Application of one side submerged ARC in Shipbuilding

—*V. N. Girijavallabhan*

1. INTRODUCTION

Today ship building is a very competitive industry. All over the world every effort is made to reduce the time and cost of ship building. New and improved welding processes are applied in welding of the ship's hull with this objective. Among these "One side welding" is the most advantageous welding technique used in shipbuilding today.

This paper deals with the various stages in the development of the following types of one side submerged arc welding processes for shipbuilding in Cochin Shipyard Ltd :

a) Submerged arc welding with Flux copper backing.

b) Submerged arc welding Flux asbestos backing and addition of metal powder.

The various problems encountered during welding procedure qualifications and actual production welding are also discussed in this paper.

2. ONE SIDE SUBMERGED ARC WELDING USING FLUX COPPER BACKING (FCB)

Process Outline

This is a submerged arc welding process where flux laid on the copper backing is used to support the weld puddle and form the weld bead on the underside of the joint. Welding of the joint is completed from the face side of the joint itself.

The Joint Set Up

The plates after proper edge preparation (Fig.1) is tack welded.

The included angle, root face and root gap are to be as per specification. A welding skid, where copper backing plates are arranged in sufficient lengths and numbers alongwith the mechanism for movement of the backing assembly, traverse of the assembled panel, pneumatic arrangement for holding the backing tight against the weld groove and the magnets for holding the panel tight, is used for better efficiency in this type of welding. The backing flux is spread over

V.N. Girijavallabhan is with Cochin Shipyard Ltd., Cochin.

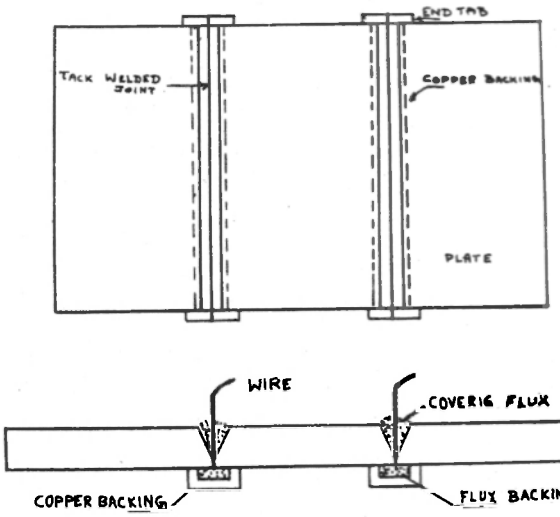


FIG.1 SET UP FOR ONE SIDE FCB WELDING

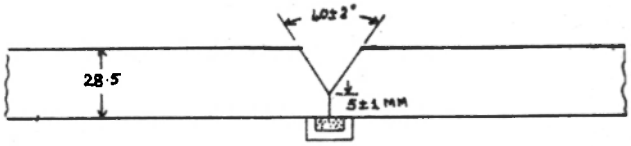


FIG.2. JOINT DESIGN FOR ONE SIDE FCB WELDING

the copper backings to a height of 6 to 8 mm. The weld grooves of the panel are aligned on top of the backing by independent movement of the copper backing assembly. By lifting the backing assembly using the pneumatic arrangement the backings are held tight to the weld joint. The panel is held tight by energising the powerful magnets arranged on the welding skid. The joint is welded using tandem or quadruple arrangement of welding heads on the submerged arc welding machine (Fig. 3 & 3A).

Welding Procedure Qualification Test

As per rules of Ship's Classification Society (Lloyds Register of Shipping in the present case). Welding Procedure Qualification Tests were conducted to ascertain the soundness

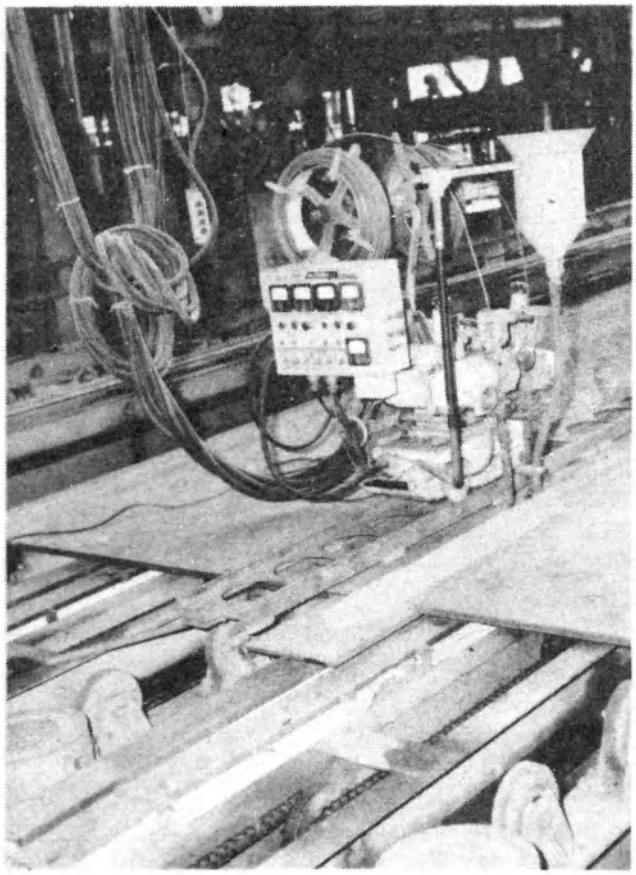


Fig. 3 Submerged ARC one side FCB process in Cochin Shipyard Ltd.

of the weldment made by the one side welding process. The details of the tests are given in the Welding Procedure Specification (Annexure - 1) and the Welding Procedure Qualification record (Annexure - 2).

The test results were satisfactory and the Welding Procedure (submerged arc welding with flux copper backing) was approved for use in shipbuilding.

As per the approved Welding Procedure Specifications, welders were qualified to perform on the job.

Common Weld Defects

i) Lack of root fusion :

This is due to increased root face and height of sealing welds. This can be prevented by controlling the root face and height of tack welds.

ii) Uneven reverse bead and overflow of molten metal :

This is due to incorrect contact between the backing and the joint. This can be eliminated by ensuring proper spreading of the backing flux and tight contact between the plate and the backing.

iii) Burn through in the joint :

This can be rectified either by reducing the excess root gap or by welding the root run either by GMAW (CO_2) or MMA.

iv) Burn through at the start and end of the joint :

This is taken care of by ensuring sound weld between the end tabs and the plates to be welded.

v) Cracks at the start and finish of the welds :

These tension cracks (Fig.(4) are bound to occur in this process. The only way is to lock the plate ends by end tabs of sufficient size.

iv) Cracks at the restart point :

The restart point is to be gouged to remove the crack before the welding from the other end overlaps.

vii) Transverse cracks :

This is due to the copper pick up in the weld, when the backing melts due to direct arcing while welding. This can be avoided by ensuring a) proper height of backing flux b) distance between copper backings to be less than 0.8 mm and c) correct root gap in the joint.

viii) Uneven bead, side undercuts and excessive reinforcement of welding :

These are to be controlled by adjusting the welding parameters.

ix) Slag inclusion in the weld :

This can be controlled by adjusting the welding parameters.

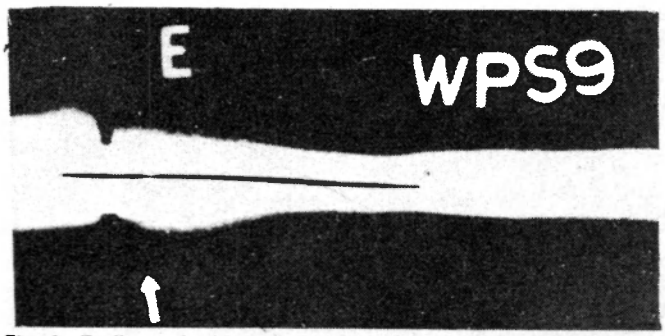


Fig. 4 Radiograph showing end crack in one side FCB Welding.

x) Overlap :

This can be controlled by adjusting the welding parameters.

Recommended Edge Preparation

Plate thickness (mm)	Included angle	Root face (mm)	Root gap (mm)
8 to 20	50 + 2°	3 + 1	0.8 max.
21 to 26	45 + 2°	5 + 1	0.8 max.
27 to 36	40 + 2°	5 + 1	0.8 max.

Note : When thickness difference of the plates forming the joint is more than 2.5 mm chamfer the thicker plate to a length of 5 times the difference in thickness.

Advantages of the Process :

- No back chipping/gouging is required as done in many other processes.
- In case where panels cannot be turned and the welding has to be done in overhead position one side FCB welding is advantageous.
- On a single 'V' double welded joint of 20 mm thick and 12 M long one side submerged arc with FCB is 12 times faster than manual metal arc welding done in flat/overhead position.
- Four or more joints can be welded simultaneously in this process depending on the skid arrangement.
- This process is extensively used in welding of flat panels where turning of the panel and positional welding are completely eliminated.

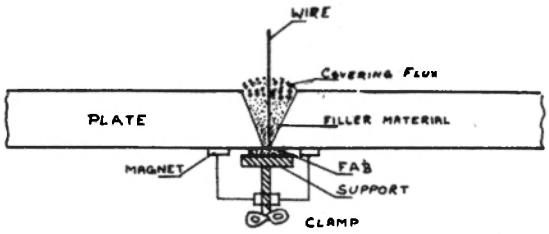
2. SUBMERGED ARC WELDING USING FLUX ASBESTOS BACKING (FAB PROCESS) (One Side welding)

Process Outline

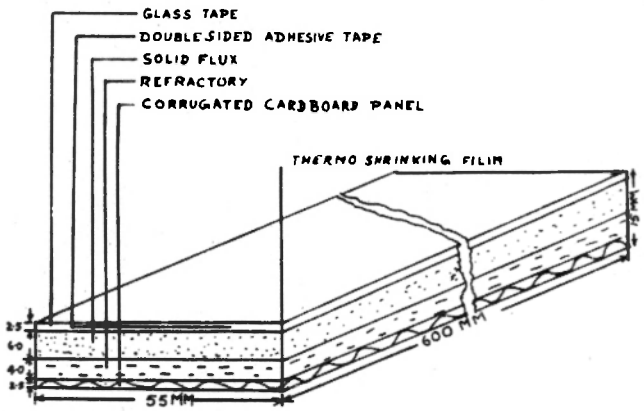
This is a submerged arc welding process where in addition to the wire and flux, a backing material and filler material are also used to complete the groove welding, including the back bead, from one side.

The Joint Set Up

The plates with single 'V' edge preparation, included angle usually 50 ± 5° is assembled with a root gap of 3 + 2 mm. (Fig. 5). The backing material FAB is placed under the joint.



SET UP FOR ONE SIDE FAB WELDING
(FIG 5)



FAB-1- CROSS- SECTION
(FIG 6)

Though the FAB itself sticks to the plate a support plate, usually 4 to 6 mm thick aluminium sheet, is placed below the FAB and clamping is done with the help of magnets. Depending on the root gap filler material (iron powder) is filled in the weld groove to the required height. The joint is welded in the conventional submerged arc welding practice using wire and flux. Single or tandem arc welding can be done.

The backing material FAB

The backing material FAB 1 (Fig. 6) developed by Kobe Steel Ltd., Japan has glass tapes for forming reverse bead, solid flux for controlling reverse bead height, refractory for fire resistance, corrugated card board for maintaining uniform pressure and glass mat cushioning material for obtaining a good contact between two FAB 1 materials. It is wrapped in a thermoshrinking film having resistance to a moisture absorption.

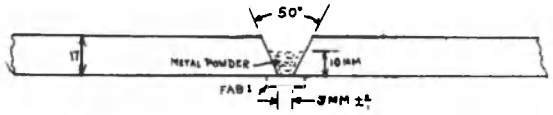


FIG-7 JOINT DESIGN FOR (FAB) ONE SIDE WELDING

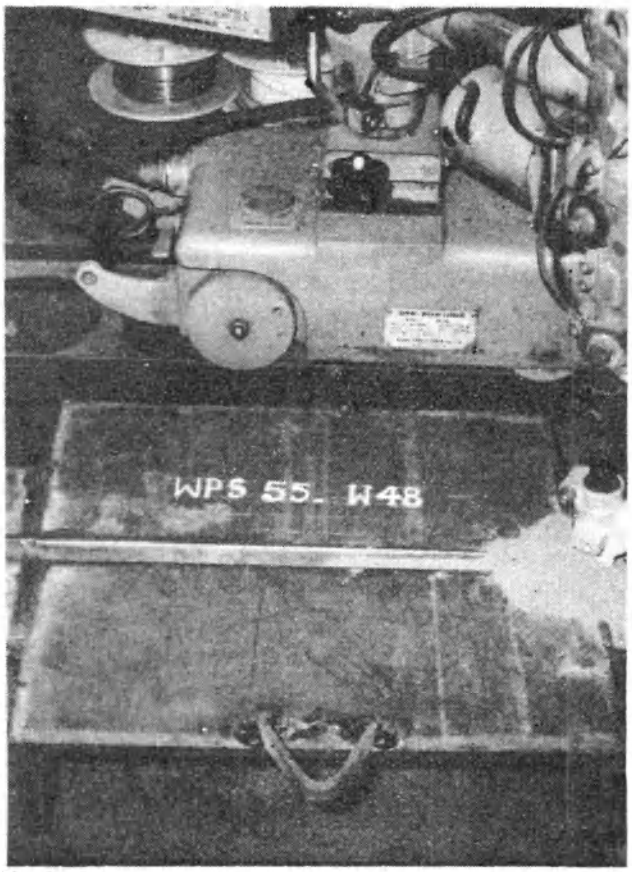


Fig. 8 Arrangement for submerged ARC one side FAB Welding (view from top).

Welding procedure qualification test

Welding Procedure Qualification Tests (Fig. 8,9, 10 & 11) were conducted as per the rules of the Ship's Classification Society. The details are given in the Welding Procedure Specifications (Annexure 3) and Procedure Qualifications Record (Annexure 4).

The test results were satisfactory and the Procedure was approved for use in shipbuilding by the Classification Society.

Welding operators were qualified as per the approved Welding Procedure.

Common Weld Defects

i) Lack of root fusion :

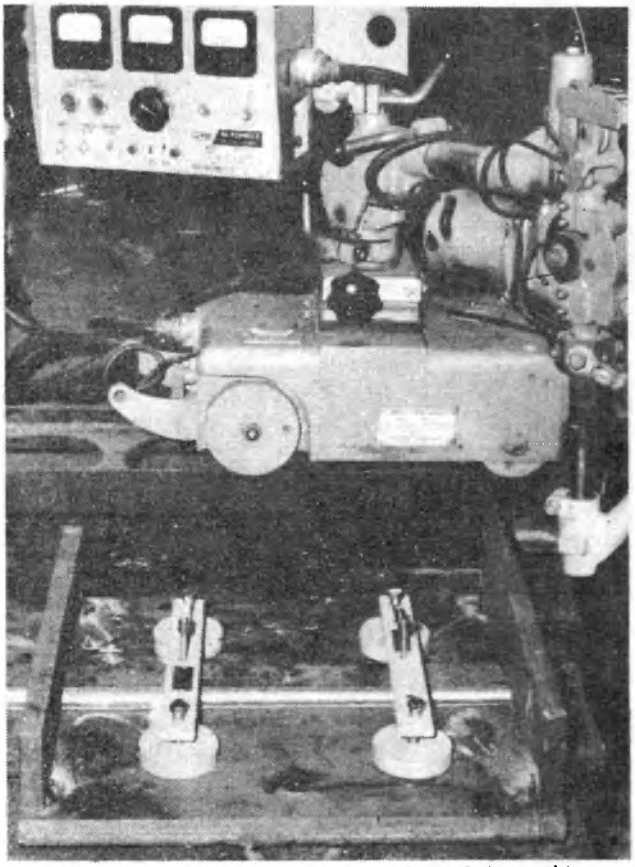


Fig. 9 Clamping of FAB at the bottom side of the weldgroove.

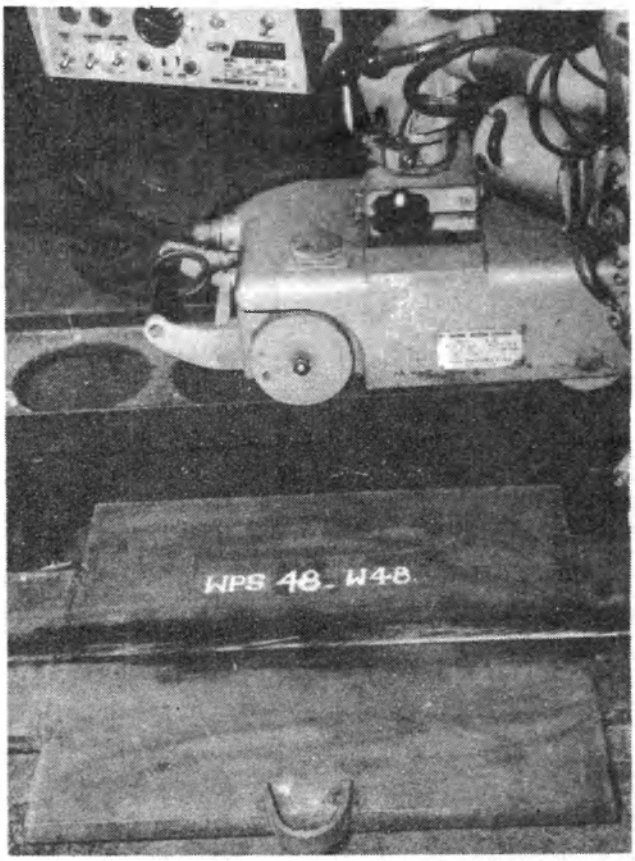


Fig. 10 Submerged ARC one side FAB Welded Plate (view from top).

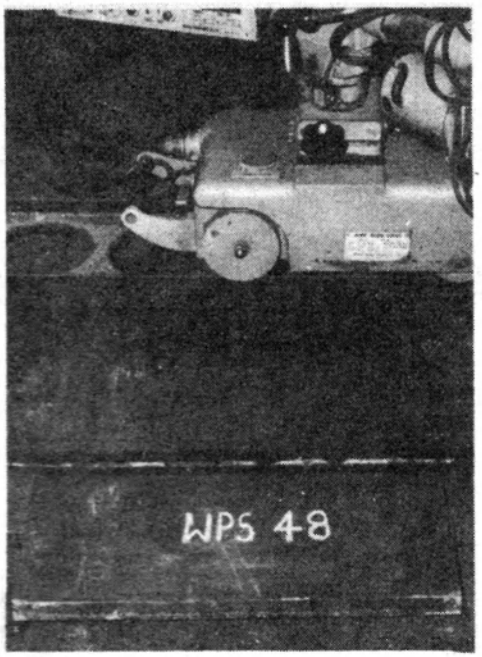


Fig. 11 Submerged ARC one side FAB Welded Plate (bottom side).

This is due to higher thickness of tack welds inside the groove -
Limit the height of tack welds to a maximum of 6 mm.

ii) Uneven reverse bead and overflow of molten metal :

This is due to incorrect fitment of FAB - Ensure correct pressure and contact between the plate and the backing material.

iii) Lack of side wall fusion :

This is due to misalignment of welding wire with the centre of the weld groove. The shift between the centre of the joint and the centre line of filler wire should not exceed more than 2 mm.

iv) Slag inclusion in case of multipass welds :

Ensure thorough cleaning of the weld joint before commencing subsequent pass.

v) Cracks at start and finish of welds :

This is avoided by manually welding both the starting and finishing ends of weld joint to a length approximately 200 to 300 mm and to a height of at least 2/3rd the thickness of the plate before starting FAB welding process. SAW should start and end over this cascade welding.

vi) Crack at restart points :

Restart points have to be gouged to a minimum length of 100 mm to clear off all weld defects before resuming the welding.

vii) Burnthrough :

This can be controlled by a) reducing the excess root gap by welding up and b) by reducing the welding current where applicable.

viii) Voids, piping etc. :

These are due to improper working conditions - This can be avoided by a) proper backing of the flux b) making the weld joint dry and c) by removing rust, dust etc. and cleaning the joint properly, especially at the back side.

Advantages of the Process

No back side chipping/gouging is required as done in many other process.

In case where jobs cannot be turned and the back side welding has to be done in overhead position, one side FAB welding is useful.

In a single 'V' double welded joint on 19 mm thick and 12 Metre long plate one side FAB (single pass finish) is 9 times faster than the MMA and 5 times faster than a combination process of MMA and SAW.

This process is advantageously used to join plates in downhand position totally avoiding turning of the panels and welding from the other side. Positional welding is completely avoided since the welding of the joint is fully done from the face side.

CONCLUSION

In Cochin Shipyard, one side FCB submerged arc welding is used in shop for welding panels and one side FAB submerged arc welding is used in Building Dock for joining prefabricated units. After completion of welding, both ends of the weld joints and restart points if any are checked by ultrasonic testing. At random, additional spots are also checked. Radiography also is done to check the welding.

The following types of one side welding are tried out in a very small scale at present :-

a) Gas metal arc (CO_2) welding with flux asbestos backing.

b) Manual metal arc welding with ceramic backing.

c) Gas metal arc (CO_2) welding with ceramic backing.

Except in the case of the stick electrodes used with ceramic backing, the backings as well as the welding consumables are imported. It will be highly desirable if indigenous manufacturers can come forward and develop these materials.

Application of one side welding methods have cut down the shipbuilding time as well as the cost of production in Cochin Shipyard.

Acknowledgement

I am very much thankful to the management of Cochin Shipyard Ltd., for permitting me to publish this paper. I am also thankful to Shri V.P. Nair, Chief Manager, I&QC Department and my colleagues who have helped me in preparation of this paper.

ANNEXURE - 1

Excerpt from

Welding Procedure Specification

1.	PROCESS	One side welding.
2.	MATERIALS	High Tensile Steel
	i) Material combination	
	ii) Material Specification/s	LRDH 36 To LRDH 36.
	iii) Material thickness to be used for test.	28.5 mm
3.	CONSUMABLES	
	i) Combination of consumables (Brand Names)	Wire US 43 Covering Flux - PF1-50 Backing Flux - PF 1-50R (Mfd. by Kobe Steel, Japan).
	ii) Grading if any	Lloyds Grade 3
4.	TECHNIQUES	
	i) Groove Design, backing etc. (Sketch of the JOINT/S)	See Figure - 2 .
	ii) Position-Welding Position-Welding Progression, whether single or double welding	Flat. Single side welding.
	iii) Initial and Interpass cleaning	Wire brushing.
	iv) Multipass or single pass (per side)	Single Pass
	v) Single or multipass electrode	Multipass electrode.
	vi) Pre heat and post heat treatment if any	Nil.
5.	ELECTRICALS	
	i) Power (AC/DC)	AC
	ii) Polarity	-----
	iii) Current	Leading 1350 A - Trailing 1200 A
	iv) Voltage	35/45-47V
	v) Travel Speed (Range)	33 cm/min.

ANNEXURE - 2

Excerpt from

Welding Procedure Qualification Record

1. WELDING PROCESS	One side welding (FCB system)
Groove Design, backing etc. (Sketch of the Joint/S)	See Figure - 2.
Material combination Specifications Thickness of test assembly	 LRDH 36 LRDH 36 28.5 mm

ANNEXURE - 2 (Contd.)

Consumables		
a) Coated electrode/wire flux combination		Wire flux combination Wire US 43 Covering flux - PF 1-50 Backing flux - PF 1-50R
b) Specification and Grade		Lloyds Gr. 3
Position : Welding position and progression		Flat
Gas type & composition of gas or gases		
Electricals		
Source AC/DC		AC
Polarity		-----
Current		Leading 1350 A - Trailing 1200 A
Volts :		Travel speed : 35 cm/min. Leading 35 V - Trailing 47 V
2. TECHNIQUE		
String or Weave bead		-----
Oscillation		-----
Multipass or single pass		Single pass
Other details		Wire dia Leading 4.8 mm and Trailing 6.4 mm
3. TEST RESULTS		
Satisfactory (Yes or No)		Yes
Details		
i) Radiography		O.K.

ii) Tensile Test

No.	UTS (kg/mm^2)	Location of Failure
1	57.75	Parent metal
2	57.1	Parent metal

iii) Bend Tests

FB 1	Results Satisfactory	RB 1	Results Satisfactory
FB 2	Satisfactory	RB 2	Satisfactory

iv) Macro Examination

M 1	Results Satisfactory
M 2	Satisfactory

v) Impact Tests (at 0°C)

Test	1	2	3	Average
Weld Centre (Face)	6.5	4.2	5.2	5.33
Weld Centre (Root)	9.6	5.0	6.4	7.0

ANNEXURE - 3

Excerpt from
Welding Procedure Specifications

1.	PROCESS	One Side Submerged Arc Welding (FAB)
	MATERIALS	
	i) Material combination	LR 'A' to LR 'A'
	ii) Material Specification/s	Lloyd's Grade A.
	iii) Material thickness to be used for test	17 mm
2.	CONSUMABLES	
	i) Combination of consumables (Brand Name)	Wire US 43 Flux PF-45 Metal Powder RR-2 Backing material FAB-1 Mfd. by Kobe Steel Ltd., Japan.
	ii) Grading if any	Lloyd's Gr. 3
3.	TECHNIQUES	
	i) Groove Design, backing etc. (Sketch of JOINT/S)	See Figure - 7
	ii) Position - Welding position, Welding Progression	Downhand (Flat) Single Welding.
	iii) Initial and interpass cleaning	Wire brushing.
	iv) Method of back gouging	Nil
	v) Multipass or single pass (per side)	Single pass (one side)
	vi) Single or multipass electrode	Single
	vii) Any other details	Wire dia. 4.8 mm
	viii) Preheat and post heat treatment if any	Nil
4.	ELECTRICALS	
	i) Power (AC/DC)	AC
	ii) Polarity	-----
	iii) Current	950 A
	iv) Voltage	33 V
	v) Travel speed (Range)	22 cm/min.

ANNEXURE - 4

Excerpt from
Welding Procedure Specifications

1.	WELDING PROCESS	One Side Submerged Arc Welding (FAB)
	Groove Design/backing etc. (Sketch of the JOINT/S)	See Figure - 7.

ANNEXURE - 4 (Contd.)

	MATERIAL COMBINATION	
	Specifications	Lloyd's Gr. 'A' To Lloyds Gr. 'A'
	Thickness of test assembly	17 mm.
	CONSUMABLES	
	Coated electrode/wire flux combination	Wire - US 43 Flux - PF 1-45 Metal Powder RR 2 Backing Material - FBA 1 Mfd. by Kobe Steel Ltd., Japan.
	Position : Welding position and progression	Flat (downhand)
	Electrical - Power AC/DC	AC
	Polarity	-----
	Current	950 A
	Volts	33 V
	Travel Speed	22 cm/min.
2.	TECHNIQUE	
	Multipass or Single pass	Single pass
	Other details	Wire dia. 4.8 mm
3.	TEST RESULTS	
	Satisfactory (Yes or No)	Yes
	Details	
	i) Radiography	O.K.

ii)	Tensile Test	No.	UTS Kg/mm^2				Location of Failure
	Transverse	1	44.9				Within weld
		2	45.8				
	Longitudinal	1	44.05				Within weld
iii)	Bend Tests	FB 1	Results O.K.	RB 1	Results O.K.		
		FB 1		RB 2			
iv)	Macro Examination	M 1	Results -----				
		M 2	-----				
v)	Impact Tests (at 20°C)	Test No.	1	2	1	3 2	3 Average
		Energy absorbed in Kgm	FACE	8.9	9.2	8.9	9.0
			Root	6.6	8.6	8.0	7.7