

# **Qualification of VBAC Submerged Arc Welding Procedures and Metal Cored Electrodes to ABS Rules for Panel Welding**

***Project Lead***

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***Project Team***

*NASSCO*

*Hobart Brothers*

*Miller Electric*

***SP7 Welding Technology Panel Meeting***

***Dayton OHIO***

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- **OUTLINE**

- **Background**
- **Task 1 – ABS Qualification of Metal Cored Electrodes for HSLA-65 and EH36 Steels**
- **Task 2 – ABS Qualification of VBAC SAW Procedures for HSLA-65 and EH36 Steels**
- **Project Status**
- **Questions?**

## BACKGROUND

- In a recent NSRP project (ref TIA 2005-386) highly productive tandem SAW procedures were developed for ½” and 1” thick DH36, HSLA-65, and HSLA-100 steels, using Miller’s VBAC technology with specifically formulated metal cored electrodes
  - Single pass one sided welding (OSW) onto a modified FCB for ½” and 1” thick DH36 and HSLA-65 steels
    - ½” plate at 30 inches per minute (ipm) travel speed, **deposition rate of 75 lbs/hr**
    - 1” plate welded at 20.5 ipm, **deposition rate of 112 lbs/hr**
  - Two sided welding (one pass per side) with no back gouging of ½” (**deposition rate of 85 lbs/hr**) and 1” thick HSLA-100 steel, **each pass at 45 ipm (deposition rate of 112 lbs/hr)**
- Project Recommended by NASSCO to Qualify Welding Consumables and Procedures to ABS Rules

## INITIAL OBJECTIVES

- **Task 1 - Qualify Metal Cored Electrodes to ABS Rules designed for EH36 and HSLA-65 Steels, Manufactured by Hobart**
  - **EH36 Weld Metal Targets**
    - **Min. 58ksi YS, 71 to 95ksi UTS, and 20% Elongation**
    - **Impacts of 20ft-lbs @ -20F**
  - **HSLA-65 Weld Metal Targets**
    - **Min. 65ksi YS, 20% Elongation**
    - **Impacts of 30 ft-lbs @ -20F**

Compositions (%)																	
C	Mn	Si	S	P	Ni	Cr	Mo	Al	B	Cu	Zr	Nb	Ti	V	N	O	Pcm
0.060	1.400	0.550	0.002	0.002	0.500	0.015	0.150	0.004	0.004	0.060	0.008	0.002	0.015	0.001			0.191

- **Single Chemistry with Lincoln MIL800-H flux to satisfy both steel requirements**
- **Estimate 78-85ksi Weld Metal YS, 88-95ksi UTS, 24% Elongation, and 100ft-lb impacts @ -20F, at heat inputs up to 215kJ/in (combined in tandem)**

## INITIAL OBJECTIVES

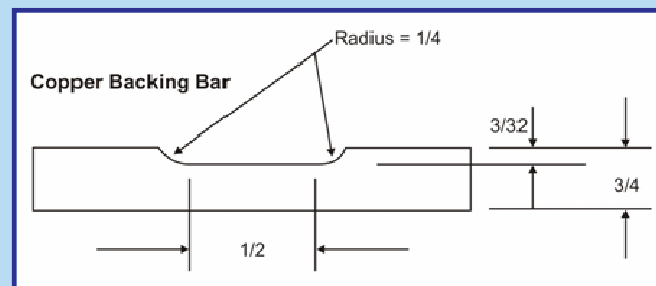
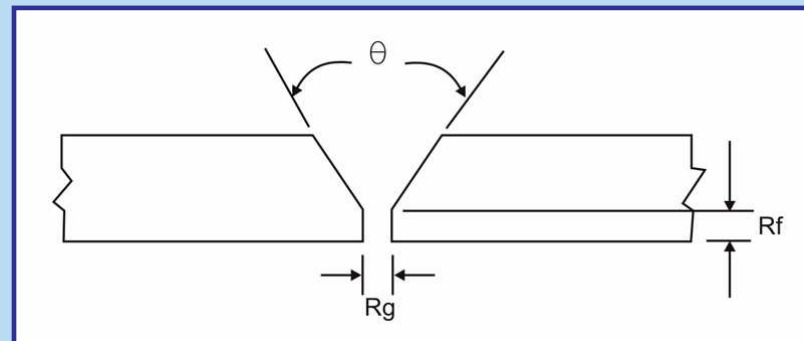
- **Task 1 – CHANGE OF PLAN FOR EH36 CONSUMABLE QUALIFICATION**
  - After Discussions with ABS, it was decided that the EH36 One Sided Welding Procedure Qualification (single pass 1 inch thickness) will be used to ALSO qualify the “electrode”, provided that the weld metal ALSO meets the CVN impact energy of 25 ft-lbs at -40F and -4F, at the subsurface (cap and root side) and T/2 locations, extracted and tested from the weld centerline of the procedure qualification weldment.
    - ABS Plate EH36 Spec of 25 ft-lbs (Longitudinal) @ -40F
    - ABS 3Y Weld Metal Qualification of 25 ft-lbs @ -4F

## PROCEDURE QUALIFICATION TEST MATRIX

- All plates to be radiographed
- 1/2" Plates
  - 2 Cross Weld Tensiles
  - 1 Macro / Micro / Hardness
  - 2 Root Bends and 2 Face Bends for OS Welds
  - 4 Side Bends for Two Sided Welds
  - Charpy V-notch Impact @ T/2
    - 5 Weld Centerline, 5 Fusion Line, 5 Fusion Line + 1mm, and 5 Fusion Line + 3mm
- 1" Plates
  - 2 Cross Weld Tensiles
  - 1 All Weld Metal Tensile (centered at 1/4" below Side #1 surface)
  - 1 Macro / Micro / Hardness
  - 4 Side Bends
  - Charpy V-notch Impact @ 1/16" from Side #1 surface
    - 5 Fusion Line, 5 Fusion Line + 1mm, and 5 Fusion Line + 3mm
    - Weld metal transition curves

## INITIAL OBJECTIVES

- Task 2 - Qualify VBAC Tandem SAW Procedures with Metal Cored Electrodes to ABS Rules (Millers Summit 1000 Power Sources), Lincoln MIL800-H Flux – as per first project
  - Single pass OSW onto modified FCB
    - $\frac{1}{2}$ " and 1" thick EH36 and HSLA-65



- $\frac{1}{2}$ " -  $\theta = 30^\circ$ ,  $R_g = \frac{3}{32}$ ",  $R_f = \frac{1}{8}$ " – 66/34 (EP/EN)
- 1" -  $\theta = 30^\circ$ ,  $R_g = \frac{3}{32}$ ",  $R_f = \frac{3}{16}$ " – 66/34 (EP/EN)
- 5/32 Electrodes,  $\frac{3}{4}$ " Spacing for  $\frac{1}{2}$ " T, and 4" Spacing for 1" T

# INITIAL OBJECTIVES

## ● CHANGE OF PLAN

- Increase Bevel Angle from 30deg to 50deg, so that NASSCO can use their current plate beveller, as well as zero root gap to accommodate quicker fit-up times
  - Will require slower travel speed, problem?
- Investigate Lincoln 880M flux, as currently in use at NASSCO, as well as KOBE backing flux.
- Decrease Electrode Spacing from 4” (Conv. AC – AC)
- Initial Parameters for 1 inch Thickness:

Mode	Constant Voltage	
Balance (EP/EN)	66/34	
Joint Preparation	Θ=30° Included Angle Rg = 3/32" Rf = 3/16"	
Electrode Spacing	4"	
Flux	Lincoln MIL800-H	
<b>Tandem Welding Parameters</b>		
	<b>Lead Electrode</b>	<b>Trailing Electrode</b>
Amperage (A)	1180	950
Voltage (V)	32.5	36.5
WFS (ipm)	225	175
<b>Travel Speed (ipm)</b>	<b>20.5 - 1 pass only</b>	
<b>Benchmark Travel Speed (ipm)</b>	<b>23.5 for 1st pass and 15.5 for 2nd pass</b>	
Travel Angle (°)	15 drag	0
CTWD (in)	1/2	1 3/4
<b>Heat Input (kJ/mm)</b>	<b>214.1 (combined)</b>	
<b>Benchmark Heat Input (kJ/in)</b>	<b>160.5 for 1st pass and 108.6 2nd pass</b>	



## INITIAL OBJECTIVES

- EH36 Steel – OSW 1 inch Thickness
  - Slowed travel speed from 20.5 ipm to 18ipm to achieve more fill per unit length of joint to accommodate the larger groove angle, and increased voltage on trail from 36.5V to 38V to widen and flatten the cap.
  - Increased CTWD on lead from ½” to 1-1/4” (ESO from 1-1/2” to 2-1/2”) and increased WFS from 225 to 265 to achieve greater deposition rate at approx same current level as in previous work (i.e. 1150A), again to accommodate larger groove angle and fill requirements.
  - Spacing of 2”, 3”, 4” and even 5” resulted in excessive flash through (even at 2 to 3 inch flux depths) and poor bead appearances with irregular shape using 880M flux
    - Went back to Lincoln MIL-800H flux
      - » 2” and 3” spacing resulted in poor bead “surface” appearance, however no flash through at 2” flux depth. Bead was not irregular in shape. Immediate Improvement.
      - » 4” spacing resulted in improved bead appearance.

- **PREQUALIFICATION**

- **Extracted 20 weld centerline CVN's each from the subsurface and T/2 locations**
  - **5 Each Tested at -4F and -40F from each Location (Req't = 25 ft-lbs)**
    - Results subsurface @ -40F = 10, 12, 12, 10, and 9 ft-lbs
    - Results subsurface @ -4F = 22, 16, 23, 18, and 20 ft-lbs
    - Results T/2 @ -40F = 15, 14, 15, 15, and 14
    - Results T/2 @ -4F = 32, 28, 25, 25, and 27
- **Extracted 10 HAZ CVN's each from the FL and FL+1mm locations, T/2 (Req't = 25 ft-lbs)**
  - **5 Each Tested at -4F**
    - Results FL subsurface = 48, 35, 28, 32, and 32
    - Results FL + 1mm = 28, 30, 25, 25, and 27
- **NOT ACCEPTABLE RESULTS!**
- **Analyze weld metal chemistry and compare to results measured in first project that produced weld metal CVN's of 100ft-lbs at -20F**

## Chemistry Check

- Compare against original formulation
  - Extracted samples from test welds completed in both 30deg and 50deg joint configurations
  - Retest original formulation from original project, but in EH36 material with 50deg joint configuration
  - Almost 100% increase in C compared to welds in DH36 steel with same flux
  - Slightly lower Ni

	Compositions (%)																	
	C	Mn	Si	S	P	Ni	Cr	Mo	Al	B	Cu	Zr	Nb	Ti	V	N	O	Pcm
<b>Original Formulation</b>	0.06000	1.40000	0.55000	0.00200	0.00200	0.50000	0.01500	0.15000	0.00400	0.00400	0.06000	0.00800	0.00200	0.01500	0.00100			0.19052
Original WM Result 006 with 10.62 flux (30 deg DH36)	0.07000	1.51000	0.41000	0.00900	0.01700	0.48000	0.05100	0.16000	0.02300	0.00170	0.11000	0.00500	0.02100	0.01200	0.03000	0.01000	0.04000	0.19738
<b>New 006 Formulation (Specified)</b>	0.06000	1.40000	0.55000	0.00200	0.00200	0.50000	0.01500	0.15000	0.00400	0.00400	0.06000	0.00800	0.00200	0.01500	0.00100			0.19052
New 006 WM with MIL-800H (50 deg angle EH36)	0.12300	1.52000	0.32900	0.00756	0.01240	0.33600	0.03840	0.06920	0.01340	0.00117	0.06780	0.00205	0.00355	0.00212	0.02160	0.00650	0.01920	0.23350
New 006 WM with MIL-800H (30 deg angle EH36)	0.14500	1.50000	0.31600	0.00708	0.01240	0.28300	0.03140	0.06020	0.01530	0.00113	0.06080	0.00194	0.00396	0.00213	0.02430	0.00680	0.01500	0.25195
Retest WM with original 005 with MIL800-H (50deg EH36)	0.11100	1.63000	0.29700	0.00655	0.01160	1.05000	0.09480	0.20300	0.01590	0.00134	0.06720	0.00441	0.01920	0.00770	0.04110	0.00600	0.16900	0.25234

## Reformulation

- Hobart making final batch of electrodes for testing

	Compositions (%)															
	C	Mn	Si	S	P	Ni	Cr	Mo	Al	B	Cu	Zr	Nb	Ti	V	Pcm
<b>Original ELECTRODE Formulation</b>	0.06000	1.40000	0.55000	0.00200	0.00200	0.50000	0.01500	0.15000	0.00400	0.00400	0.06000	0.00800	0.00200	0.01500	0.00100	0.19052
<b>Revised ELECTRODE Formulation</b>	0.02000	1.60000	0.45000	0.00200	0.00200	2.00000	0.05000	0.50000	0.00400	0.00400	0.03000	0.00800	0.01000	0.03000	0.00400	0.20607
<b>Hobart 0299H-01-006</b>	0.027	1.833	0.341	0.008	0.015	2.214	0.05	0.465	0.005	0.001	0.074	0.003	0.004	0.014	0.007	0.20972
<b>Weld Metal Chemistry w/MIL800-H</b>	0.06	1.74	0.6	0.008	0.013	2.14	0.048	0.59	0.028	0.0054	0.055	0.047	0.007	0.117	0.01	0.27515

**QUESTIONS?**

