The Center for Naval Metalworking presents the Navy ManTech Project

S2831 – Semi-Automatic GTAW Welding Process

(A collaboration effort between ONR, CNM, Electric Boat and EWI)

POP June 2020 – February 2023

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Agenda

- Acknowledgements
- Background
- Objective
- Benefits
- Technical Approach
- Results

Photo source: https://news.usni.org/2019/09/13/general-dynamics-taps-new-leader-for-electric-boat

Acknowledgements

- Project funding provided by the Office of Naval Research (ONR) Navy ManTech Program
- Navy ManTech program oversight provided by
  - Jeff Farren – ONR Program Officer
  - Daniel Reed – CNM Project Manager
  - Paul Blomquist – CNM Technical Director
- General Dynamics Electric Boat
  - Maksim Vasilchenko – Project Manager
  - Luke Bittner – Technical Lead
- Edison Welding Institute
  - Larry Brown – Project Manager
  - Zane Bogosian – Technical Lead

Background

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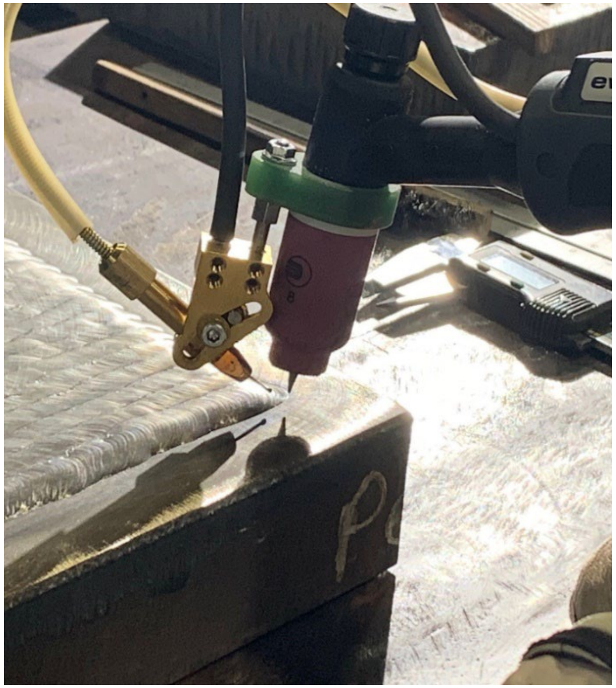
- GDEB currently uses labor-intensive manual Gas Tungsten Arc Welding (GTAW) operations and processes for cladding, pipe welding, alloy welding of tanks, and some structural welds on the VIRGINIA Class Submarine (VCS) and COLUMBIA Class Submarine (CLB)
- GDEB Operations identified this as a cost savings opportunity and high priority schedule risk
  - Manual GTAW requires a high level of craftsmanship, due to the dexterity required to manipulate the weld torch with one hand and feed the filler metal with the other hand.
  - Manual GTAW is very time consuming, particularly for large diameter circumferential welds

Objective

- GDEB proposes replacing select manual GTAW applications with a semi-automatic variant of the GTAW process. “Semi-Auto” refers to a portion of the process being automatic, which in this case is the mechanized feeding of the filler metal into the weld pool.



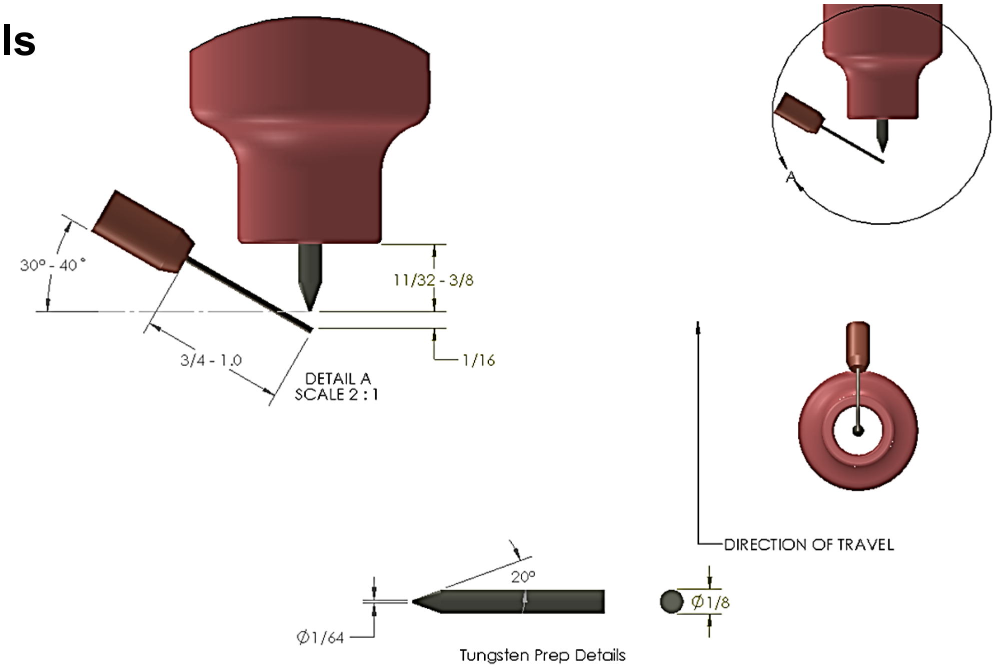
Benefits

- **By replacing manual GTAW with a semi-automatic variant, GDEB expects to be able to**
  - ↗ Significantly improve the deposition rate compared to manual GTAW where the filler metal is fed into the weld pool by hand.
  - ↗ For some applications, semi-automatic GTAW is projected to improve welding efficiency by 50% on average.

Photo source: https://www.ewm-group.com/en/downloads

Technical Approach

Torch Setup Details



Parameter	Value
Tungsten Extension (measured from gas cup)	11/32 – 3/8-in.
Wire Extension (measured from wire tip)	3/4 – 1-in.
Wire Entry Angle (measured from horizontal)	30 – 40°
Wire-to-Tungsten Distance	1/16-in.
Wire-to-Travel Direction Angle (measured from direction of travel)	20 – 30°
Tungsten Grind Angle	20°
Tungsten Blunt	1/64-in.

Technical Progress

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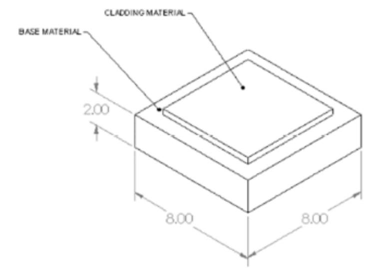
● *Candidate Part Identification*

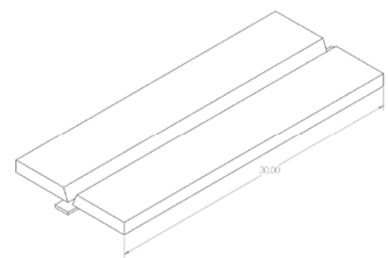
- Below are the candidate assemblies to be welded in phase I. These candidate assemblies were determined to give the most opportunity for improvement in duration of welding and first time quality.

Qualification Lanes	Application
Cladding	Select System Tanks
	Critical Castings
	Multiple System Valves
Structural	Ferrous and Non-Ferrous Tank Joints
	Duplex Structural Applications
Complex geometry	1.5”, 2.0”, and 3.0” Ø CuNi Boss Joints
	1.25”Ø CRES Boss Joints
	Specific Inconel Boss Joints
	Carbon Steel Boss Joints

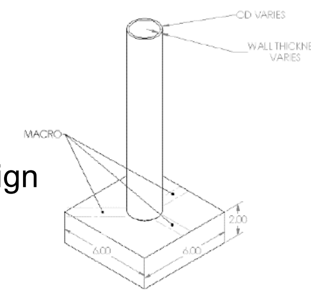
Cladding Test Coupon Design



Structural and Piping Test Coupon Design



Complex Geometry Test Coupon Design



Electric Boat EWI

NAVY MANTECH Manufacturing Technology Program

Technical Progress

- ***Semi-Auto GTAW Equipment Selection***

  - Below shows the evaluation factors:
    - Does the offered equipment have semi-automatic cold wire feed capability?
    - Does the offered equipment have automatic hot wire feed capability?
    - Does the offered equipment have wire oscillating capability?
    - Is the offered equipment compatible with any welding power supply?
    - Does the offered equipment have an available integrated power supply?
    - Is the vendor based in the USA?
    - Does the vendor offer training and/or support?
    - Did the vendor respond to all inquiries?
    - Was the vendor open to loaning equipment before purchasing/leasing?
    - Is the quoted system cost within the budgeted amount for the project?

•EWM tigSpeed System Selected

Photo source: https://www.ewm-group.com/en/downloads

Technical Progress

Determine NAVSEA Qualification Requirements

- Requirements defined for qualifying semi-automatic GTAW in accordance with NAVSEA Technical Publication S9074-AQ-GIB-010/248 Requirements for Welding and Brazing Procedure and Performance Qualification (Tech Pub 248)
  - *Position and Coupon Requirements for Qualification*
  - *Nondestructive Testing Requirements for Qualification*
  - *Destructive Testing Requirements for Qualification, per coupon*
  - *Novel Parameters specific to semi-automatic GTAW*


S9074-AQ-GIB-010/248

NAVSEA Technical Publication

REQUIREMENTS FOR WELDING AND BRAZING PROCEDURE AND PERFORMANCE QUALIFICATION

DISTRIBUTION STATEMENT A: APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

Novel Parameter	Setting
Hot Wire	Hot Wire On/Off
	Hot Wire Amperage Range
Wire Oscillation	Wire Oscillation On/Off
	Wire Oscillation Range (Hz)
Torch Setup	Tungsten to Wire Distance
	Tungsten to Wire Angle
	Wire to Travel Direction Angle

Technical Progress

● *Develop Welding Parameters*

- All evaluated semi-auto GTAW-weld parameters passed required NDT and destructive testing, thus validating developed semi-auto GTAW welding parameters for the material types and thicknesses evaluated.

NDT And Destructive Testing Summary

Assy. No.	Joint Type	Base Material 1	Base Material 2	Filler Metal	Destructive Testing							
					VT	PT	UT	RT	Cross Section Macros			Chemical Analysis
									1st	2nd	3rd	
1	Cladding	HY80	N/A	MIL-EN60	Pass	Pass	Pass		Pass	Pass	Pass	Complete
2	Cladding	HY80	N/A	MIL-EN60	Pass	Pass	Pass		Pass	Pass	Pass	Complete
3	Cladding	HY80	N/A	MIL-EN625	Pass	Pass	Pass		Pass	Pass	Pass	Complete
4	Cladding	HY80	N/A	MIL-EN625	Pass	Pass	Pass		Pass	Pass	Pass	Complete
7	B1V.1	QQ-N-281D	QQ-N-281D	MIL-EN60	Pass	Pass		Fail	Fail	Pass	Pass	
8	B1V.1	QQ-N-281D	QQ-N-281D	MIL-EN60	Pass	Pass		Fail	Pass	Pass	Pass	
8-1	B1V.1	QQ-N-281D	QQ-N-281D	MIL-EN60	Pass	Pass		Pass	Pass	Pass	Pass	
9	PT2V.5	UNS S31803	UNS S31803	ER2209	Pass	Pass	Fail		Fail	Pass	Pass	
10	PT2V.5	UNS S31803	UNS S31803	ER2209	Pass	Pass	Pass		Pass	Pass	Pass	
11	B2V.2	UNS S31803	UNS S31803	ER2209	Pass	Pass		Pass	Pass	Pass	Pass	
12	B2V.2	UNS S31803	UNS S31803	ER2209	Pass	Pass		Pass	Pass	Pass	Pass	
13	PT2S.1	UNS S31803	UNS S31803	ER2209	Pass	Pass	Pass		Pass	Pass	Pass	
14	PT2S.1	UNS S31803	UNS S31803	ER2209	Pass	Pass	Pass		Pass	Pass	Pass	
15	T1V.1	UNS S30400	UNS S30400	MIL-308L	Pass	Pass	Pass		Pass	Pass	Pass	
16	T1V.1	UNS S30400	UNS S30400	MIL-308L	Pass	Pass	Pass		Pass	Pass	Pass	
17	PT2V.5	UNS S30400	UNS S30400	MIL-308L	Pass	Pass	Pass		Pass	Pass	Pass	
18	PT2V.5	UNS S30400	UNS S30400	MIL-308L	Pass	Pass	Pass		Pass	Pass	Pass	
19	C2V.5	UNS S30400	UNS S30400	MIL-308L	Pass	Pass	Pass		Pass	Pass	Pass	
20	C2V.5	UNS S30400	UNS S30400	MIL-308L	Pass	Pass	Pass		Pass	Pass	Pass	
21	P-72	C71500	QQ-N-281D	MIL-EN60	Pass	Pass			Pass	Pass	Pass	
22	P-72	C71500	QQ-N-281D	MIL-EN60	Pass	Pass			Pass	Pass	Pass	
23	P-72	C71500	QQ-N-281D	MIL-EN60	Pass	Pass			Pass	Pass	Pass	
24	P-72	C71500	QQ-N-281D	MIL-EN60	Pass	Pass			Pass	Pass	Pass	
27	P-72	CRES	UNS S30400	MIL-308L	Pass	Pass			Pass	Pass	Pass	
28	P-72	CRES	UNS S30400	MIL-308L	Pass	Pass			Pass	Pass	Pass	
29	P-72	Inconel 625	Inconel 625	MIL-EN625	Pass	Pass			Pass	Pass	Pass	
30	P-72	Inconel 625	Inconel 625	MIL-EN625	Pass	Pass			Pass	Pass	Pass	
31	P-72	ASTM A234 Grade WPB	ASTM A515 Gr. 65	MIL-70S-3	Pass	Pass			Pass	Pass	Pass	
32	P-72	ASTM A234 Grade WPB	ASTM A515 Gr. 65	MIL-70S-3	Pass	Pass			Pass	Pass	Pass	

Technical Progress

● *Execute the Weld Quality Test Plan*

- Weld Quality Testing Results
- All evaluated test assemblies met NDT and destructive testing acceptance criteria, thus validating developed semi-auto GTAW welding parameters for the material types and thicknesses evaluated.

Application	Assy. No.	Joint Type	Position	Base Material	Filler Material	NDT			Destructive Testing											
						VT	PT	RT	Side Bends			Macros			Tensile Tests					Ferrite Content
															AWM		Transverse			
									1st	2nd	3rd	1st	2nd	3rd	1st	2nd	1st	2nd	3rd	
System Tank	WQA_1	Cladding	Flat (1G)	HY80	EN60															
Critical Casting	WQA_2	Cladding	Flat	HY80	EN625															
Valve X	WQA_3	Cladding	(1G)	HY100	EN625															
Joint	WQA_4	B1V.1	Vertical (3G)	QQ-N-281D	EN60															
CWST (low heat input)	WQA_5	B1V.1	Vertical (3G)	S31083	ER2209															
CWST (high heat input)	WQA_6	B1V.1	Vertical (3G)	S31083	ER2209															
CWST (repair)	WQA_7	B1V.1	Vertical (3G)	S31083	ER2209															
INDUCT Sump Tank	WQA_8	B1V.1	Vertical (3G)	S30400	308L															
CuNi Boss Joint	WQA_9	B1V.1	Horizontal (2G)	C71500	EN60															
CRES Boss Joint	WQA_10	B1V.1	Horizontal (2G)	S30400	308L															
Inconel Boss Joint	WQA_11	B1V.1	Horizontal (2G)	Inconel 625	EN625															
Carbon Steel Boss Joint	WQA_12	B1V.1	Horizontal (2G)	515 Gr. 65	70S-3															

Technical Progress - Video

Technical Progress

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Create Shipyard Evaluation Test Plan

- Rather than replicating every test assembly completed by EWI during previous tasks, the shipyard testing will focus on the viability of the weld parameters and process using Electric Boat facilities and personnel. Thus, a selection of weld assemblies have been identified for each application type.
- Nondestructive testing is specified to verify weld quality, and shall be conducted in accordance with practices for weld procedure qualification.

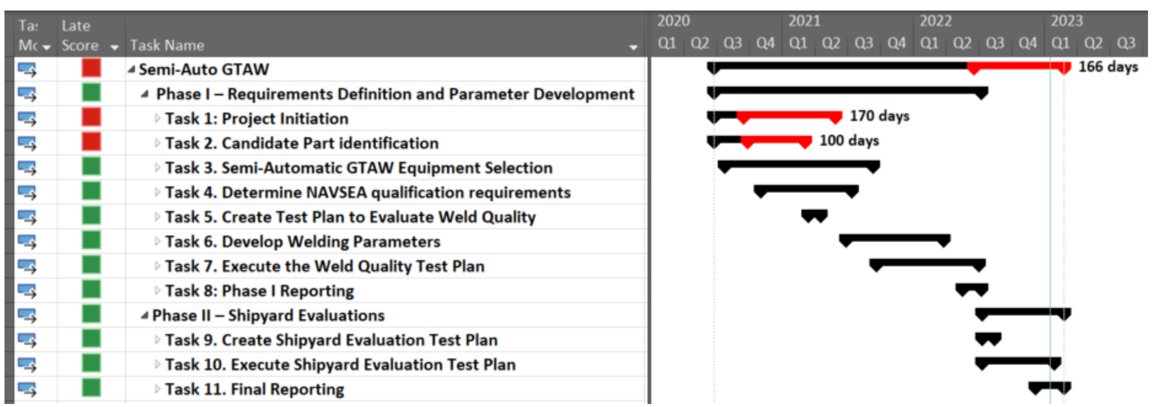
Assembly #	Base Material	Filler/Cladding Material	Position	Dimensions	Notes
1	HY-80	CuNi Cladding	Flat	2” thick plate	High Heat Input
2	HY-80	Inco 625 Cladding	Flat	2” thick plate	High Heat Input
3	NiCu	NiCu	Vertical	1” thick, butt weld	High Heat Input
4	Duplex	Duplex	Vertical	1.5” thick, butt weld	Fast Cooling Rate
5	CRES	CRES	Vertical	1” thick, butt weld	High Heat Input
6	CuNi	NiCu	Vertical	1” thick, butt weld	High Heat Input
7	CuNi	NiCu	Horizontal Fixed	1.5” Boss	
8	CuNi	NiCu	Horizontal Fixed	3.0” Boss	
9	CRES	CRES	Horizontal Fixed	1.25” Boss	
10	Inco 625	Inco 625	Horizontal Fixed	1.5” Boss	
11	Carbon Steel	MIL-70S	Horizontal Fixed	1.0” Boss	

Technical Progress

- ***Shipyard Evaluation Test Plan***

Status

Task No.	Description	Status
1	Project Initiation	100%
2	Candidate Part Identification	100%
3	Semi-Automatic GTAW Equipment Selection	100%
4	Determine NAVSEA Qualification Requirements	100%
5	Create Test Plan to Evaluate Weld Quality	100%
6	Develop Welding Parameters	100%
7	Execute the Weld Quality Test Plan	100%
8	Phase I Reporting	100%
9	Create Shipyard Evaluation Test Plan	100%
10	Execute Shipyard Evaluation Test Plan	100%
11	Final Reporting	100%



Results

- Projected savings over a 5-year period will include 9 VPM hulls, 1 VCS hull and 2.5 COLUMBIA hulls
- Projected 5-year EROM Savings = $14M
- ROI = 4.46

Questions?

Enabling better quality welds at a higher deposition rates compared to manual Gas Tungsten Arc Welding (GTAW)

Project Number: S2831
Title: Semi-Automatic GTAW Welding Process
Performing Activity: Center for Naval Metalworking (CNM)
Objectives: Use semi-automatic GTAW welding equipment to increase production throughput.
Start / End Dates: Jul 20 – Feb 23
Project Cost:
ManTech Investment: $2.1M
Weapon System: VIRGINIA Payload Module (VPM), COLUMBIA (CLB) Class

Performing Entities:

- Navy ManTech – Program Oversight
- CNM – Project Management / Technical Oversight
- PMS 450, 397 – Project Oversight
- GDEB – Project Lead
- EWI – Technical Execution/Support

Technical Achievements:

Jun	**20**	**Project Initiation**
Oct	**20**	**Candidate Applications Report**
Jul	**21**	**Equipment Selection Report**
Jul	**21**	**Weld Qualification Requirements Summary**
Apr	**21**	**Weld Quality Test Plan**
Mar	**22**	**Weld Parameter Report**
Jul	**22**	**Weld Quality Test Report**
Aug	**22**	**Shipyard Evaluation Test Plan**
Jan	**23**	**Shipyard Evaluations Report**
Jan	**23**	**Implementation Plan and Business Case**
Feb	**23**	**Final Report**

Implementation:

System: VPM, CLB
Site: General Dynamics Electric Boat (GDEB) – Quonset Point, RI
Schedule: June 2022
Status: On track - implementation anticipated 2Q FY24 (SSN-808; SSBN-826)

Cost
Schedule
Technical

Payoff:

- Reduction in time for pipe bosses
- Reduction in time for DST (Cladding)
- Reduction in time for assorted small alloy tanks
- Savings:
  - Projected 5-year savings: $14M
  - Projected 5-year ROI: 4.46

Integrated Project Team

CENTER FOR NAVAL METALWORKING

NAVY MANTECH

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