SUBMERGED ARC WELDING

AUSTENITIC STAINLESS STEELS

CONTENTS

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1. INTRODUCTION

Submerged arc welding (SAW) can be effectively applied to the fabrication of austenitic stainless steels, combining fast deposition of high quality weld metal with mechanised process efficiency. SAW is a highly productive alternative for joint filling on:

- circumferential or longitudinal seams which can be welded in the flat position (ASME, 1G; BS EN, PA)
- pipework or vessels in excess of 150mm (6in) diameter, which can be rotated.
- material in excess of approximately 15mm (0.6in) thickness

SAW is conventionally utilised for joint filling on top of initial root welds made using the TIG and MMA processes, the latter principally for additional deposit thickening up to 10-12mm to avoid 'burn-through' and/or single-side weld underbead thermal damage. For plate, or large diameter vessels with access from both sides, a double sided SAW procedure can be used, with back grinding or gouging, which overcomes the need for TIG/MMA root runs.

2. FILLER MATERIALS

Data sheets are given in Appendix 1.

2.1 Wires

Suitable wires are available for all of the standard austenitic stainless steels:

Metrode Designation	*AWS A5.9*	*BS EN 12072*	*BS 2901 pt 2*
308S92	ER308L	S 19 9 L	308S92
308S96	ER308H	S 19 9 H	308S96
347S96	ER347	S 19 9 Nb	347S96
316S92	ER316L	S 19 12 3 L	316S92

2.2 Flux

There are three fluxes relevant to the welding of austenitic stainless steels:

Metrode Designation	*BS EN 760*
SSB	SA AF 2 DC
SSCr	SA FB 2 63Cr DC
LA491	SA FB 255 AC

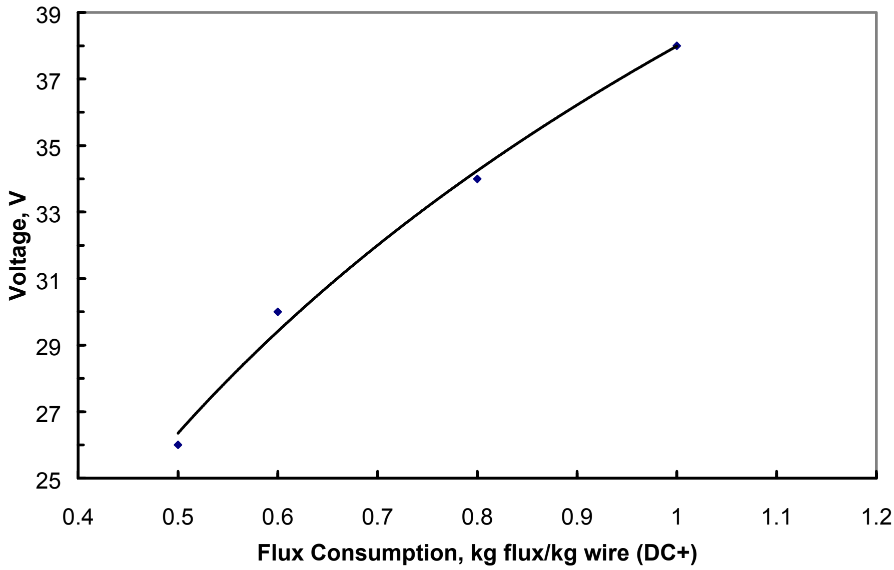
The flux predominantly used with the standard austenitic stainless steel wires is Metrode **SSB**, which is an agglomerated basic non-alloying flux. This flux will generally result in a minor loss of Mn (~0.3%) and Cr (~0.3%) and a slight pick-up of Si (~0.15%), see Table 1.

Table 1: Wire and deposit analyses for two batches of 316S92 wire (A & B) and SSB flux

		C	Mn	Si	S	P	Cr	Ni	Mo	Cu	WRC Ferrite FN
A	**Wire**	0.014	1.51	0.38	0.014	0.013	18.43	11.60	2.60	0.10	8
	Deposit 2.2kJ/mm	0.012	1.19	0.52	0.014	0.014	18.05	11.51	2.62	0.10	8
B	**Wire**	0.013	1.51	0.44	0.012	0.024	18.22	12.12	2.48	0.15	6
	Deposit 1.0kJ/mm	0.010	1.18	0.59	0.012	0.025	17.90	11.98	2.53	0.14	6
	Deposit 1.8kJ/mm	0.010	1.20	0.57	0.011	0.025	17.98	11.94	2.48	0.14	6
	Deposit 2.7kJ/mm	0.014	1.25	0.55	0.011	0.024	17.79	11.73	2.42	0.14	5

The flux usage allowed for on a weld is normally about1½ times the weight of wire. The actual amount of flux consumed in making a weld is actually less than this and will vary with voltage. Flux consumption for SSB flux on DC+ polarity is shown in the following graph:

Figure 1: Flux Consumption Using SSB Flux on DC+ Current



There is also another flux available, Metrode **SSCr**, which is an agglomerated fully basic chromium compensating flux, with a basicity index of about 2. This is used in applications where a loss of chromium can not be tolerated or to help provide some control of ferrite content.

The third flux, Metrode **LA491**, has proved to be useful for applications which require good cryogenic toughness. LA491 is a fully basic agglomerated flux (BI ≈ 3) which has been tested with both 308S92 and 316S92 wires and has been shown to be capable of achieving 0.38mm lateral expansion at -196°C. The LA491 flux results in a similar Cr loss to SSB (~0.3%), a slightly lower Si pick-up (~0.10%) and very little Mn loss (~0.1%). LA491 is not recommended for use with 347S96 wire or for welding 321/347 base material using 308S92 wire; for these applications we recommend SSB flux.

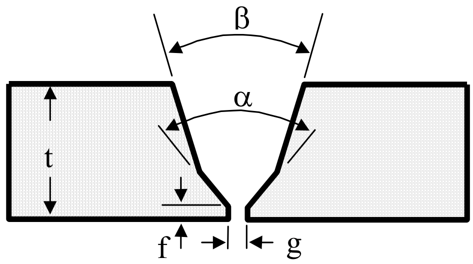
3. JOINT CONFIGURATION

Table 2 details typical joint configurations appropriate to SAW of thicker section material, designed to facilitate root access whilst minimising joint volume and facilitating maximum productivity.

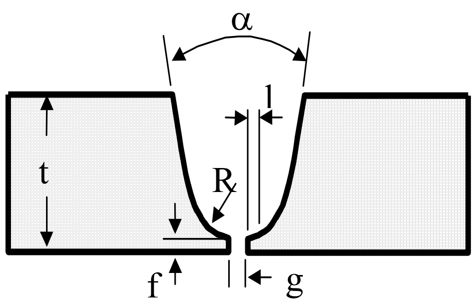
With wall thicknesses up to approximately 20mm (0.8in), conventional single V-joint configurations are recommended, for wall thicknesses above 20mm (0.8in) compound V or U configurations are recommended. With double-sided welding applications, based on twin V- or U- grooves, fabricators may opt for modified root configurations to dispense with TIG in favour of MMA (or MIG) for initial weld runs.

With any single-sided joint configurations it is important that sufficient weld thickness is deposited using TIG, MMA or MIG before using SAW to avoid burning through. The actual thickness of weld deposit required in practice will vary depending on the wire diameter and current to be used for SAW but will normally be a minimum of three runs (one TIG and two MMA for example) producing a deposit thickness of about 10mm.

Table 2: Joint preparations



t (mm)	α	β	f (mm)	g (mm)
< 20	70-80°	-	0.5-1.5	3-4
> 20	70-80°	20-30°	1-1.5	3-4



t (mm)	α	3 (mm)	l (mm)	f (mm)	g (mm)
> 20	20-30°	6-10	0-2	0.5-1.5	3-4

4. WELDING PARAMETERS

The following guidelines are based on typical fabrication experience:

Wire diameter: 2.4mm ($^{3}/_{32}$in) diameter is the most commonly used size; 1.6mm ($^{1}/_{16}$in), 3.2mm ($^{1}/_{8}$in) and 4mm ($^{5}/_{32}$in) diameter are also available in some grades.

Welding current: DC+ polarity is normally used; the LA491 will also operate on AC. It is important to select the correct current. A current which is too low produces an unstable arc; as the current is increased, penetration increases but excessive current can produce undercut or excessive bead reinforcement. Typical currents for different wire diameters are as follows:

Diameter mm	*Range A*	*Typical A*
1.6	200 – 350	250
2.4	250 – 450	350
3.2	300 – 500	400
4.0	400 – 600	500

Arc voltage: Careful control is recommended to optimise weld bead geometry (eg depth/width ratio <1) and avoid risk of centreline solidification cracking. As voltage is increased a wider, flatter weld bead is produced. Typical voltages for different wire diameters are:

Diameter mm	*Voltage*
1.6	27 – 31
2.4	28 – 32
3.2	29 – 34
4.0	30 – 35

Travel speed: Typically 400-500 mm/min (16-20in/min), though speeds upwards of 650mm/min (26in/min) may be required to maintain bead shape control with smaller diameter components, eg 150mm (6in) diameter pipe.

Electrode extension: 20-25mm (0.8-1in); < 20mm (1in) 'stick-out' risks loss of effective Joule heating effect and stable metal droplet detachment resulting in arc instability and uneven, erratic weld beads. > 25mm (1in) leads to excessive resistive heating and imbalance in weld deposition/penetration relationship.

Flux pile depth: 25-30mm (1-1.2in); < 25mm (1in) risks arc flaring through flux cover, arc/weld pool instability, possible entrainment of air into the arc cavity and incidence of weld porosity. > 30mm (1.2in) flux pile may inhibit release of gases generated during welding and cause weld surface porosity or 'gas flats'.

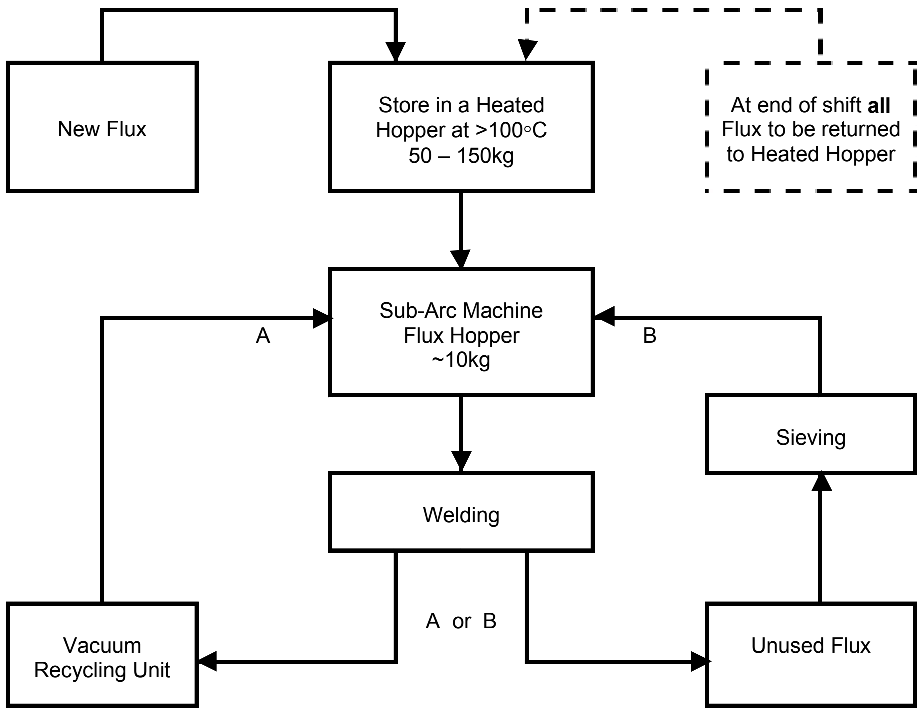
Electrode angle: 90° for all weld runs, ie no angling in towards sidewall. With circumferential butt joints, wire should be positioned 25-30mm (1-1.2in) before top centre and angled back along a line intersecting the pipe central axis.

Weld sequence: Weld deposit layers composed of 3 rather than 2 (wider) beads, symptomatic of higher arc voltage, are recommended to avoid risks of solidification cracking.

Flux control:

Flux used must be maintained in a reliably dry condition, ideal storage conditions are <60%RH and >18°C (>65°F). Whilst flux from freshly opened drums, which have been stored correctly, may be used without prior baking, it is recommended that ***all*** flux be incorporated in a system that routinely re-bakes flux for a minimum of 1 hour at 250-400°C (450-750°F). Welding with flux hotter than 150°C (300°F) should be avoided to ensure satisfactory operation. General requirements for flux handling are shown in Figure 2.

Figure 2: Flux handling



With repeated handling and recycling of agglomerated flux, excessive build-up of fine particles and a shift in grain size balance ultimately leads to deterioration in operating characteristics. To counter this effect, recycled flux should be routinely diluted with new flux on a 1:1 ratio.

Preheat:

Whilst preheat is not normally required, initial weldment temperatures < 5°C (<40°F) should be avoided and weld surfaces should be clean and dry. With thick section material, preheating to temperatures up to 100°C (200°F) may be considered beneficial in reducing weld solidification rate to assist release of gases generated and further minimise incidence of weld porosity, particularly with initial SAW weld runs.

Interpass temperature:

This should be measured using a contact pyrometer, at the precise start point of each run. For standard austenitic stainless steels, a maximum interpass temperature of 250°C (450°F) should be used.