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Electron beam and gas metal arc welding of nickel aluminum bronze assemblies

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Electron Beam and Gas Metal Arc Welding of Nickel Aluminum Bronze Assemblies

Kevin Morrison
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Arnprior, Ontario, Canada

Contract Report #W7707/008095/001/HAL

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Defence R&D Canada

Contractor Report
DREA CR 2001-087
July 2001

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DEFENCE RESEARCH ESTABLISHMENT ATLANTIC

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Approved by

Dr. Richard Morchat

Head Dockyard Lab(Atlantic)

Approved for release by

K. Foster

Chair DRP

Contract Report # W7707-008095/001/HAL

Abstract

Low heat input electron beam welding has been proposed as a method for the fabrication and repair of nickel aluminum bronze valves and propulsers. This report describes weld procedures used to produce 40mm thick nickel aluminum bronze weld assemblies for testing purposes. Two different electron beam and one gas metal arc weld process were used. Testing of these weld assemblies is in progress.

Résumé

Le soudage par bombardement électronique à faible apport de chaleur a été propose comme méthode de fabrication et de réparation des valves et des propulseurs en cuproaluminium au nickel. Le présent rapport décrit les procédés de soudage utilisés pour produire, aux fins d'expérimentation, des assemblages soudés de 40 mm d'épaisseur en cuproaluminium au nickel. On s'est servi de deux différents faisceaux d'électrons et d'un soudage à l'arc sous gaz avec fil plein. Les assemblages obtenus sont actuellement à l'essai.

Executive summary

Introduction: Electron beam welding, and related process such as deep penetration laser welding, have been proposed as methods for the manufacture of submarine valves and are used for the manufacture of submarine propulsers. Such methods also have the potential to reduce weld residual stresses, allowing the very restrictive limits on weld repair of propellers to be relaxed. Unanswered questions concerning the toughness and fatigue behaviour of such welds remain. Additionally, there is little Canadian experience with deep penetration welding of these materials. To obtain this information, DREA has undertaken a study of the effect of deep penetration welding variables on the microstructure and properties of laser and electron beam welds in nickel aluminum bronze. The present paper describes welding procedures used to produce a set of experimental electron beam weldment along with a reference pulsed gas metal arc weld

Principle results. Two electron beam welding conditions were used. Plates extracted from the thick and thin area of a 3900 lb propeller blade were welded together so that casting microstructure effects might be considered.

Future Work The weldments are being evaluated at DREA. Future electron beam welds will be made in a different orientation to reduce drop-through related defects.

Morrison, Kevin, 2001, Electron Beam and Gas Metal Arc Welding
DREA CR 2001- 087
Defence Research Establishment Atlantic

Sommaire

Introduction : Le soudage par bombardement électronique et les procédés connexes tels que le soudage à forte pénétration au laser ont été proposés pour la fabrication de valves de sous-marins, et l'on s'en sert actuellement pour produire des propulseurs de sous-marin. Ces procédés ont la capacité potentielle de réduire les contraintes résiduelles de soudure, ce qui permet de recourir plus librement au soudage pour réparer les hélices, méthode qui d'habitude présente des limites très restreignantes Des questions restent toutefois sans réponse quant à la résistance de ces soudures et à leur comportement face à la fatigue. D'autre part, le soudage à pénétration profonde de ces matériels est peu pratiqué au Canada. Pour en avoir le cœur net, le CRDA a effectué une étude de l'effet des paramètres du soudage à pénétration profonde sur la microstructure et les propriétés des soudures au laser et au faisceau d'électrons faites sur du cuproaluminium au nickel. Le présent document décrit les procédés de soudage utilisés pour fabriquer, aux fins d'expérimentation, un assemblage soudé par bombardement électronique avec comme référence une soudure pulsée à l'arc sous gaz avec fil plein.

Résultats principaux : On s'est servi de deux conditions de soudage par bombardement électronique. Des plaques extraites de la surface épaisse et de la surface mince d'une pale d'hélice pesant 3 900 livres ont été soudées ensemble afin qu'on puisse étudier les effets de la microstructure du moulage.

Prochaine étape : Les assemblages soudés sont actuellement évalués au CRDA. À l'avenir, les pièces à souder par bombardement électronique seront placées de façon à éviter les défauts provoqués par l'écoulement de la soudure.

Morrison, Kevin, 2001, Electron Beam and Gas Metal Arc Welding
DREA CR 2001-087
Centre de recherches pour la défense Atlantique

Production of NAB Weld Samples Using The P-GMAW and EBW Processes

1.0 Introduction

Defense Research Establishment Atlantic (DREA) supplied machined nickel aluminum bronze plates to Nu-Tech, which were to be welded together using the pulsed gas metal arc (P-GMAW) and electron beam welding (EBW) processes. These flat plate weldments were designed to allow weld zone property evaluations at DREA. The following reports the welding procedures and consumables used to fabricate these test weldments.

2.0 Gas Metal Arc Welding

One full penetration "K" type butt joint weldment was joined using the pulsed variation of the GMAW process. The supplied machined preparation was a balanced 35º double bevel groove preparation with a 3mm land in 38mm thick plate. The 3mm land was reduced to a 1.6mm land by machining at Nu-Tech. This was to reduce the second side root grinding and minimize the possibility of fusion related weld discontinuities in the root area. The root gap was set at 3.2mm to allow welding torch access for root area welding and to permit good root area fusion for the initial root pass. This would also reduce the machining required from the second side into sound weld metal.

A Miller Maxtron 450 power source and programmable, synergic Miller 64M feeder was used for all welding. A range of pulsed welding parameters, shielding gases, welding parameters and welding techniques were evaluated using a 1.2mm (0.045") diameter solid welding wire. The final welding procedure, equipment and consumables used are presented in Appendix A.

The welding procedure was considered comfortable to apply using a motorized travel carriage with torch oscillator (Gullco Kat/track with Gullco oscillator - Figure 1). Full fusion, monitored by observing the leading edge of the weld puddle, appeared to be attained.

Some difficulty was experienced during welding which appeared to be wire feeding problems. This resulted in portions of weld with questionable fusion. When this occurred, welding was stopped and the difficulty was remedied by inserting a new liner and contact tip. A considerable amount of waxy material was accumulating at the wire feeder drive roll area and it was suspected that this material was accumulating in the liner and causing the wire feed problems. The wire supplier was contacted (Unibraze) and asked if this was a recognized characteristic of this wire. No explanation was offered.

3.0 Electron Beam Welding

Three sets of square machined 38mm thick NAB plates were forwarded to Nu-Tech by DREA for assembly and square butt welding by the EBW process. The objective was to provide three ≈ 737mm long EB welds for evaluation at DREA. Nu-Tech was required to produce 2 welds using welding parameters which produce a narrow weld geometry and one weld with a wider weld geometry. The plate assemblies were identified by DREA and the type of weld for each assembly was prescribed as shown in table 1.

In preparation for welding, the plates assemblies were tack welded together and restraint plates were welded to the end to prevent separation of the weld joint. An automatic full length bead was applied on the underside of the square butt joint using the P-GMAW process and welding parameters similar to that used for fill passes in the "K" joint weldment. Strong backs were then machined and attached to the underside of the plate assemblies to prevent distortion from EB welding.

Nine 12mm x 38mm x 150mm long NAB pieces were provided for EBW procedure development. These were stacked together to provide 150mmm long 38mm thick square butt joints 12mm apart. P-GMAW backing beads were applied to the underside of the butt joints, similar to that used for the 737mm long program plate assemblies.

Initial trials resulted in excessive drop through on the weld backside and heavy underfilling (loss of material) on the top side. Sectioning of these welds showed weld melt voids which appeared elongated in the penetration direction (Figure 2).

Based on a review of the literature provided by DREA, one source [(1)] welding 6, 13 and 25mm thick NAB plate by EBW reported a tendency to undercutting and used transverse beam oscillation to reduce this effect. There was also a suggestion that pipes, pores and large linear defects similar to lack of fusion were suspected in welds which were radiographed. Based on Nu-Tech's initial EB results and the report of improvements with beam oscillation, the wide weld requirement of this program did utilize beam oscillation.

Since the trial weld samples provided did not represent actual conditions, a trial weld was conducted on one of the program assemblies at a location well outside of the weld joint. This was intended to isolate the material weldability by eliminating the joint feature and any contamination that may be contributing to the weldability difficulties experienced for the initial trials. The trial weld location and macro sample orientation are illustrated in Figure 3.

Sections removed from the full plate trials illustrated large voids, excessive underfilling and drop through as previously experienced and shown in Figure 2.

Since there appeared to be a material related weldability problem that was not obvious from the NAB composition or the open literature, it was decided with the scientific authority to proceed with the "best effort" philosophy. Two plate assemblies were, therefore, welded using a focussed beam and one with oscillation. The actual EBW parameters used are also reported in Appendix A.

4.0 Discussion

The P-GMAW procedure was easy to apply using the parameters reported and torch oscillation. The wire feed problems were suspected to be related to the wire and this must be considered for future work.

Based on the EBW results where the EB weldability of thick NAB sections is in question, several quick trials were conducted at Nu-Tech using the GTAW and EB processes in an attempt to explain the presence of voids in welds. These were as follows:

- Bead on plate GTAW was carried out where no boiling or porosity was experienced.

- 25mm diameter circles were welded on the plate surface using the EB process. Power was varied to provide different penetration depths. Shallow (3-5mm) welds did not show any evidence of the weldability problems (voids) experienced in larger full penetration welds. As the penetration was increased, irregular weld surface, metal expulsion from the joint and voids were experienced.

Although it is not proposed that conclusions can be made on such limited testing, there does seem to be some suggestion that the voids present in program welds are not necessarily generated from gases but may be voids associated with deeper welds in this NAB material. If voids were related to the formulation of gases during welding there should have been some evidence of boiling during GTAW and porosity in the shallow welds. The voids were also not present in the shallow bead on plate EB welds, only the deeper welds.

Future work in EB of NAB should include a weldability study which explores the effect of plate thickness and process parameters for full penetration welds.

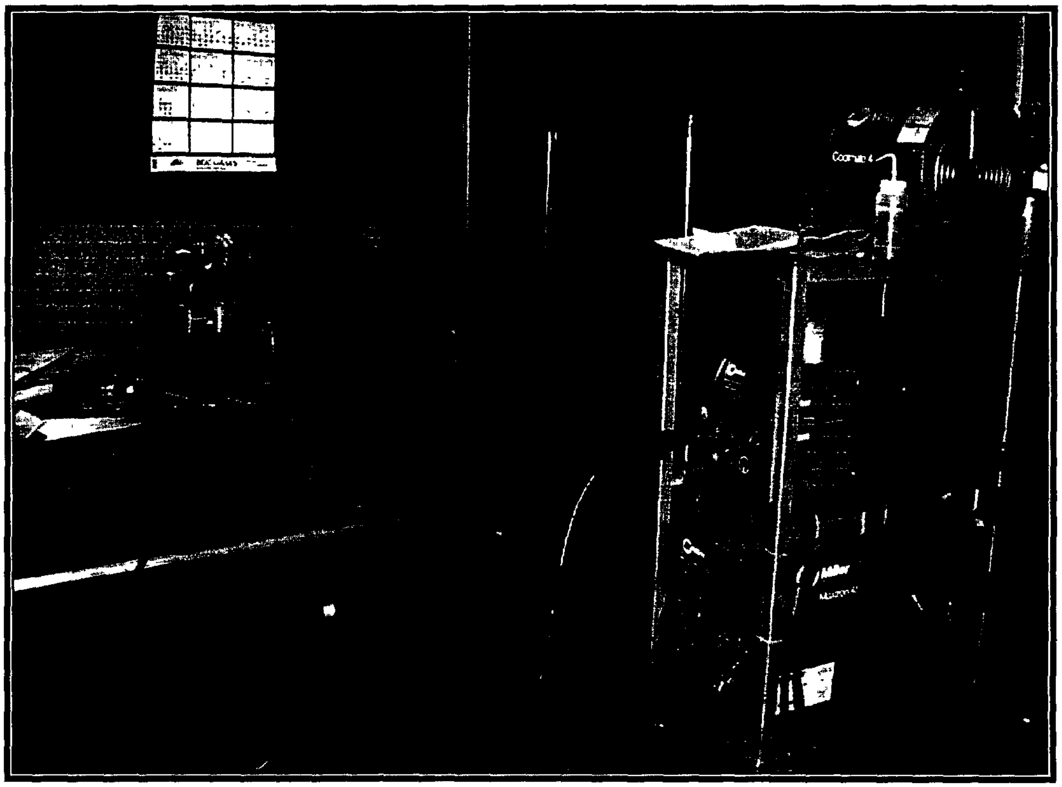
5.0 Conclusions

A P-GMAW procedure was successfully developed and applied to produce a "K" preparation butt weld in 38mm NAB plate.

The EBW process was unable to produce sound weld metal in the three 40mm plates used in the program. Welds contained voids, excess drop through and underfill.

References:

1. G. Newcombe, AIM, MWeldI, C. Dimbylow, BTech, PhD, MInstP, and R. Jones, MSc, Welding and its influence on the performance of two cast copper - base alloys in sea water.



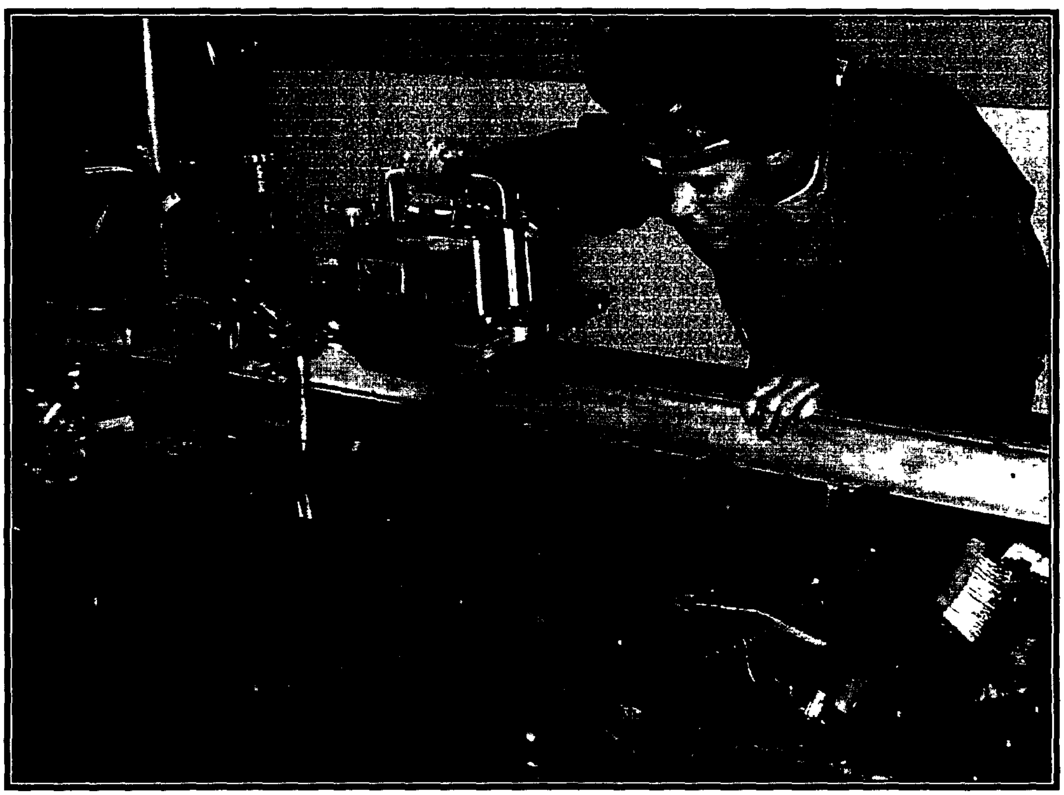


Figure 1 **GENERAL VIEW & CLOSE UP OF NAB-GMAW SET UP**

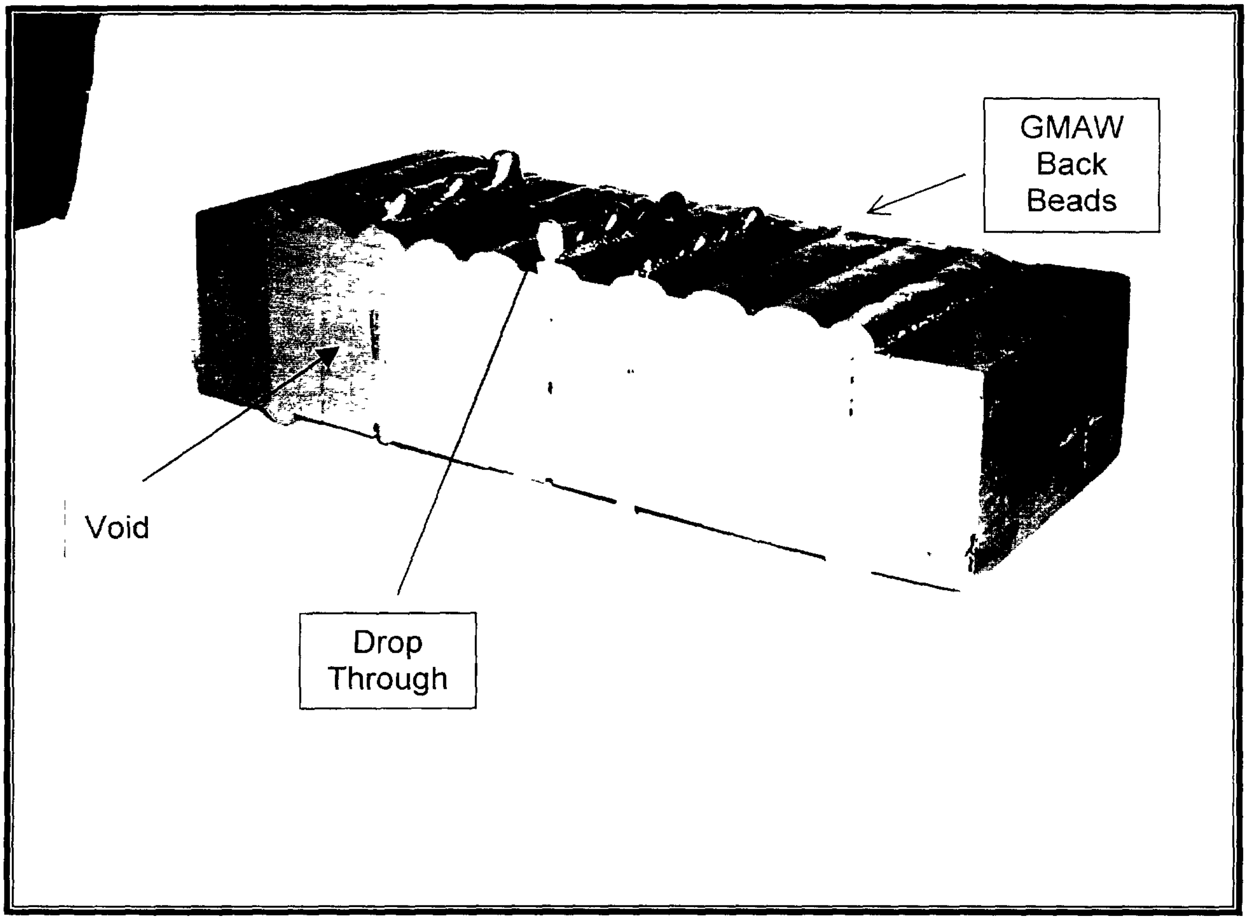
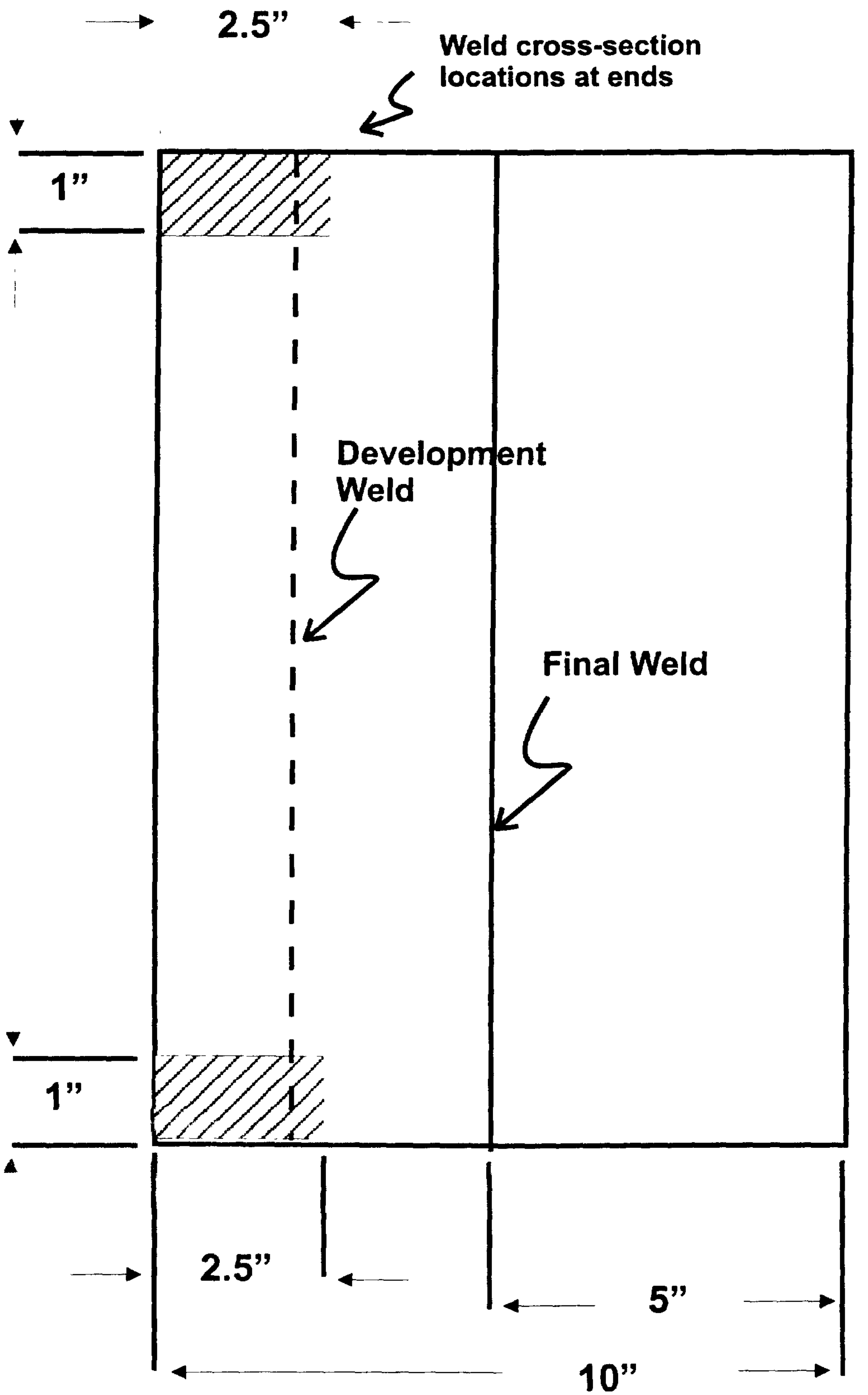


Figure 2 **NAB-EBW CROSS SECTION ILLUSTRATING DROP THROUGH, VOIDS AND OTHER DETAILS**

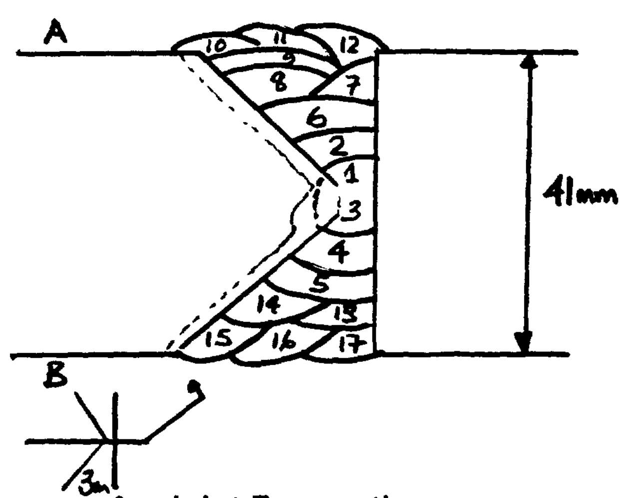
FIGURE 3: Location of Trial Welds on Final Assemblies



WELDING PROCEDURE SPECIFICATION (WPS)

Project No: 40-1477 DREA
PQR No.: Procedure Development
*Program Plate

Material Specification: Nickel Aluminum Bronze
Welding Process/Equip: GMAW
Manual or Machine: Machine Assisted
Position of Welding: 1G
Filler Metal: Unibraze Ampcotrode 4b 045 (ER Cu Ni Al)
Shielding Gas: 75 He/25 Arg Flow Rate: 45 CFH
Auxiliary Shielding: Flow Rate:
Nozzle Orifice Size: 0.75"
Single or Multipass: Multipass
Positioner Type: N A
Preheat Temperature:
Interpass Temperature: 150°C Max
Preheat Method: N A
Root Treatment:



Joint Preparation

ID	SIDE	Pass No.	Location	Machine Settings: Ip (amps)	Ip on (%)	Ib (%)	Freq (PPS)	Travel IPM	Travel Dial	WFS (dial)	TTWD (mm)	Comments/Results
	A	1	root						8	300	75"	
	A	2	fill						8	300	75"	
	B	3	root						8	300	5"	
	B	4-5	fill						7/8	300	5"	
	A	6	fill						7	300	5"	
	A	7-9	fill						12	225	5"	
	A	10-12	cap						12/14	225	5/8"	
	B	13	fill						12	225	5/8"	
	B	14	fill						12	300	5/8"	
	B	15-17	cap						8	250	5/8	

Procedure Notes

Machine Root to sound metal from Side B.

Technique

Date	Developed from Working WDS. May 2001	Welder's Name K G Morrison/B Larone	Inspected By	Procedure By K G. Morrison

Nu-Tech
Joining Technology Division

460 McCartney Street
Arnprior, Ontario K7S 3H2 (613) 623-6544

ELECTRON-BEAM WELDING DATA SHEET

DATE: ORIGINAL 02/28/01 **NU-TECH W.O. NO.** 40-1577

CUSTOMER: DREA **CONTACT:** DR. C. HYATT

☐ **WELD DEVELOPMENT** ☒ **PRODUCTION PARTS**

Part Ident.:

Material: Nickel Aluminum Bronze

Joint Type: Square Butt

Weld Classification: Full Penetration

Cleaning Requirements: Acetone Wipe

Vacuum: 1×10^{-4}

Gun/Filament Type: R167 - Ribbon

Filament Setting:

Anode/Cathode Spacing:

Weld Type	kV	mA	Welding Speed IPM	Cycles/Deflect	Focus	GTWD	Slope Cont. In	Slope Cont. Out
TACK	140	15	30	STRAIGHT	SHARP	10 0'		
WELD #1	140	140	30	STRAIGHT	010 OVER TRACE	10.0'		
WELD #2	140	150	30	10 DIV 500 CPS	010 OVER TRACE	10.0'		

Cool Down Time Before Venting to Atmosphere: **Minutes**

Special Welding and Handling Requirements:

- plates were strongbacked to reduce distortion
- strongbacks were also welded to the plate ends to reduce lateral plate movement
- P-GMAW backing welds were used to allow quality full penetration welds

Results and Comments:

- underfill, weld melt voids and heavy drop-through

Q.A. Requirements: ☐ LPI ☐ He Leak Test ☒ N A

Approved by: *Y.A. Marion* Date: *Jan /2001*

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(highest classification of Title, Abstract, Keywords)

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1 ORIGINATOR (the name and address of the organization preparing the document Organizations for whom the document was prepared, e g Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8) Nu-Tech Precision Metals Joining Technology Division, 460 McCartney Street Arnprior, Ontario, K7S 3H2	2 SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable) UNCLASSIFIED

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4 AUTHORS (Last name, first name, middle initial If military, show rank, e g Doe, Maj John E)

Morrison, Kevin

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Electron Beam
Arc Welding
Nickel Aluminum Bronze

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