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TITLE

Welding Procedures for Welding HY80 Steel

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Welding Procedures for Welding HY80 Steel

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*****NDHQ, DGMEPM, DMSS 2-4**

ABSTRACT

In light of the acquisition of the Upholder class submarines by the Canadian Navy, some benchmark procedures have been developed for welding HY80 steel. These procedures for welding in the vertical up position comprised one for the shielded metal arc welding process, and two for semi-automatic processes (GMAW with TIME shielding gas and MCAW with argon 2% oxygen as the shielding gas). The filler metals employed were matching in strength. State of the art, Lincoln Powerwave 450 welding machine was used for all the welds.

The main considerations in finalizing the welding procedures were to minimize the heat input and interpass grinding but without incidence of lack of fusion type of flaws. The weld metal notch toughness for the three welds is reported.

Welding Procedures for Joining HY-80 Steel

by

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presented at

8th CF/CRAD Meeting on Naval Applications of Materials Technology

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Background

- **The Acquisition of the Upholder Class Submarines has Increased CF Welding Procedure Requirements:**
  - Oberon Class constructed from QT28
  - Upholder Class constructed from Q1N (HY-80 equivalent)
- **CF Welding Practice Calls for SMAW for Pressure Hull Welding, However, There is a Desire to Move to P-GMAW in the Future to Take Advantage of Superior Mechanical Properties.**

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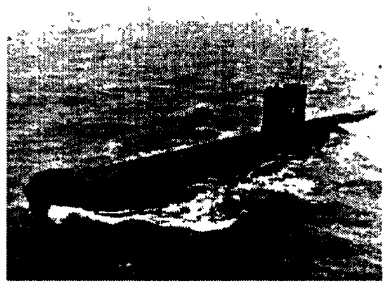
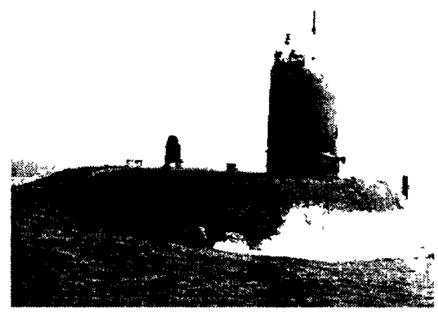
Oberon to Upholder



Oberon - QT-28

Upholder - Q1N (HY80)



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Objectives

- Identify a Preferred SMAW Electrode for CF HY-80 Applications (DMSS).
- Develop and Evaluate an SMAW Procedure Suitable for Emergency Repairs and Minor Modifications (DMSS).
- Develop and Evaluate Benchmark P-GMAW Procedures (DREA).

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Scope

GMAW

- Procedures Developed and Evaluated for ER100S-1 and MIL-100S-2C Consumables in 3G Position

SMAW

- E10018M1 Electrode Selected for Matching Strength and Improved Ductility Over E11018.
- Procedure Developed and Evaluated in 3G Position to Simulate Most Difficult Scenario Likely to be Encountered in Repairs or Modifications.

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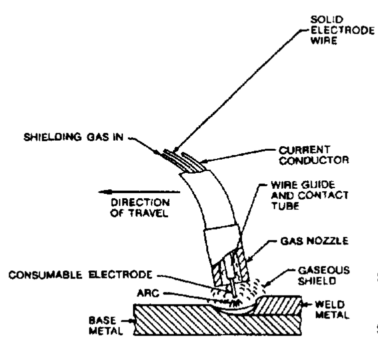
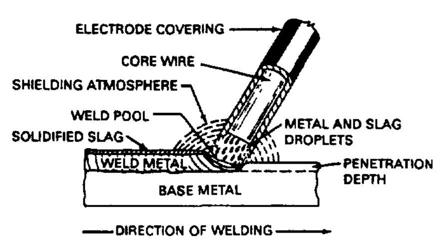
Process Descriptions





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Consumable Selection - GMAW

- **ER100S-1 Solid Wire With TIME Gas Shielding Selected Based on Good Performance in Past Test Programs.**
- **Metal Cored MIL-100-S2 with 2% O_2 Gas Shielding Selected Based on Good Published Properties and a Desire to Investigate Possible Alternatives to Solid Wire.**

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Consumable Selection - SMAW

Electrode	Designation	Specification	Yield (ksi)	UTS (ksi)	CVN ft.lbs.@°C	Hydrogen mL/100 g
ESAB	10018-M1	MIL-E-22200/10	89 5	97 4	67 @ -51	2 6
Air Liquide	10018-M	CSA W48 3	97	103	26 @ -50	N/A
Hobart	10018-M	MIL-E-22200/1	95 3	106	56@-51	N/A
Lincoln	**10018-M1**	**MIL-E-22200/10C**	**90 (1G)* 109 (3G)**	**102 116**	**66 @ -51 48 @ -51**	**1.0**
Fortrex Q2N	10016		109 (3G)	118	44 - 74 @-50	3 0
Spec	10018-M1	MIL-E-22200/10C	82 to 110		35 @ -51	3 2 to 3 5

* Heat input 41 1 kJ/in (1.62 kJ/mm) in the 1G position and 35 1 kJ/in (1 38 kJ/mm) in the 3G position

Lincoln Electrode Selected Based Upon:

•Good Toughness and Strength
•Lowest Diffusible Hydrogen
•Only Supplier With Bonded Stock Tested to MIL-E-22200/10C

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Procedure Development - GMAW

- Past GMAW - TIME work at DREA has produced excellent toughness but lots of defects or required extensive grinding.
- The goal with this procedure was to produce good toughness with minimal defects and minimal interpass grinding.
- Procedure developed provided good wetting with a "crisp" arc.

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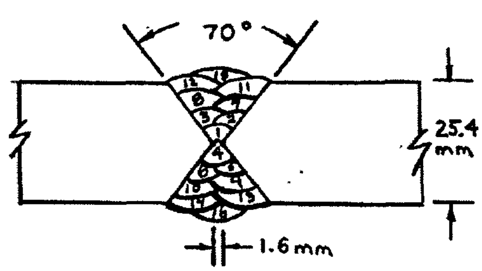
GMAW Procedure Details

Filler Metal Classification	100S-1
Filler Metal Diameter (mm)	1 2
Preheat Temperature – min (°C)	90
Interpass Temperature – max (°C)	120
Heat Input (kJ/mm) - Range - Average	0 64 to 1 0 0 89
Shielding Gas	T I M E 26 5%He- 8%CO_2-0 5%O_2-bal Ar



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Procedure Development - MCAW

- Same goals as with solid wire, it was hoped that lower current densities could be used, allowing even lower heat inputs to be and thus better toughness.
- It was found that "stringer beads" were very difficult to obtain with an acceptable profile so wide weaves and resulting high heat inputs were required.
- Weld puddle found to be very "sluggish" with poor wetting action.

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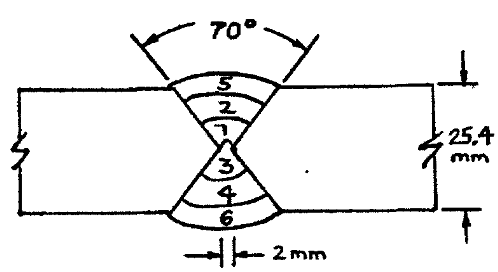
MCAW Procedure Details

Filler Metal Classification	100S-2C
Filler Metal Diameter (mm)	1 2
Preheat Temperature – min (°C)	90
Interpass Temperature – max (°C)	120
Heat Input (kJ/mm) - Range - Average	1 2 to 2 4 1 83
Shielding Gas	M2 Ar-2%0_2



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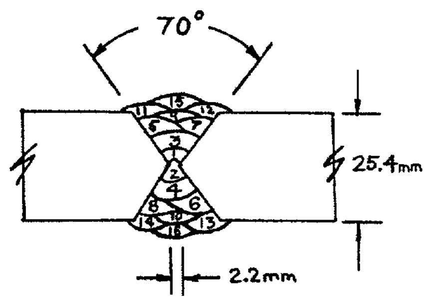
SMAW Procedure Details

Filler Metal Classification	E10018-M1
Filler Metal Diameter (mm)	3 2 root, 4 0 fill
Preheat Temperature – min (°C)	90
Interpass Temperature – max (°C)	120
Heat Input (kJ/mm) - Range	1 2 to 1 8
- Average	1 45

•Maintain average heat input below 1.7KJ/mm

•Employ "temper bead" technique in cap layers



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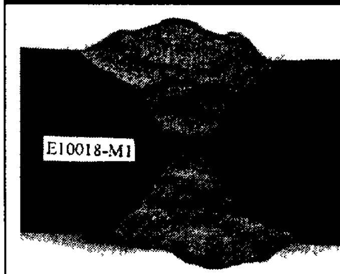
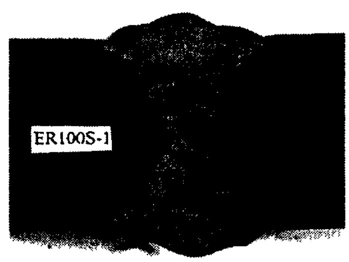
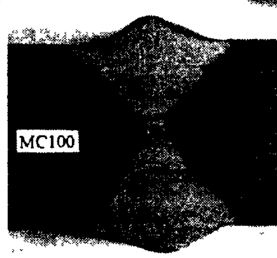
Resulting Welds







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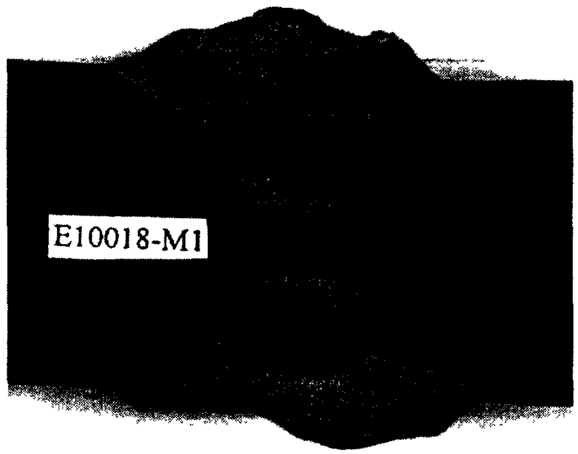
SMAW Macro



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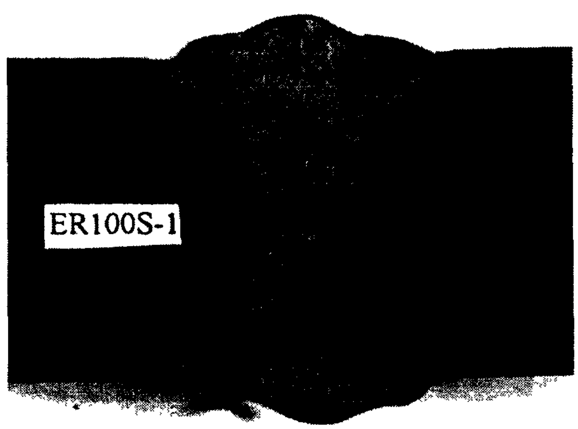
P-GMAW Macro



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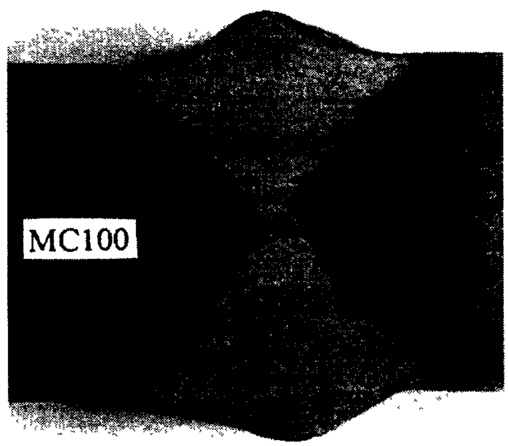
P-MCAW Macro



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Tensile Testing

Weld ID	Ultimate Tensile Strength (MPa)	(ksi)	Fracture Location
ER100S-1	752	109 0	Base Material
	746	108 2	Base Material
MC100	736	106 8	Base Material
	730	105 9	Base Material
E10018-M1	728	105 6	Base Material
	732	106 2	Base Material

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Hardness Results

Hardness Results (HV, 5Kg load)

Weld ID	Location	Hardness (avg.)	Range
ER100S-1 + T I M.E	base metal	231	225 – 236
	HAZ	394	386 – 396
	weldmetal @1 5 mm subsurface	276	265 – 299
	weldmetal @ t/2	308	306 – 310
MC100 + Ar-2% O_2	base metal	234	225 – 246
	HAZ	381	376 – 386
	weldmetal @1 5 mm subsurface	277	268 – 303
	weldmetal @ t/2	314	313 – 317
E10018-M1	base metal	228	223 – 234
	HAZ	384	332 – 394
	weldmetal @1 5 mm subsurface	246	232 – 254
	weldmetal @ t/2	277	271 – 283

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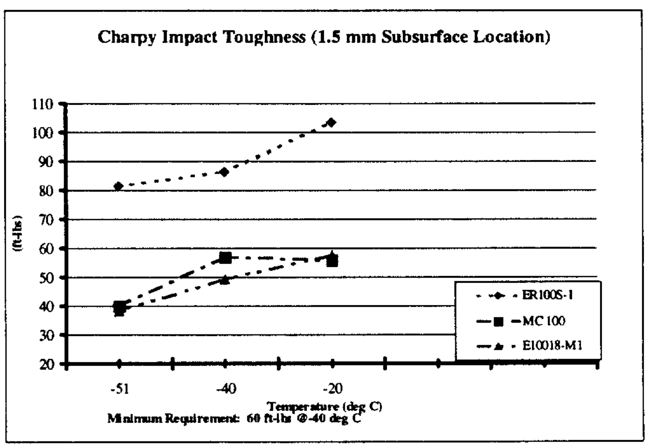
Charpy Impact Results



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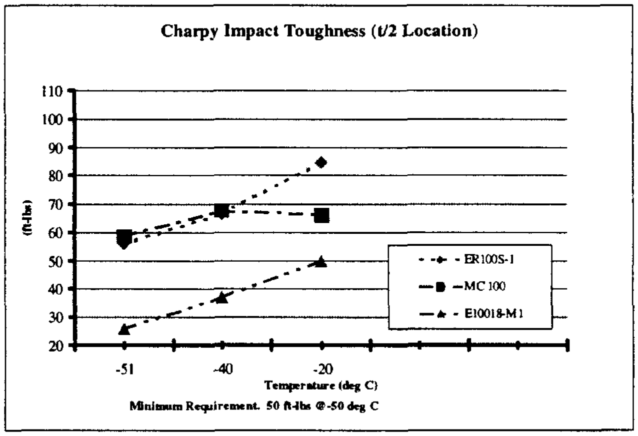
Charpy Impact Results(cont.)



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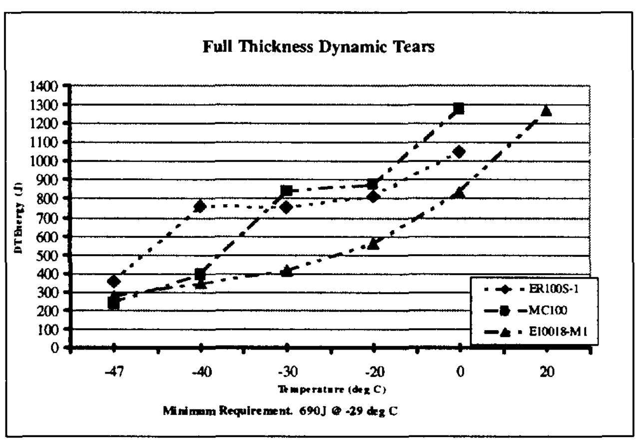
Dynamic Tear Results



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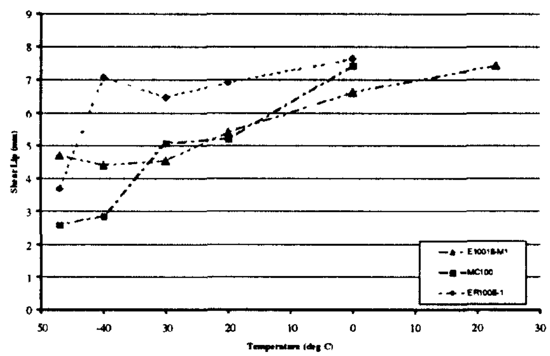
Dynamic Tear Shear Lip Results

Full Thickness Dynamic Tears



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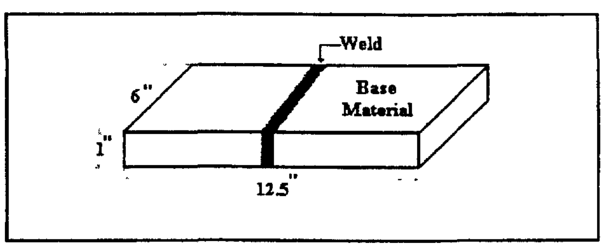
Bend Bar Test

- Full Section Bend Bar Samples Tested as a Simple Alternative to Explosion Bulge
- Single Axis of Deformation and Slower Loading Rate



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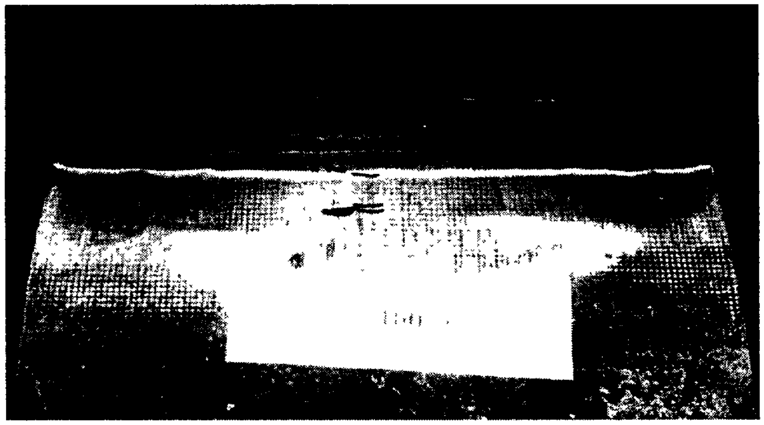
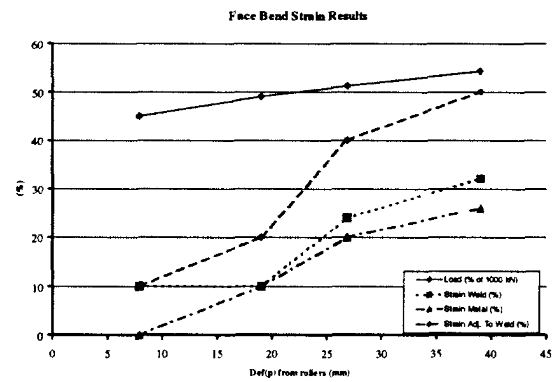
Bend Bar Test (cont.)



Bend Bar Test(cont.)

100S1

Bend Bar Results - GMAW(100S-1)



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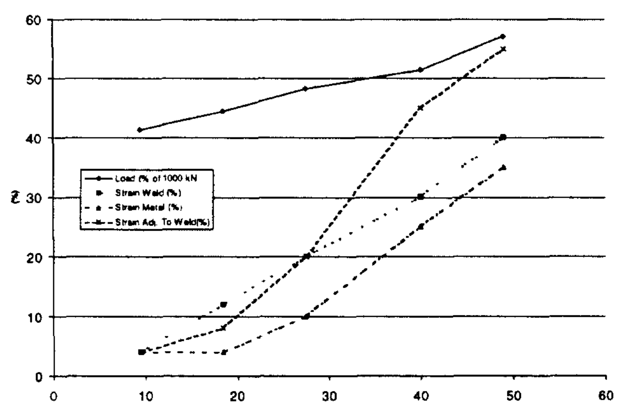
Bend Bar Results - MCAW (MC-100)



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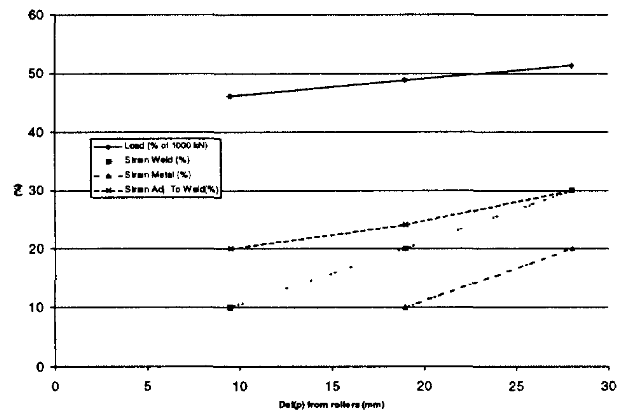
Bend Bar Results - SMAW(10018M1)



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Conclusions

- **P-GMAW :**
  - Met all requirements comfortably.
  - No defects detected with radiography at +/- 20° to normal
  - Minimal interpass grinding required (10sec/foot of pass)
- **P-MCAW:**
  - Has not met charpy requirements and DT energy and shear lip transition is marginal
  - Poor arc manipulation characteristics
- **SMAW:**
  - Did not meet acceptance criteria for Charpy energy, DT energy, and DT shear lip.

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Recommendations for Future Work

- **Discontinue MCAW work for present time.**
- **Complete further P-GMAW procedure testing to define a suitable operating envelope.**
- SMAW:
  - Further refinement of developed procedure to reduce heat input average.
  - Reduce preheat and interpass temperatures slightly.
  - Microstructural and chemical analysis of completed welds.

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