</td>
</tr>
<tr>
<td>POSITIVE</td>
<td>FLAT</td>
</tr>
<tr>
<td>JOINT PREPARATION</td>
<td>SINGLE-BEVEL</td>
</tr>
<tr>
<td>&amp; SIDE NUMBER</td>
<td>31</td>
</tr>
<tr>
<td>INTERPASS CLEANING</td>
<td></td>
</tr>
<tr>
<td>REPAIRS</td>
<td></td>
</tr>
<tr>
<td>PREHEAT TEMPERATURE</td>
<td>NA</td>
</tr>
<tr>
<td>INTERPASS TEMPERATURE</td>
<td>NA</td>
</tr>
<tr>
<td>WELD TECHNIQUE</td>
<td></td>
</tr>
<tr>
<td>ACTUAL TRAVEL SPEED</td>
<td></td>
</tr>
<tr>
<td>(I.P.M.)</td>
<td>1/16</td>
</tr>
<tr>
<td>FILLER METAL DIAMETER</td>
<td>210-220</td>
</tr>
<tr>
<td>AMPERAGE RANGE</td>
<td>31</td>
</tr>
<tr>
<td>ARC VOLTAGE RANGE</td>
<td>FLAT</td>
</tr>
<tr>
<td>WELDING POSITION</td>
<td>COVER PASS</td>
</tr>
</tbody>
</table>

**Control Panel Mode:**

- Power on - [ ]
- Weld/inch toggle switch: Weld [ ]
- Inch/pre-purge push button: Pre-Purge [ ]
- Wire feed speed control potentiometer [ ]

**Tractor Travel:**
- Break-delay motion [ ]
- Left [ ] Right [ ]

**Tractor Travel Speed Control:** 3.45

**Oscillation:**
- normal [ ] delay [ ]
- Oscillation stroke: long [ ] short [ ]
- Oscillation speed control [ ]

**Stroke amplitude:** OPEN Outside dwell control 10 Inside dwell control 10

**WELDING ENGINEER**

<table>
<thead>
<tr>
<th>Approval</th>
<th>Date</th>
</tr>
</thead>
</table>

---

GILLILAND MACHINE SETTINGS
**DESCRIPTION**

<table>
<thead>
<tr>
<th>WELDER</th>
<th>MIL-STD-248C</th>
<th>PROCEDURE</th>
<th>MIL-STD-248C</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUALIF.</td>
<td></td>
<td>QUALIF. STD.</td>
<td>NAVSHIPS 0900-000-1001</td>
</tr>
<tr>
<td>BASE METALS</td>
<td>LOW-CARBON STEEL</td>
<td>PROCESS</td>
<td>F.C.A.W.</td>
</tr>
<tr>
<td>SPEC./TYPE FILLER METAL</td>
<td>0.045 inch diameter</td>
<td>POWER SOURCE; MODEL/TYPE</td>
<td>GILLILAND</td>
</tr>
<tr>
<td>POSITION OF WELD</td>
<td>Vertical-Up</td>
<td>GAS:</td>
<td>FLOW RATE/TYPE</td>
</tr>
<tr>
<td>JOINT PREPARATION &amp; SIDE NUMBER</td>
<td>22½° Bevel on each plate.</td>
<td>35 C.F.H. 75% Argon 25% CO₂</td>
<td>TORCH TYPE GILLILAND</td>
</tr>
<tr>
<td>INTERPASS CLEANING</td>
<td>REMOVE ALL SLAG &amp; WIRE BRUSH EACH PASS</td>
<td>CUP SIZE</td>
<td>5/8</td>
</tr>
<tr>
<td>REPAIRS</td>
<td>NONE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WELD TEMPERATURE</td>
<td>60°</td>
<td>INTERPASS TEMPERATURE</td>
<td>NA</td>
</tr>
<tr>
<td>WELD TECHNIQUE</td>
<td>ROOT OPENING 1/2&quot;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ACTUAL TRAVEL SPEED (I.P.M.)</th>
<th>FILLER METAL DIAMETER</th>
<th>AMPERAGE RANGE</th>
<th>ARC VOLTAGE RANGE</th>
<th>WELDING POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 T.P.M.</td>
<td>0.045</td>
<td>200-240</td>
<td>24 - 26</td>
<td>Vert-Up Root &amp; 1st Fill Pass</td>
</tr>
<tr>
<td>6 I.P.M.</td>
<td>0.045</td>
<td>200-240</td>
<td>24 - 26</td>
<td>Vert-Up 2nd &amp; 3rd Fill Pass</td>
</tr>
<tr>
<td>6½ I.P.M.</td>
<td>0.045</td>
<td>200-240</td>
<td>24 - 26</td>
<td>Vert-Up COVER PASS</td>
</tr>
</tbody>
</table>

Control Panel Mode:
Power on - □

Weld/inch toggle switch: Weld □
Inch/pre-purge push button: Pre-Purge □
Wire feed speed control potentiometer □

Tractor Travel: Break-delay □ motion □
Tractor Travel: Left □ Right □
Tractor Travel Speed Control: □

Oscillation: normal □ delay □
Oscillation stroke: long □ short □
Oscillation speed control □ Cover pass □
Stroke amplitude □ Outside dwell control □ Inside dwell control □

**GILLILAND MACHINE SETTINGS**

**FIGURE 24**
FIGURE 25 - GILLILAND UNIT IN VERTICAL-UP MODE: FCAW WELD TEST SET-UP.
FIGURE 26 - GILLILAND UNIT IN VERTICAL-UP MODE: FCAW WELD TEST SET-UP: FILL PASSES.
FIGURE 27 - GILLILAND UNIT IN VERTICAL-UP MODE: FCAW CHEMETRON 8000-2NI 0.045 INCH DIAMETER FILLER.
FIGURE 28 - GILLILAND UNIT IN VERTICAL-UP MODE: INTERPASS CLEANING OF WEAVE PASSES.
**DESCRIPTION**

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WELDER</strong></td>
<td>MIL-STD-248C</td>
</tr>
<tr>
<td><strong>QUALIF.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>BASE METALS</strong></td>
<td>LOW CARBON STEEL</td>
</tr>
<tr>
<td><strong>SPEC./TYPE</strong></td>
<td>0.045 Inch Diameter</td>
</tr>
<tr>
<td><strong>FILLER METAL</strong></td>
<td>Chemtron 8000 2N1</td>
</tr>
<tr>
<td><strong>POSITION OF WELD</strong></td>
<td>OVHD</td>
</tr>
<tr>
<td><strong>POWER SOURCE; MODEL/TY</strong></td>
<td>Gilliland</td>
</tr>
<tr>
<td><strong>TYPE</strong></td>
<td>CU 600</td>
</tr>
<tr>
<td><strong>POLARITY</strong></td>
<td>D.C. R.P.</td>
</tr>
<tr>
<td><strong>GAS: FLOW RATE/TYPE</strong></td>
<td>75% Argon 25% CO₂</td>
</tr>
<tr>
<td><strong>TORCH TYPE</strong></td>
<td>Gilliland</td>
</tr>
<tr>
<td><strong>CUP SIZE</strong></td>
<td>1/2</td>
</tr>
<tr>
<td><strong>PREPARATION &amp; SIDE NUMBER</strong></td>
<td>45° Bevel: 1/8&quot; Land</td>
</tr>
<tr>
<td><strong>CLEANING</strong></td>
<td>Clean all slag with wire brush</td>
</tr>
<tr>
<td><strong>REPAIRS</strong></td>
<td>Repair any defects before next pass is put in</td>
</tr>
<tr>
<td><strong>TEMPERATURE</strong></td>
<td>60° Min</td>
</tr>
<tr>
<td><strong>INTERPASS TEMPERATURE</strong></td>
<td>INTERPASS</td>
</tr>
<tr>
<td><strong>NOTES:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ACTUAL TRAVEL SPEED (I.F.M.)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>FILLER METAL</strong></td>
<td></td>
</tr>
<tr>
<td><strong>AMPERAGE RANGE</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ARC VOLTAGE RANGE</strong></td>
<td></td>
</tr>
<tr>
<td><strong>WELDING POSITION</strong></td>
<td></td>
</tr>
<tr>
<td>10 - 12 IPM</td>
<td>0.045</td>
</tr>
<tr>
<td>10 - 12 IPM</td>
<td>210 - 230</td>
</tr>
<tr>
<td>10 - 12 IPM</td>
<td>27 - 29</td>
</tr>
<tr>
<td>10 - 12 IPM</td>
<td>OVHD</td>
</tr>
<tr>
<td>10 - 12 IPM</td>
<td>210 - 230</td>
</tr>
<tr>
<td>10 - 12 IPM</td>
<td>28 - 30</td>
</tr>
<tr>
<td>10 - 12 IPM</td>
<td>OVHD</td>
</tr>
</tbody>
</table>

**Control Panel Mode:**
- Power on -  ✓
- Weld/inch toggle switch: Weld  x
- Inch/pre-purge push button: Pre-Purge  —
- Wire feed speed control potentiometer  3.35
- Tractor Travel: Break-delay  — motion  A
- Tractor Travel: Left  — Right  x
- Tractor Travel Speed Control:  2.69
- Oscillation: normal  x delay  —
- Oscillation stroke: long  — short  —
- Oscillation speed control  —
- Stroke amplitude  — Outside dwell control  — Inside dwell control  —

**APPROVAL**

**DATE 4/78**

**GILLILAND MACHINE SETTINGS**

**FIGURE 29**
FIGURE 30 - GILLILAND WELDING UNIT IN OVERHEAD WELDING POSITION.
FIGURE 31 - GILLILAND WELDING UNIT IN OVERHEAD WELDING POSITION.
FIGURE 32 - GILLILAND WELDING UNIT IN OVERHEAD WELDING POSITION.