NSRP | National Shipbuilding Research Program

GMAW Electrode and Procedure Technology for Silicate-Free Weld Deposition

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Overview

- Project Team
- Background
- Bead on Plate Trials
- Qualification Demonstration Testing
- Conclusions

Project Team

- EWI (prime)
  - Jim Hansen (PI), Joe Getgen (Engineering support), Dennis Harwig (Senior Technical Leader)
  - Katie Hardin (PM), Mark Schimming (VP Govt Business)
- ATI PM
  - Ryan Schneider
- NSRP Program Technical Representative (PTR)
  - Paul Hebert
- Participant
  - HII-Ingalls – John Walks, Kevin Roossinck
  - NSWCCD – Matt Sinfield
  - Ravi Menon – ESAB

Background

- In GMAW of shipbuilding steels, silicates (small slag islands) form on the weld deposit surface and must be removed prior to multipass welding and before structural painting
  - A new silicate-free wire has been developed by ESAB for lean CO_2 shielding
    - This wire has produced sound deposits in industrial fillet welding evaluations
  - Need to evaluate, apply, and / or modify silicate free electrodes for multi-pass groove welding to improve shipbuilding productivity and affordability

Goals

- Develop silicate-free GMAW technology mitigating the need for multipass weld interpass cleaning
- Explore & demonstrate (if possible) use with existing procedures , classify within existing Tech Pub 248 groupings, and expedite impact across shipyards using existing procedures

Technical Objectives

- Develop a matrix of welding procedures for tandem GMAW (T-GMAW) process at minimum and maximum heat inputs for two HSLA-65 steel plate thicknesses
  - Min / max HI based on existing Ingalls T-GMAW procedures
- Evaluate the T-GMAW properties using representative procedure qualification tests per MIL-STD-271 and Tech Pub 248
  - Coordinate with NSWCCD to identify requirements for MIL-Spec classification
  - Compare qualification results to MIL-70S-6 weld wire
- Determine next steps to drive transition of the silicate-free wire technology into NSRP member shipyards
  - Silicate-free T-GMAW Demonstration & Transition workshop at EWI

Task 1 – Project Initiation and Kickoff Meeting:

- Initiate project – issue subcontracts
- Project kickoff meeting – discuss project and select candidate application
  - Current MIL-70S-6 procedures provided by Ingalls for 0.5″ and 1″ thick HSLA-65 plate
  - HSLA-65 plate provided by Ingalls

Task 2 – Develop T-GMAW Procedures Using Silicate-Free Electrode

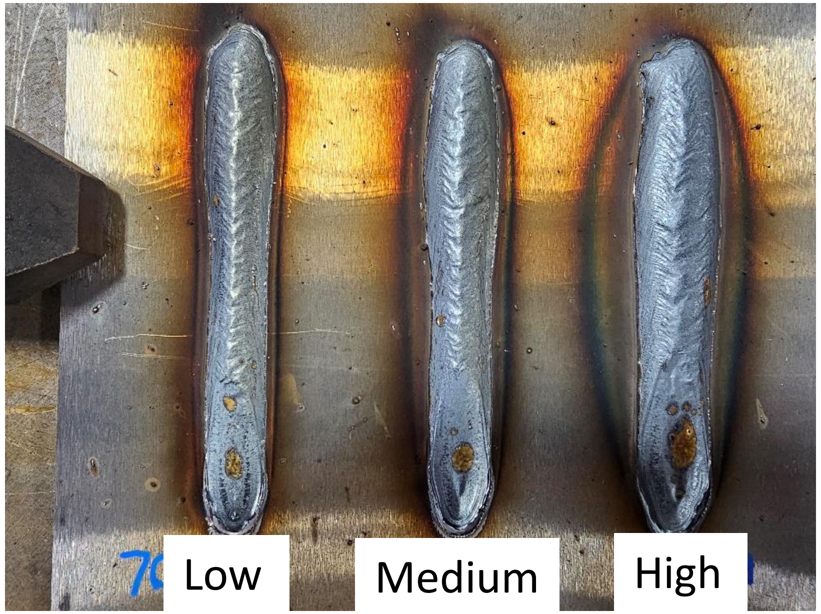
- T-GMAW selected to directly support panel line processes for maximum productivity on long V-groove butt joints
  - Screen existing electrode and discuss any modifications with ESAB to meet property and classification requirements for MIL-STD electrode
  - Develop procedure matrix at min / max heat inputs for two HSLA-65 steel plate thicknesses
    - If possible, use procedures within qualified range of existing procedure to demonstrate equivalence
  - Compare T-GMAW procedures of silicate-free and MIL-70S-6 with matching shielding gas (94% Ar – 6% CO_2)
    - High speed video analysis will be utilized to compare metal transfer between the two electrodes

Bead on Plate Benchmarking Study

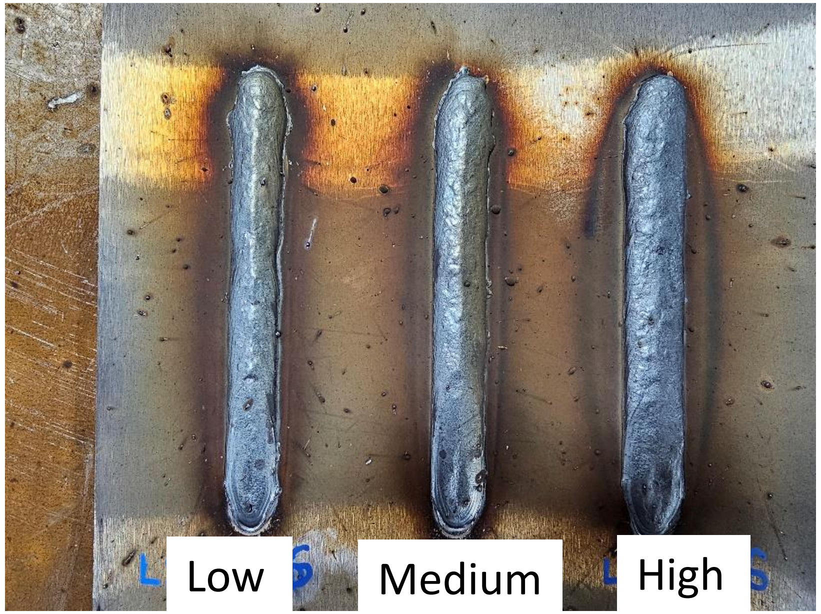
- Reduced silicate wire resulted in no silicate islands left on the weldment.
- After thorough wire brushing some silicates remained on the legacy wire weldments.
- Legacy wire had an improved toe angle and appearance.
  - Wetting characteristics were similar when the pool was molten.
- The following slides show bead on plate comparison between legacy MIL-70S-6 electrode and reduced silicate electrode.

Bead on Plate Benchmarking Study

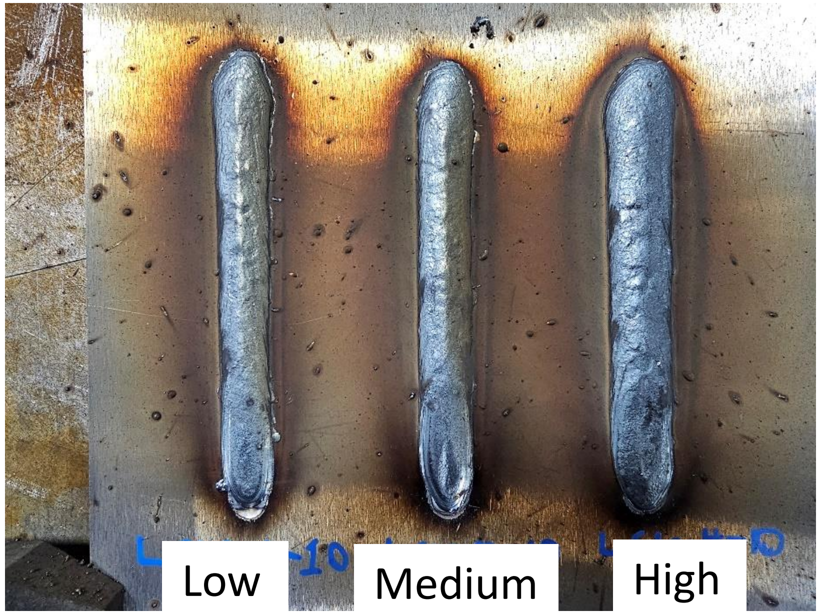
- Bead on plate weld prior to cleaning bead surface



Legacy MIL-70S6
94% Ar – 6% CO_2



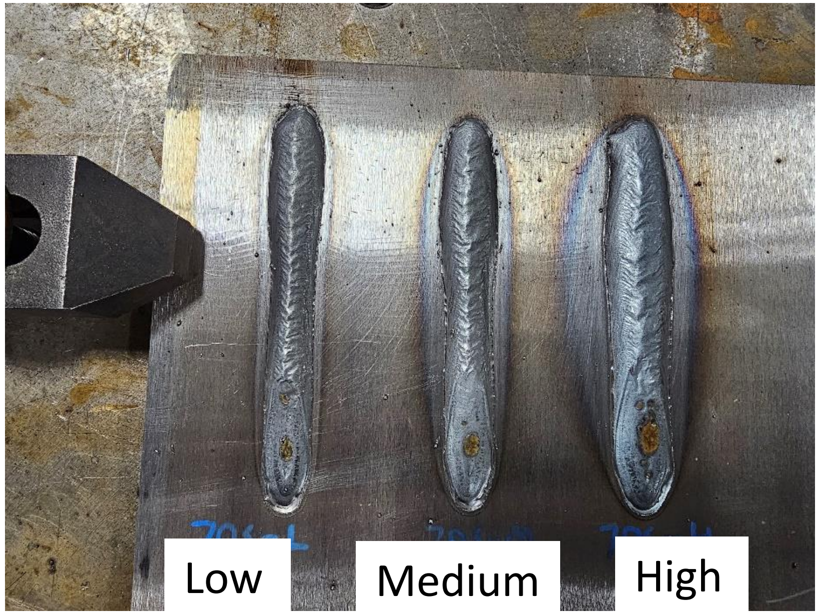
Low Silicate Electrode
94% Ar – 6% CO_2



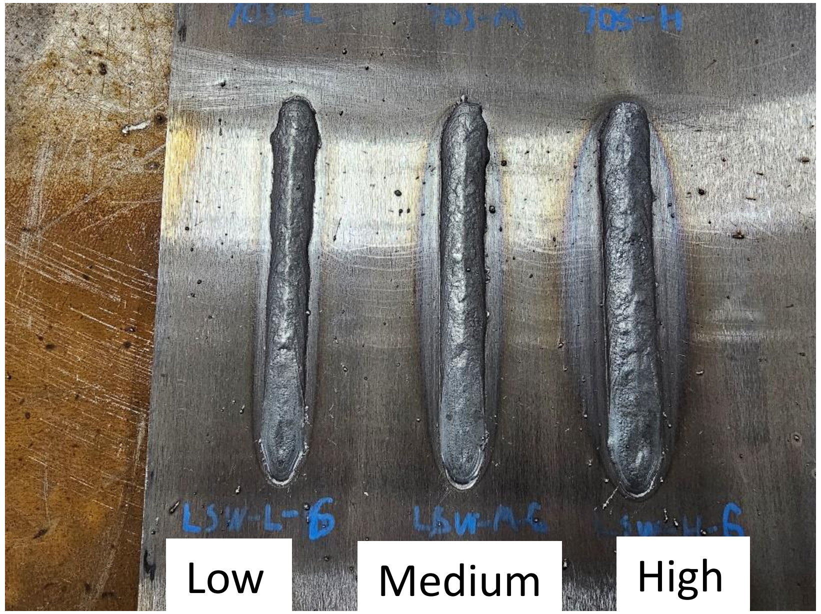
Low Silicate Electrode
90% Ar – 10% CO_2

Bead on Plate Benchmarking Study

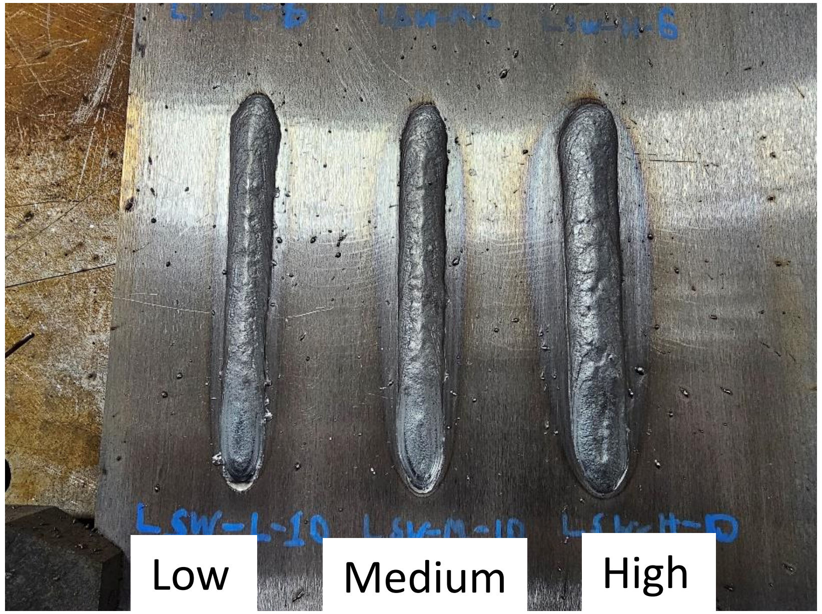
- Bead on plate welds after cleaning bead surface



Legacy MIL-70S6
94% Ar – 6% CO_2

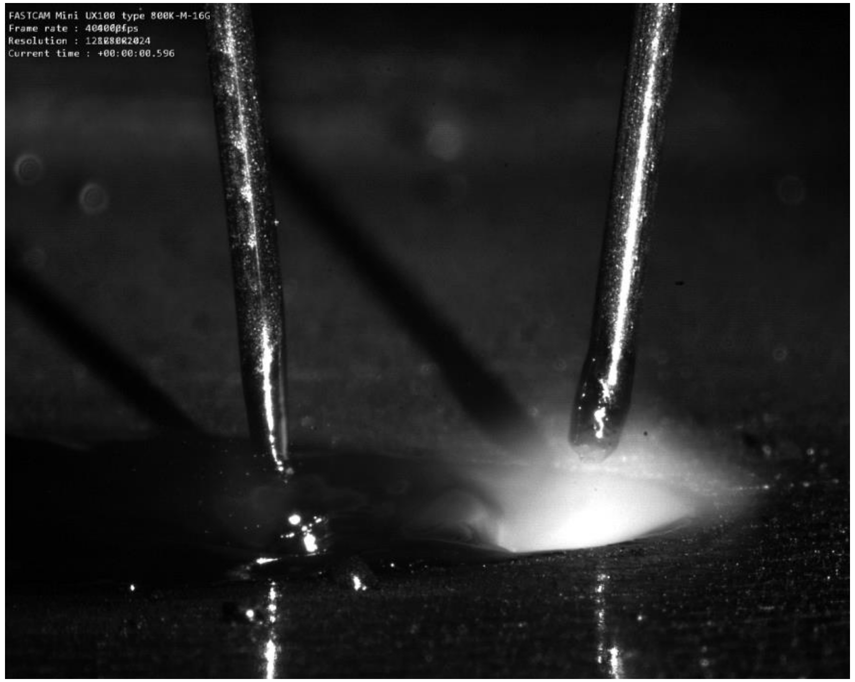


Low Silicate Electrode
94% Ar – 6% CO_2

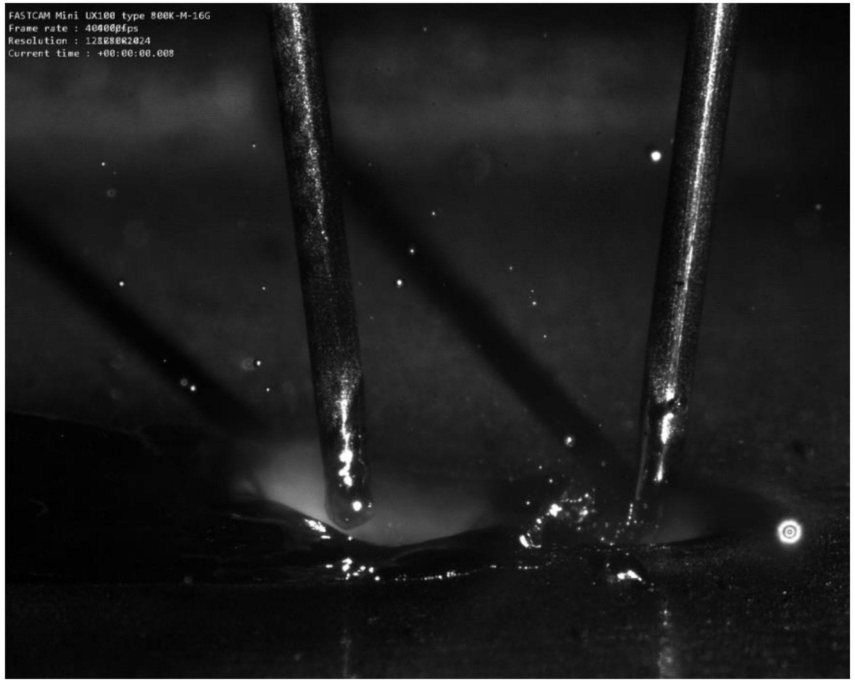


Low Silicate Electrode
90% Ar – 10% CO_2

High-Speed Video Benchmarking



Direction of Travel



Legacy 70S-6 Wire

Reduced Silicate Wire

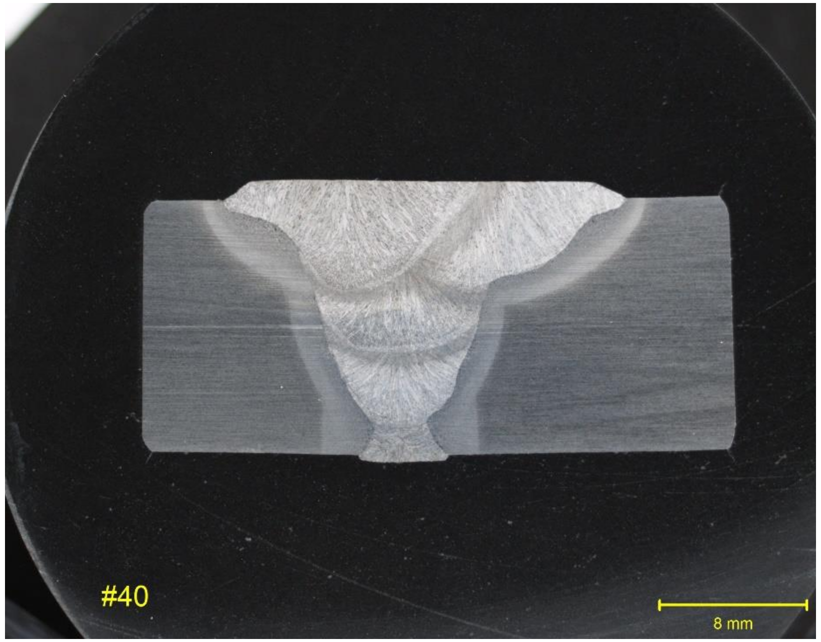
- Reduced silicate wire operated at a shorter arc length when welded at the same parameter set as the MIL-70S-6.
- Similar levels of process stability across both electrodes analyzed

Task 3 – Representative Welding Procedure Qualification Tests and Property Evaluation of T-GMAW V-Groove Butt Joints

- Evaluate properties of the T-GMAW HSLA-65 Representative PQRs
  - Fabricate two silicate free T-GMAW (min and max heat input) and one MIL-70S-6 T-GMAW baseline at each thickness per Tech Pub 248
  - NDT per MIL-STD-271 and MIL-STD-2035A
  - Destructively test (tensiles, bends, Charpys) per Tech Pub 248 and NSWCCD requirements for electrode classification
    - Deposit composition, microhardness distribution maps, and microstructure analysis will also occur to correlate any changes to properties
  - B1V.1 joint design with a 3/32" root opening on copper backing

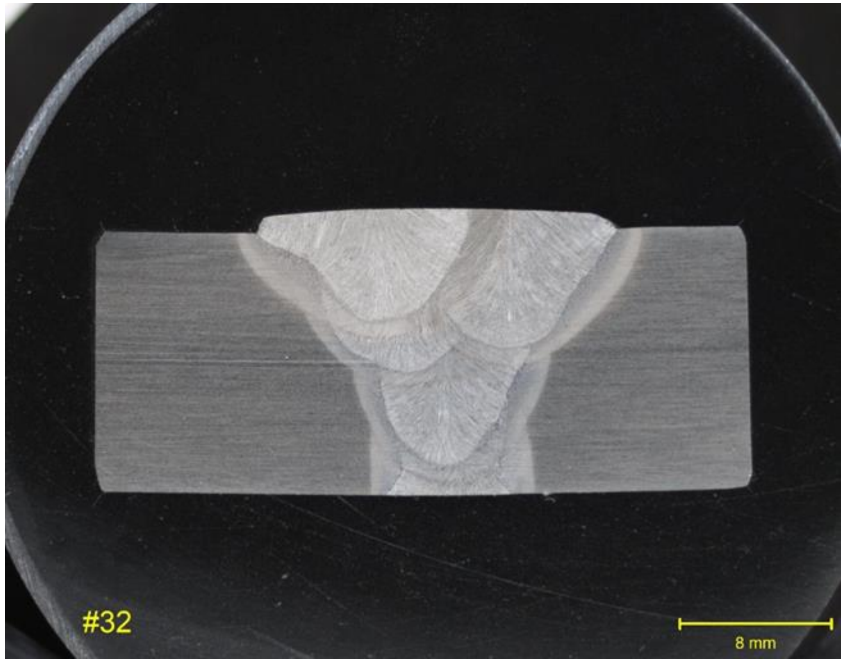
Legacy MIL-70S-6 0.5" Plate

- Weldment inspected to MIL-STD 2035, Class 1
  - VT, MT, UT, RT
- 2 Tensile Tests – Pass, Average UTS: 85,940 psi
- 2 Face Bends – Pass
- 2 Root Bends – Pass
- Charpy V-Notch – -20 °F Test Temperature
  - 4 Weld Centerline – Pass
    - Average Impact: 125 J
  - 3 HAZ – Pass
    - Average Impact: 207 J
  - 3 Base Metal – Pass
    - Average Impact: 300 J +
- Macro Specimen – Pass



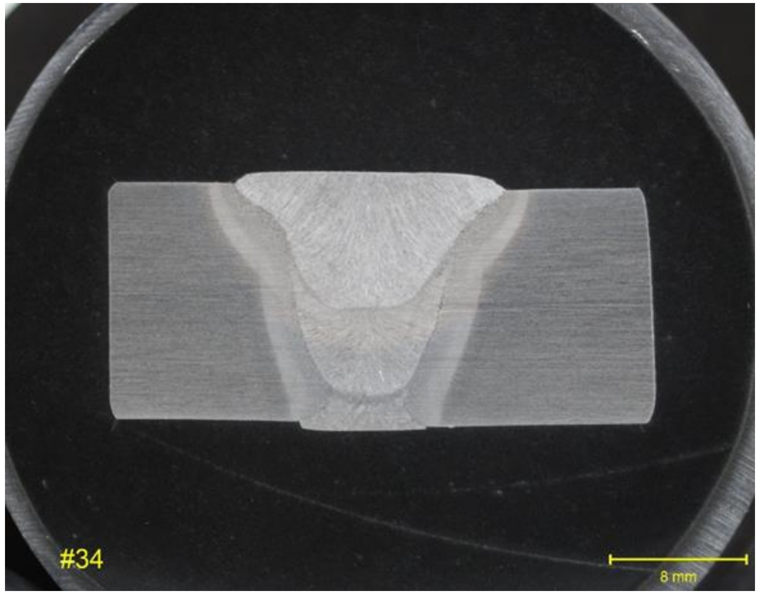
Reduced Silicate Low Heat Input 0.5″ Plate

- Weldment inspected to MIL-STD 2035, Class 1
  - VT, MT, UT, RT
- 2 Tensile Tests – Pass, Average UTS: 86,330 psi
- 2 Face Bends – Pass
- 2 Root Bends – Pass
- Charpy V-Notch – -20 °F Test Temperature
  - 4 Weld Centerline – Pass
    - Average Impact: 50 J
  - 3 HAZ – Pass
    - Average Impact: 224 J
  - 3 Base Metal – Pass
    - Average Impact: 300 J +
- Macro Specimen – Pass



Reduced Silicate High Heat Input 0.5” Plate

- Weldment inspected to MIL-STD 2035, Class 1
  - VT, MT, UT, RT
- 2 Tensile Tests – Pass, Average UTS: 86,510 psi
- 2 Face Bends – Pass
- 2 Root Bends – Pass
- Charpy V-Notch – -20 °F Test Temperature
  - 4 Weld Centerline – Pass
    - Average Impact: 50 J
  - 3 HAZ – Pass
    - Average Impact: 182 J
  - 3 Base Metal – Pass
    - Average Impact: 300 J +
- Macro Specimen – Pass

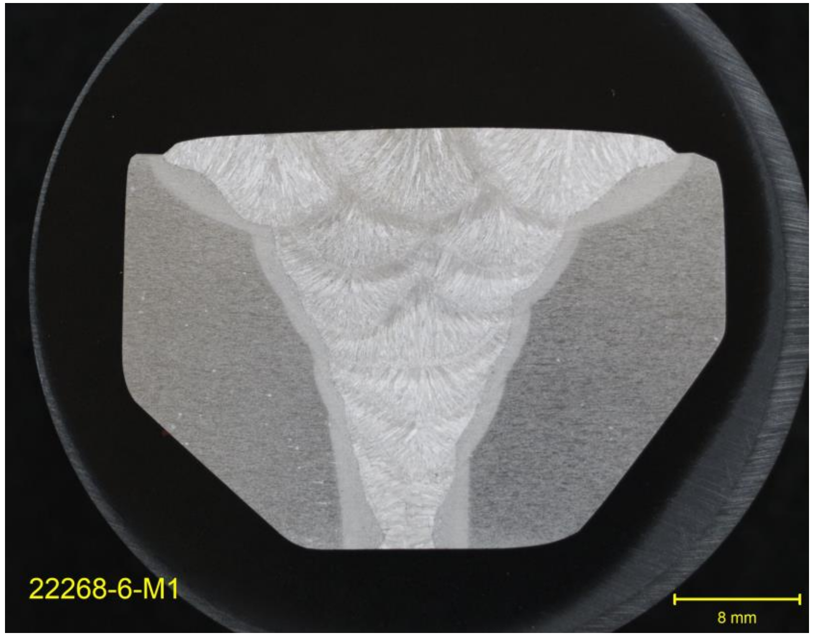


0.5" Plate Comparison

	NDE	Tensile (psi)	Face Bend	Root Bend	Weld Metal Charpy (J)	HAZ Charpy (J)
Legacy Electrode	Pass	85,940	Pass	Pass	125	207
Reduced Silicate Low Heat Input	Pass	86,330	Pass	Pass	50	224
Reduced Silicate High Heat Input	Pass	86,510	Pass	Pass	50	182

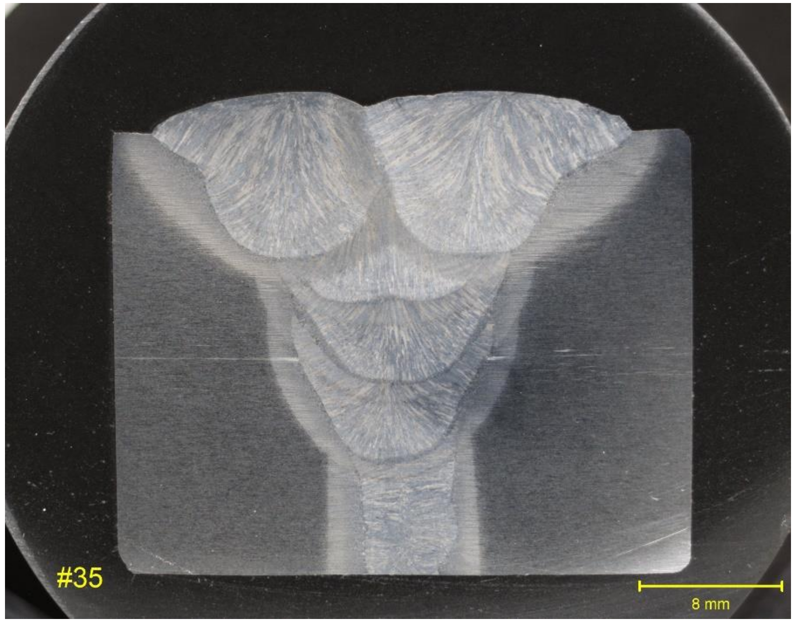
Legacy MIL-70S-6 1.0" Plate

- Weldment inspected to MIL-STD 2035, Class 1
  - VT, MT, UT, RT
- 2 Tensile Tests – Pass, Average UTS: 85,920 psi
- 2 Face Bends – Pass
- 2 Root Bends – Pass
- Charpy V-Notch – -20 °F Test Temperature
  - 4 Weld Centerline – Pass
    - Average Impact: 161 J
  - 3 HAZ – Pass
    - Average Impact: 226 J
  - 3 Base Metal – Pass
    - Average Impact: 300 J +
- Macro Specimen – Pass



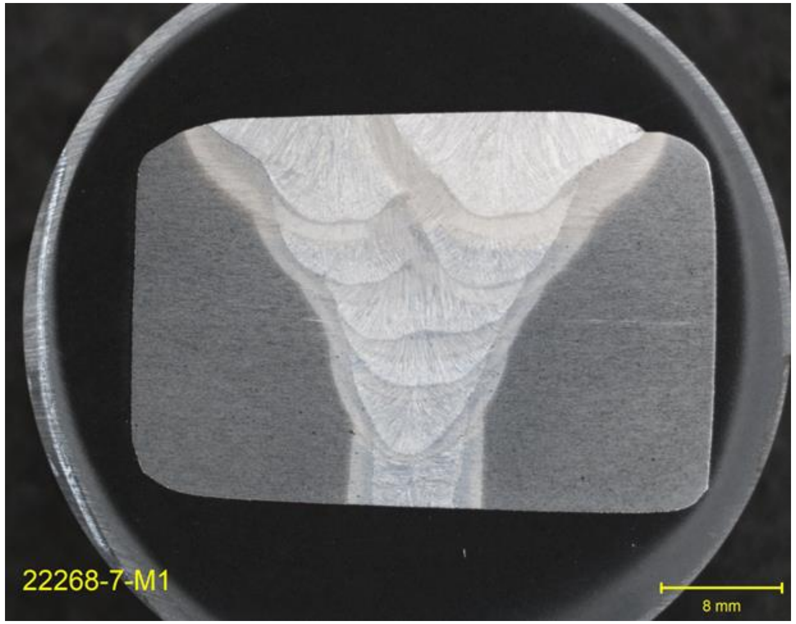
Reduced Silicate Low Heat Input 1.0″ Plate

- Weldment inspected to MIL-STD 2035, Class 1
  - VT, MT, UT, RT
- 2 Tensile Tests – Pass, Average UTS: 86,010 psi
- 2 Face Bends – Pass
- 2 Root Bends – Pass
- Charpy V-Notch – -20 °F Test Temperature
  - 4 Weld Centerline – Pass
    - Average Impact: 37 J
  - 3 HAZ – Pass
    - Average Impact: 263 J
  - 3 Base Metal – Pass
    - Average Impact: 300 J +
- Macro Specimen – Pass



Reduced Silicate High Heat Input 1.0" Plate

- Weldment inspected to MIL-STD 2035, Class 1
  - VT, MT, UT, RT
- 2 Tensile Tests – Pass, Average UTS: 86,065 psi
- 2 Face Bends – Pass
- 2 Root Bends – Pass
- Charpy V-Notch – -20 °F Test Temperature
  - 4 Weld Centerline – Pass
    - Average Impact: 60 J
  - 3 HAZ – Pass
    - Average Impact: 191 J
  - 3 Base Metal – Pass
    - Average Impact: 300 J +
- Macro Specimen – Pass



1.0" Plate Comparison

	NDE	Tensile (psi)	Face Bend	Root Bend	Weld Metal Charpy (J)	HAZ Charpy (J)
Legacy Electrode	Pass	85,920	Pass	Pass	161	226
Reduced Silicate Low Heat Input	Pass	86,010	Pass	Pass	37	263
Reduced Silicate High Heat Input	Pass	86,065	Pass	Pass	60	191

Chemical Composition Comparison

Legacy Electrode

Analyte	Average
Specimen ID	Legacy Elecrode
Number of Burns	6
C	0.076
Mn	1.39
Si	0.74
P	0.014
S	0.009
Cr	0.036
Ni	0.087
Mo	0.001
Cu	0.120
V	0.004

Reduced Silicate Electrode

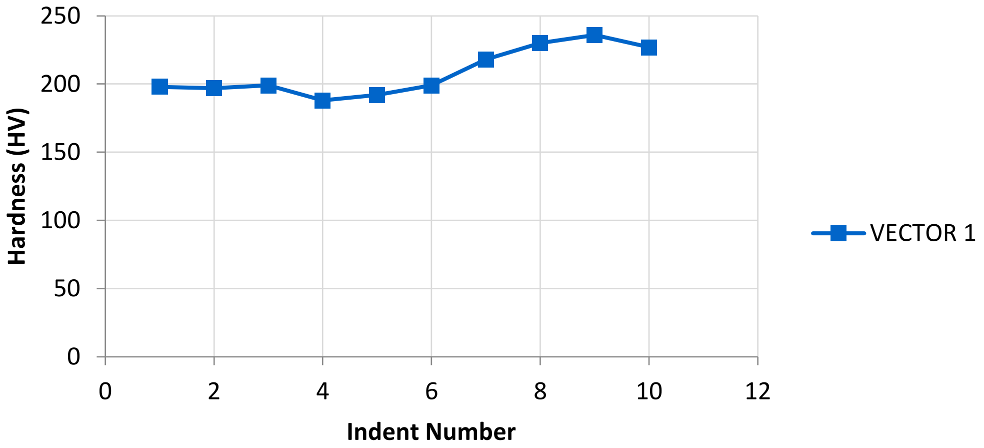
Analyte	Average
Specimen ID	Reduced Silicate
Number of Burns	6
C	0.096
Mn	1.48
Si	0.13
P	0.012
S	0.006
Cr	0.108
Ni	0.382
Mo	0.014
Cu	0.170
V	0.014

Hardness Map Comparison

Legacy Electrode

Indent #	Distance	Hardness	HRB	HRC	Location
1	0.1032 mm	198 HV	93 HRB		BASE METAL
2	0.5995 mm	197 HV	93 HRB		BASE METAL
3	1.1001 mm	199 HV	93 HRB		BASE METAL
4	1.6025 mm	188 HV	91 HRB		BASE METAL
5	2.0984 mm	192 HV	92 HRB		HAZ
6	2.5993 mm	199 HV	93 HRB		HAZ
7	3.1001 mm	218 HV	97 HRB		HAZ
8	3.6000 mm	230 HV	98 HRB		WELD
9	4.0993 mm	236 HV	99 HRB	21 HRC	WELD
10	4.6024 mm	227 HV	98 HRB		WELD

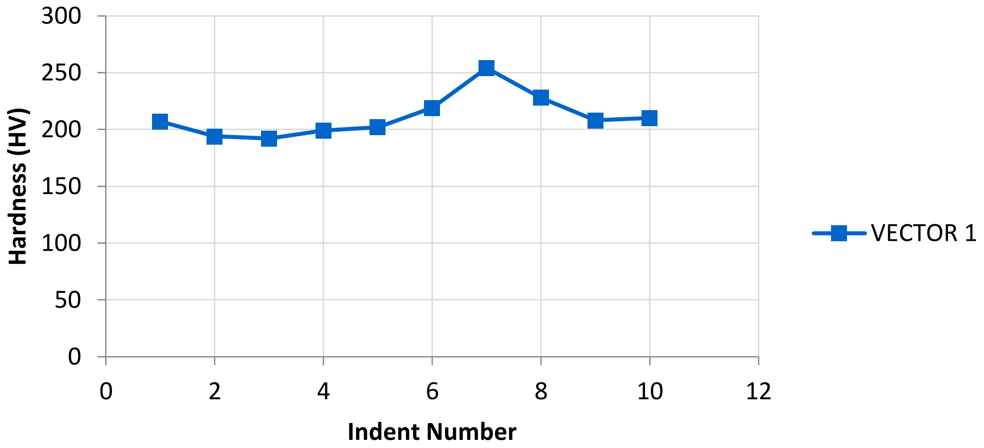
VECTOR 1



Reduced Silicate Electrode

Indent #	Distance	Hardness	HRB	HRC	Location
1	0.1040 mm	207 HV	95 HRB		BASE METAL
2	0.6030 mm	194 HV	92 HRB		BASE METAL
3	1.1010 mm	192 HV	92 HRB		BASE METAL
4	1.6029 mm	199 HV	93 HRB		BASE METAL
5	2.1028 mm	202 HV	94 HRB		HAZ
6	2.6016 mm	219 HV	97 HRB		HAZ
7	3.1010 mm	254 HV		23 HRC	HAZ
8	3.6012 mm	228 HV	98 HRB		WELD
9	4.1007 mm	208 HV	95 HRB		WELD
10	4.6023 mm	210 HV	95 HRB		WELD

VECTOR 1



Task 4 – Silicate-Free T-GMAW Demo, Next Steps, and Technology Transition

- Host workshop with shipyard participants – March 27th
  - Demonstrate silicate-free electrode procedures
  - Review project results
  - Next steps to support implementation
  - Tech Transition
    - Procedures and data will be available to potential U.S. shipbuilding industry users
    - Progress reports will be made to NSRP Panels throughout the project
    - Project results will be documented in a final written report and disseminated via NSRP

Project Conclusions

- The reduced silicate wire resulted in silicate free weld deposits with comparable NDE and mechanical test results
- When utilizing 94% Ar – 6% CO_2 shielding gas toe wettability was reduced when using the reduced silicate electrode
  - The addition of a small weave helped to ensure better tie in to compensate for reduced wettability
  - Switching to a 90% Ar – 10% CO_2 shielding gas resulted in better toe wettability during bead on plate trials

Questions?