WELDING WITH METRODE FLUX CORED WIRES

"GETTING THE BEST OUT OF THE PROCESS"

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Welding with METRODE Gas Shielded FCW's

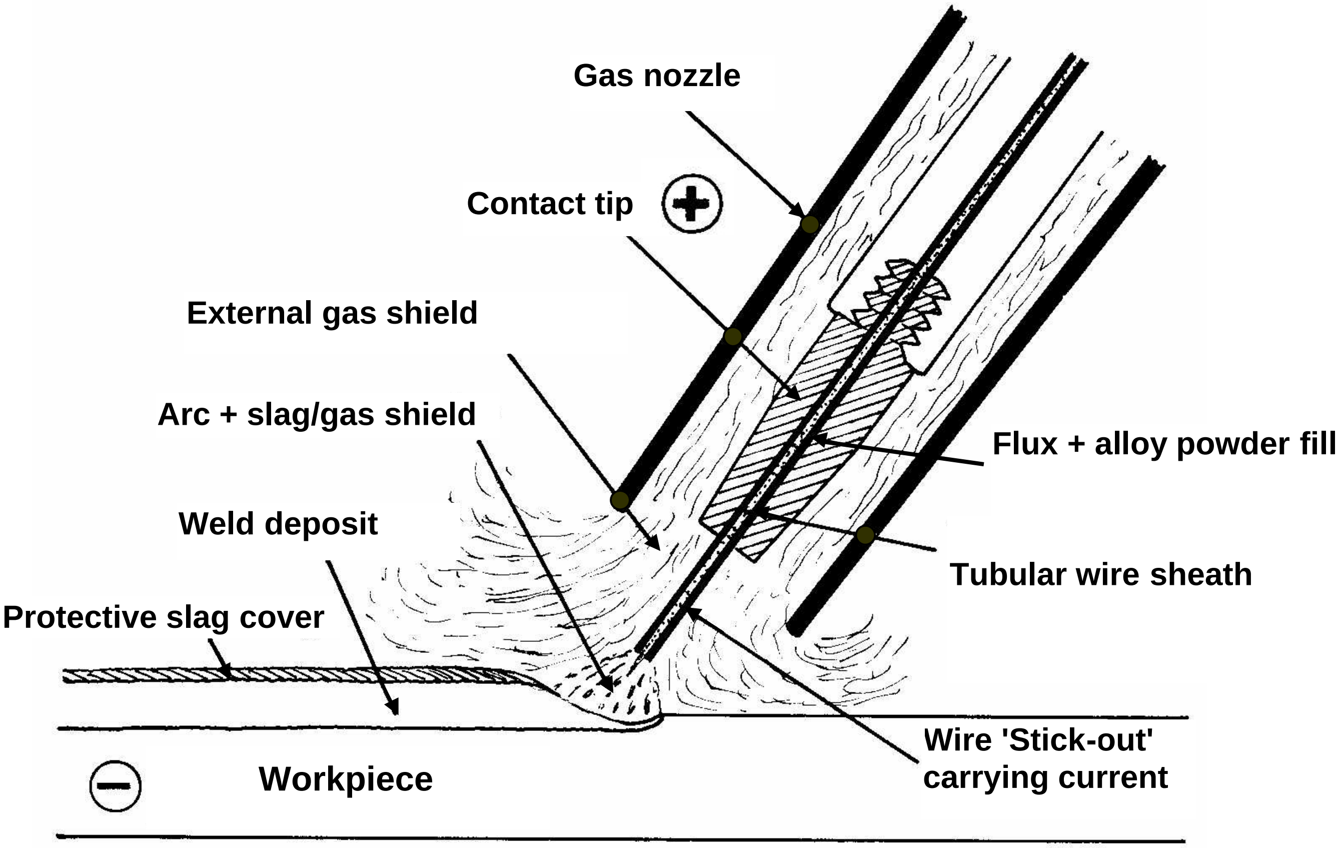
Contents

Cormet

METRODE Supercore

Gas Shielded Flux Cored Arc Welding (FCAW)

The Process



- Supercore and Cormet FCW's are recommended for use with any MIG (GMAW) equipment, incorporating single or twin drive roll wire feed systems.
- The widely popular 1.2mm ø sized wires are predominantly suitable for welds in material 5mm thick and above.

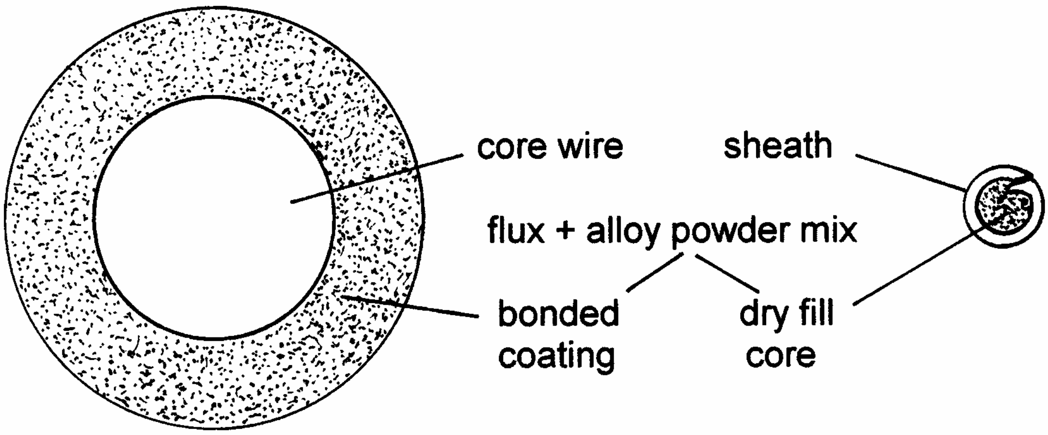
  Certain applications involving material down to 3mm thickness can also be viably welded using 1.2mm ø wire, eg high speed manual seam welding of lap fillet joints, sealing runs, vessel limpet coil attachments, etc
- 1.6mm ø wire is principally suitable for higher current, automatic downhand welding of thicker wall fabrications.

What is Flux Cored Wire ?

"It's an inside-out stick electrode!!"

Flux Coated Electrode
4mm ø

Flux Cored Wire
1.2mm ø



FCW's thin wall tubular sheath has a comparatively smaller cross-sectional area than solid wire or manual welding electrodes. Consequently, the current-carrying wire 'stick-out' from the contact tip shows a higher electrical resistance (R) to passage of the welding current (I).

This has 2 important effects:

1. Higher current density, Amp/mm^2 at the wire tip, eg @ 200A

4mm ø MMA (SMAW)	**eg, @ 150A,**	1.2mm ø FCW
12A / mm^2	← Current Density →	240 A / mm^2

❖ **Arc intensity and penetrating potential more than x20 that of MMA (SMAW).**

2. Joule Effect (I^2R) preheating of the wire is increased. See Section on Electrical 'Stick-Out'.

❖ **Faster wire melt-off; higher weld metal deposition rate.**

Summary of Procedural Recommendations

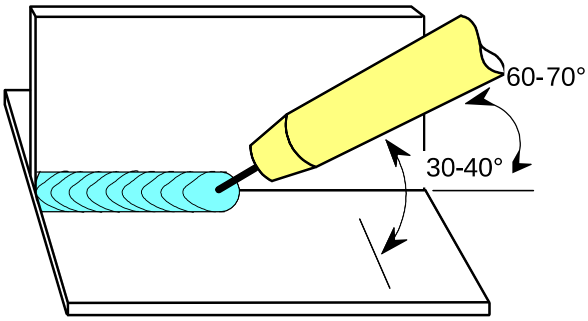
Effective application of the FCAW process is maximised by ensuring that operational procedure follows a number of recommended guidelines, which can be summarised:

1. Use Welding Current / Arc Voltage combinations which fall within the '**optimum operating conditions**' area of the tolerance box overleaf, to achieve smooth, stable, minimum spatter arc operability and maximum effective travel speed. See page 6.

2. Use Argon + 15-25%CO_2 at a flow rate between 15 and 20 lpm (30 to 40 cfh).

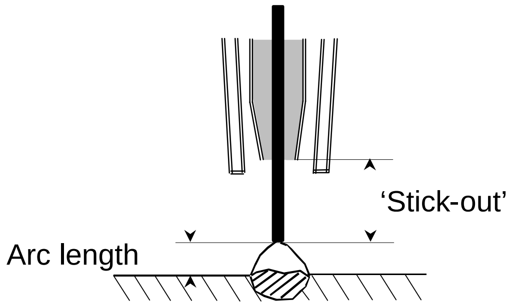
   Other gases are either:
   - less expensive, and less effective, or,
   - more expensive, and no more effective.

   See page 8.



3. Use backhand/pulling technique with the gun at an angle 60° - 70° from the horizontal:-

   The forehand / pushing technique shows limitations in effectiveness. See page 12.



4. Operate with an electrode extension from the contact tip, 'stick-out', in the range 12 to 20mm:-

   See page 7.

5. Avoid excessively slow travel speed; typically welding at **twice** the speed normally associated with operating MMA (SMAW) electrodes.

   This will ensure an adequate balance of '**Fill & Fusion**', satisfactory weld profile and easier / clean slag release.

   See page 10.

FCAW Process Controls: 1

Welding Current

Standard DC rectifier or inverter power supplies are sufficient.

Pulsed power supplies are also acceptable, though are not essential to ensure satisfactory arc operability and process stability.

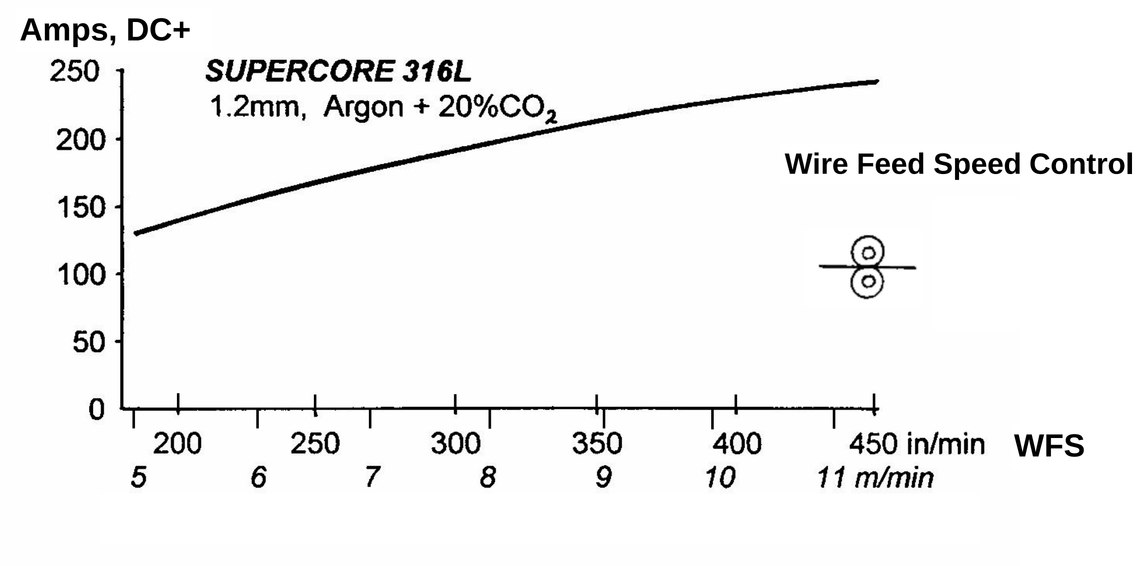
Welding current (Amp), directly controlled via adjustment of Wire Feed Motor speed setting, is selected to ensure:

- a level of arc energy / heat input sufficient to achieve weld joint penetration and fusion, to suit the material thickness being welded.
- an appropriate rate of filler metal deposition, to suit the type and size of weld being deposited.

With respect to any material thickness being welded, use of excessively high welding currents, to speed up weld deposition, risks loss of bead shape control and finished weld appearance.

Use Wire Feed Speed (WFS) control to fine tune arc length during welding. Increased WFS reduces arc length, and vice versa.

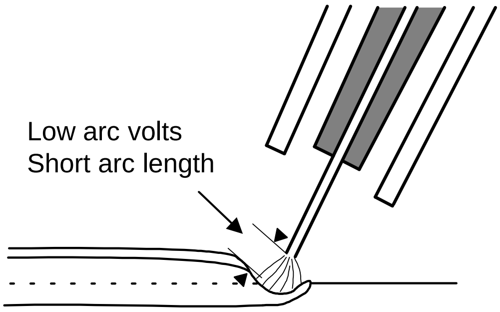
Typical **Wire Feed Speed** relationship with **Welding Current**:

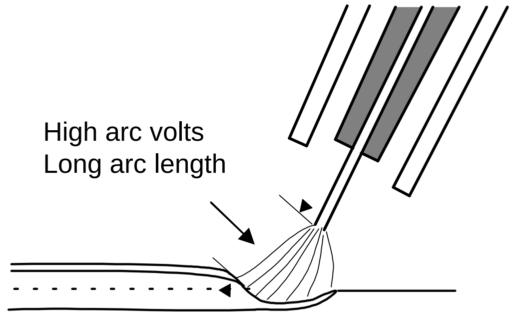


FCW Welding Process Controls: 2

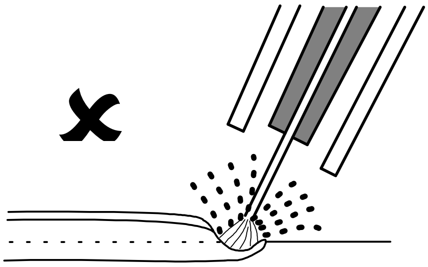
Arc Voltage

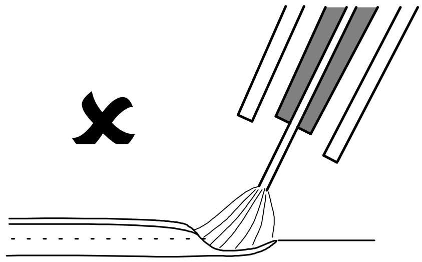
- Arc voltage directly influences the length of the welding arc, ie the distance between the tip of the wire and the weld pool surface:





- Arc length control is the key to maximum welding operability:

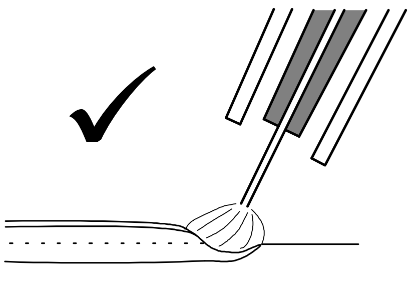




Arc voltage too low
- wire tip contacting weld pool
- harsh arc condition
- excessive weld spatter
- narrow, peaky bead profile

Arc voltage too high
- excessively long arc
- weak arc directionality
- wide low penetration beads
- inconsistent weld bead profile

- **Correct selection of arc voltage results in:**



- uniformly smooth arc operability
- minimum weld spatter
- maximum weld pool control & travel speed
- clean easy slag release
- maximum weld appearance
- **maximum weld quality**

FCAW Welding Process Controls: 3

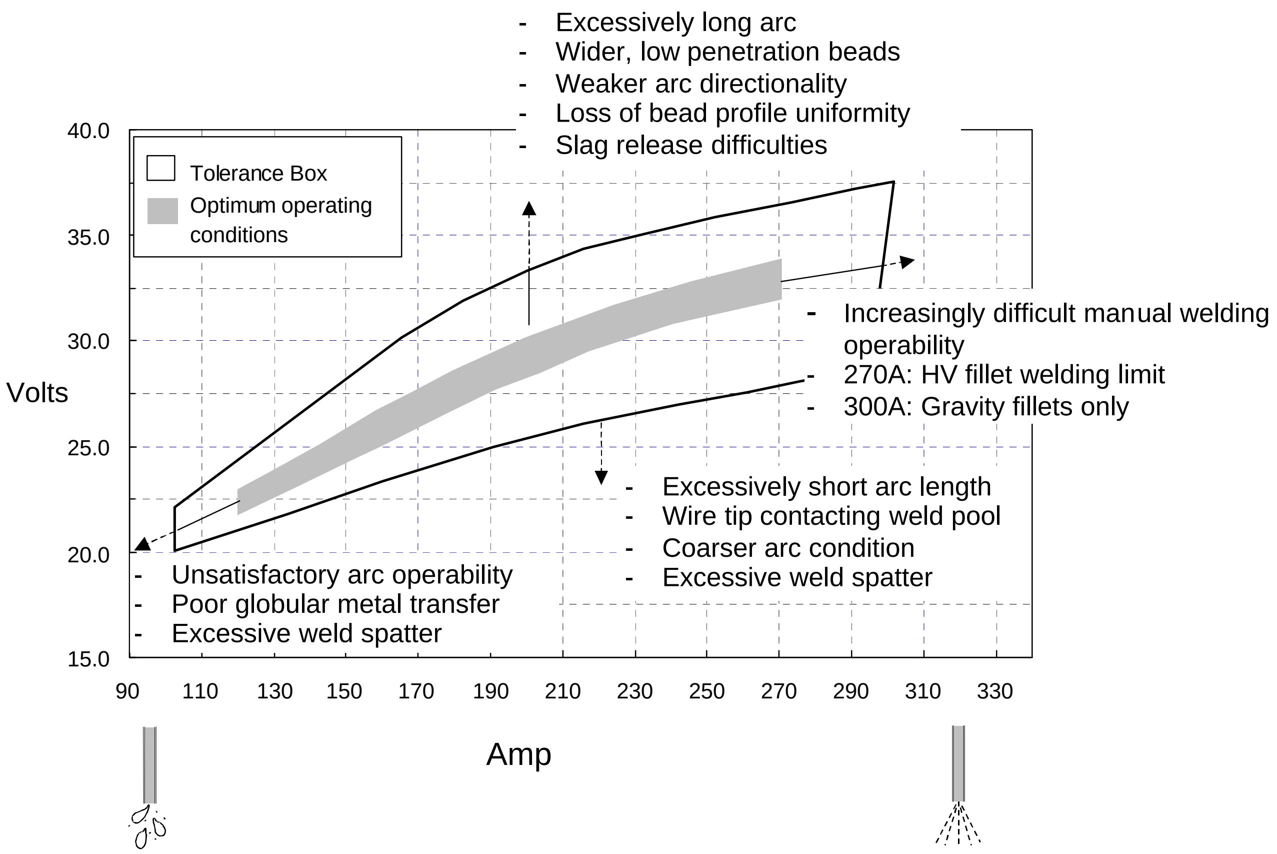
Operability Tolerance Box for Downhand Welding Applications

Effective operation of the FCAW process is maximised via selection of a balanced combination of amps & arc volts. At any particular current level, there is an arc voltage range, within which tolerable arc operability can be experienced. The limits of these combinations form an 'Operability Tolerance Box'.

However, over the full recommended current range for Supercore and Cormet FCW's, a narrower 'Power Band' within the tolerable operability limits, approximately 2V wide, defines the limits within which "optimum welding operability" performance will be experienced.

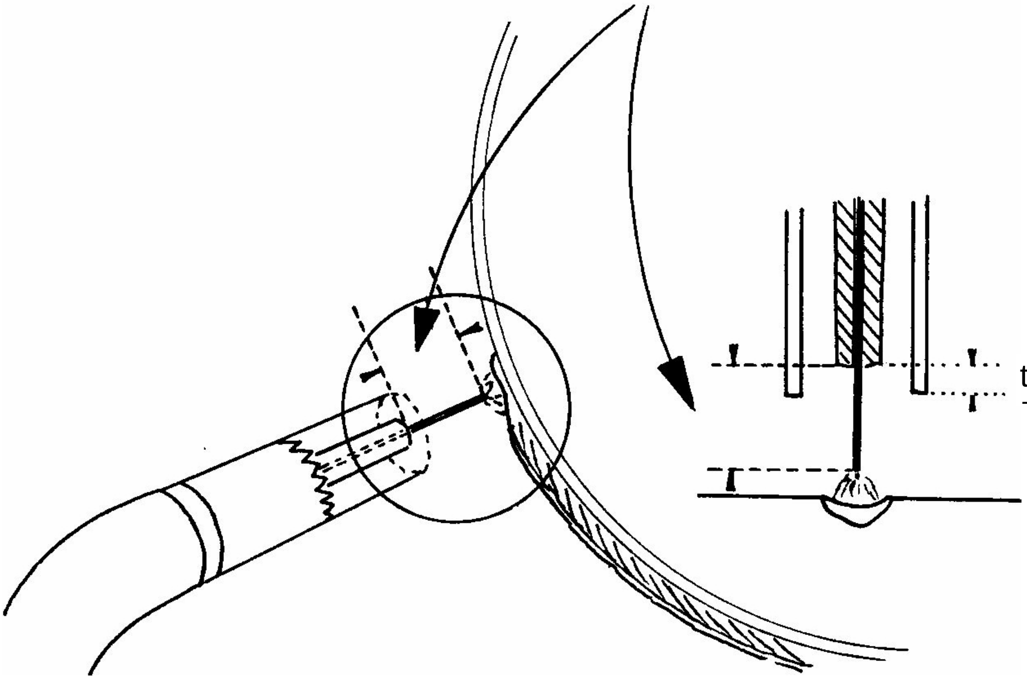
Operation outside this 'Power Band' will result in progressively inferior process performance, as arc voltage is increased or reduced.

Supercore & Cormet FCW's: 1.2mmø, Ar +15-25%CO_2



FCAW Process Controls: 4

Electrical 'Stick-Out'



The length of wire electrode protruding from the contact tip during welding, termed the electrical 'stick-out' (ESO) plays an important role in FCAW process effectiveness.

The 'stick-out', carrying welding current, becomes electrically preheated prior to it being fed into the arc zone. This usefully:

- increases efficiency of wire tip 'melt-off', and overall weld metal deposition rate.
- ensures that any wire surface 'contaminant' is effectively burned-off before it enters the arc, and avoids risk of gas porosity.

Welding with a **fixed 'stick-out'** in the range of 12 to 20mm is recommended.

Fluctuations in 'stick-out' **during welding** can lead to excessive changes in welding current and arc operability. For example:

ESO, mm	8	12	16	20	24
Current	202	187	172	162	154
Arc Voltage	27	27.8	28.1	28.4	28.6

Any variations should be restricted to the practical limits of manual welding.

FCAW Process Controls: 5

Gas Shielding

Supercore and Cormet FCW's are designed for maximum performance under standard Argon + 20% CO_2 type gas shielding.

However, with a slight adjustment in arc voltage level, they operate satisfactorily under the range of Ar + 15-20%CO_2 type shielding gases, with and without a residual O_2 component, used in many other countries around the world.

Eg At, typically, 200A:	Ar + 25%CO_2 (+/- 2%O_2)	30V
	Ar + 20%CO_2 (+/- 2%O_2)	29V
	Ar + 12%CO_2 (+ 2%O_2)	27V
	Ar + 5%CO_2 (+ 2%O_2)	26V
	Ar + 38%He* + 2%CO_2	25V
	100%CO_2 **	32V

* Proprietary gas mixtures, containing proportions of Helium, can be used, though offer no technical advantages.

** Not recommended for use with Supercore P' grade positional welding wires.

The change in effective arc voltage results in a slight upward or downward shift in the optimised 'power band'. See page 9.

Gas flow rate selected should be sufficient to ensure adequately effective shielding under the prevailing environmental conditions.

Excessively high flow rates are both wasteful and conducive to turbulence, with a consequent loss of effectiveness and overall arc stability.

Welding outdoors, eg on-site, will require higher flow rates, and should involve essential precautions (eg tent enclosure) to protect welding from adverse windy conditions, to avoid excessive influence of oxygen and nitrogen pick-up, and consequent weld porosity.

Typical gas flow rate recommendations:

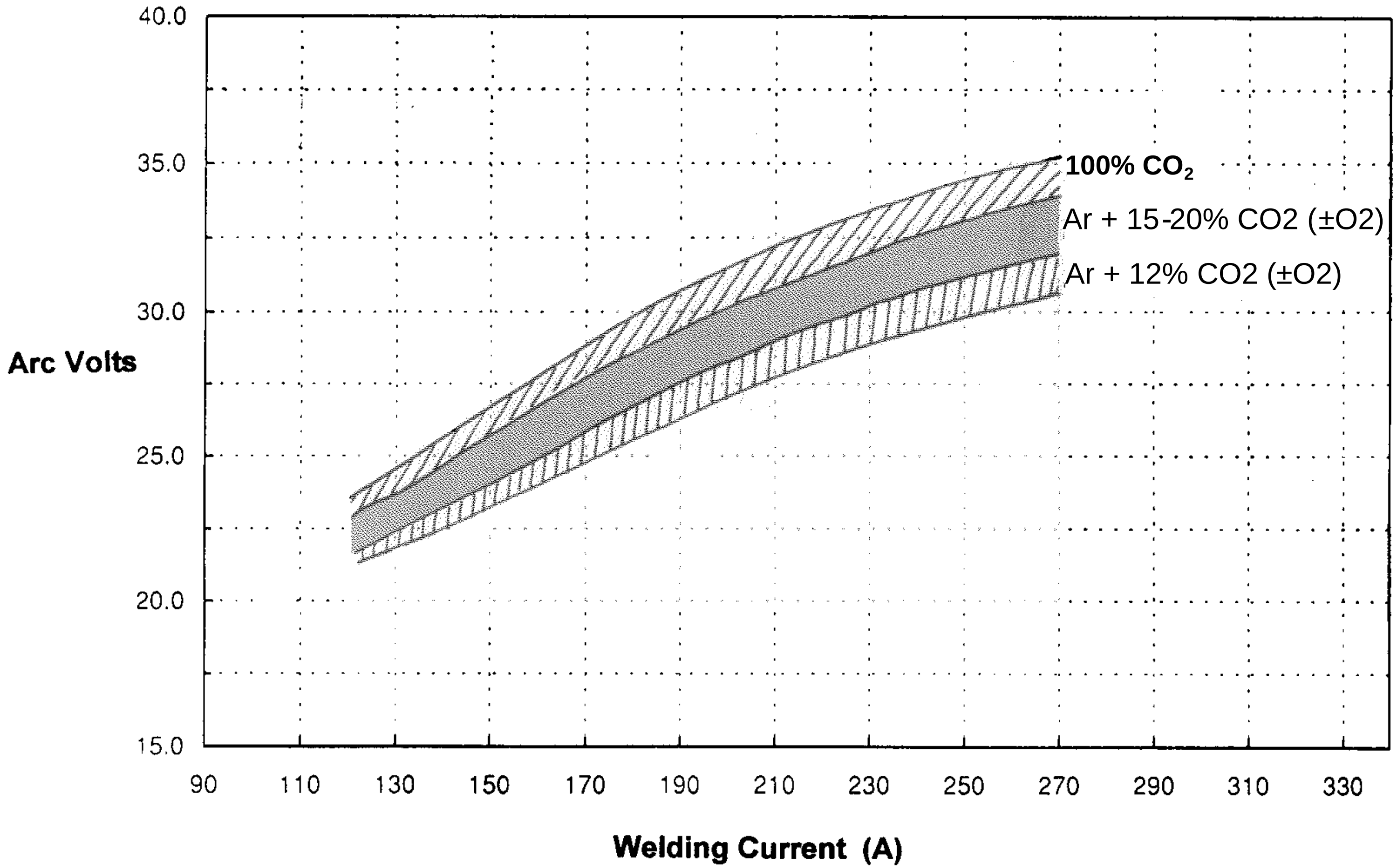
Protected workshop:	10 – 15 lpm	(20 – 30 cfh)
Draughty workshop:	15 – 20 lpm	(30 – 40 cfh)
Welding outdoors:	20 – 25 lpm	(40 – 50 cfh)

Both CO_2 and Argon/CO_2 gas shielding result in suitably low carbon weld metal, for corrosion resistance purposes. Argon-based gases promote slightly lower C, increased alloy transfer and weld Ferrite phase level:

Supercore 316L	**C**	**Mn**	**Si**	**S**	**P**	**Cr**	**Ni**	**Mo**	**Cu**	**Ferrite**
CO_2	0.03	1.60	0.63	0.010	0.022	19.2	12.3	2.6	0.07	8FN
Argon+20%CO_2	0.024	1.67	0.63	0.008	0.027	19.6	12.4	2.7	0.09	10FN

Supercore FCW: Optimum Operating Conditions

Influence of shielding gas composition on 'power band' optimised settings



FCAW Process Controls: 6

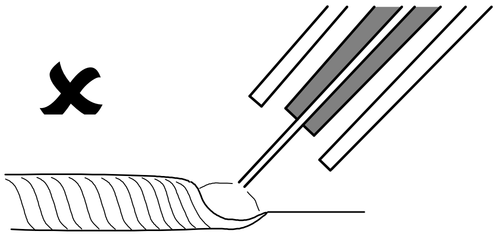
Influence of Travel Speed

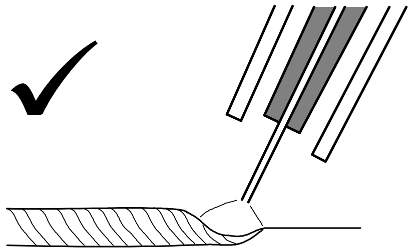
- Operating using optimum 'power band' Amps / Arc Volts enables welder to control and maximise travel speed.

- **Supercore** and **Cormet** FCW deposition rate is approximately twice as fast as that with **MMA** (SMAW) electrodes, at the same current. See page 11. Consequently, travel speed must be increased proportionately to maintain control of the weld pool, bead shape and balance of deposited metal versus weld fusion,
ie a balanced ***FILL / FUSION*** ratio.

  Torch angle also becomes, ultimately, a related factor.

  Eg:



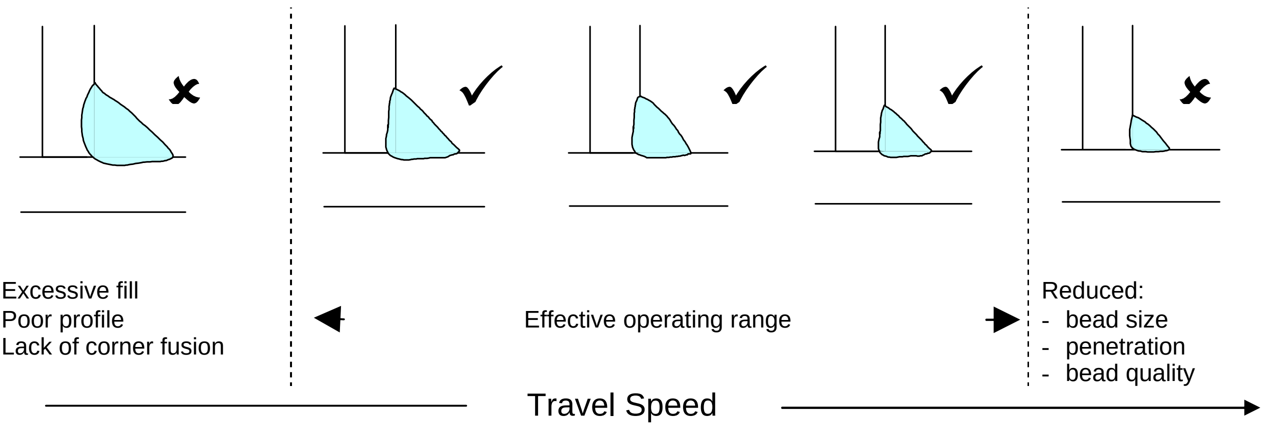


- too slow, heavier build-up
- welding torch angled lower to control weld pool slag
- arc operating in wrong position to secure fusion/penetration

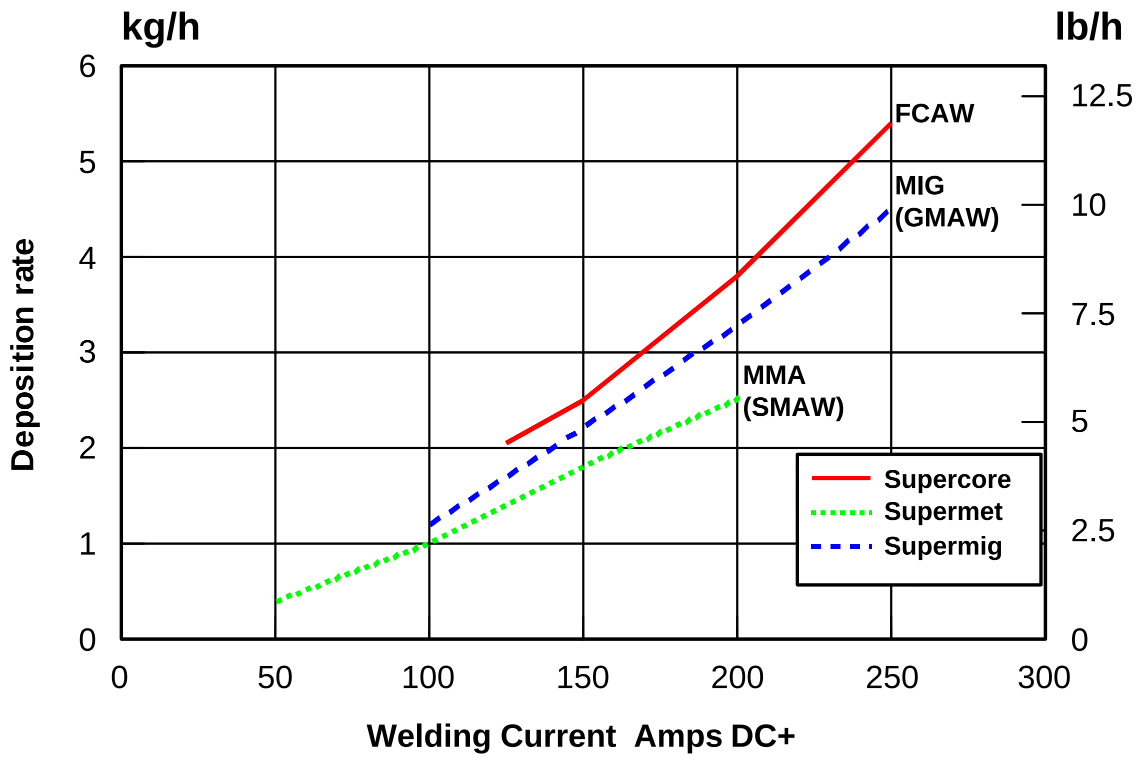
- faster travel speed, reduced build-up
- weld torch can be angled to arc nearer leading edge of weld pool to maximise fusion/penetration

Under balanced current/voltage volts conditions, travel speed can be increased to achieve smaller size weld beads, whilst maintaining requisite bead shape, eg mitre profile fillet welds of reduced leg length.

However, excessively slow or fast travel speeds result in loss of essential **FILL / FUSION** balance:



MMA, MIG & FCW Weld Metal Deposition Rates



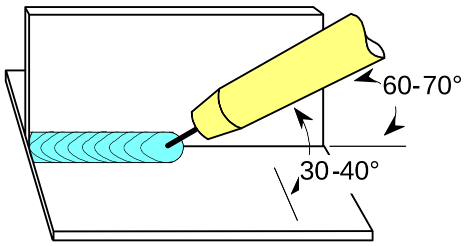
Eg @ 200A	Supercore 316L	1.2mm:	3.6 kg/h
	Supermig 316L	1.2mm	2.7 kg/h
	Supermet 316L	5mm	2.2 kg/h

Welding Techniques: 1

Downhand

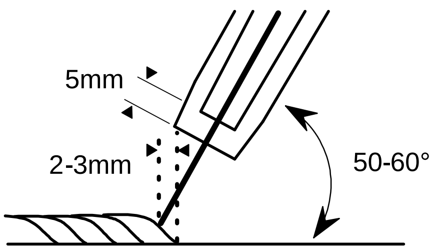
Welding torch angle influences weld pool/slag control, weld bead profile and the degree of penetration depending on whether a backhand/pulling or a forehand/pushing technique is used.

Backhand/Pulling Technique



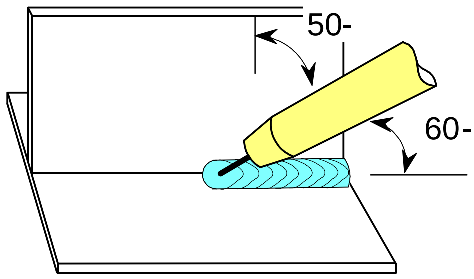
As with the other important slag shielded process, MMA (SMAW), the backhand technique is both a natural and a recommended mode of torch operation for most applications:

- Arc forces control the weld pool and slag, preventing cold laps and slag entrapment.
- Penetration is maximised
- With horizontal-vertical fillet welds, the wire tip should be aimed directly into the joint corner. A 30-40° torch angle ensures that equi-leg length fillets are achieved. A 60-70°backhand torch angle, typical of MMA (SMAW) welding practice, produces slightly convex fillet weld profiles. Steeper, almost upright, torch angles may be used to produce flat, mitre profile fillets without loss of essential slag control.



For ***weld cladding*** applications, the backhand technique is employed to produce high build-up weld deposits and ensure essential fusion between adjacent beads. To minimise penetration into the base material, and associated dilution effects, the technique of aiming the wire tip in-board of the 'toe' of the previous bead is recommended. This results in approx 50% bead overlap, full fusion and a neat tie-in between adjacent beads to give a uniformly flat clad layer.

Forehand/Pushing Technique



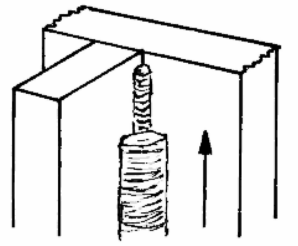
The forehand technique associated with MIG (GMAW) solid wire welding produces flat/ concave cosmetically attractive fillet welds and/or low reinforcement butt welds. Penetration is minimised, and the technique may be preferred in situations where improved visibility and seam following are important, eg high speed sealing run along the back side of a 2-run double side weld in thin material, eg 3mm thick. However, the technique is not recommended for thicker material where the lower travel speed involved could result in loss of slag control and full fusion with the base material. This applies also to weld cladding where the gains of minimal penetration, important to reduced dilution in first layer cladding on the C-Mn steel, may be offset by the risk of incomplete fusion.

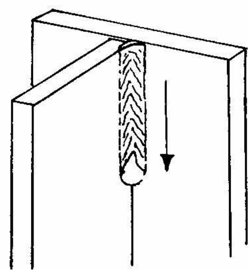
Welding Techniques: 2

Positional Welding

Standard Supercore Wires These wires, designed to show maximum operating smoothness, productivity and finished weld appearance when used in the downhand or horizontal-vertical positions (eg ASME 1G/2G, BS EN PA/PC), are suitable, to a limited degree, for weld joins in other positions:

Vertical-up and Uphill: Single 'stringer' bead welding of thin section material, eg 5 to 8mm, not recommended, due to difficulties in optimising arc operability and weld profile. Weave welding, eg 150-160A, 24-26V with 1.2mmø wire, offers the opportunity to deposit flatter profiles, with multi-pass welds in thicker section material.





Vertical-down and Downhill: Can be used, with fast travel speeds to maintain weld pool control, to produce smoothly uniform concave profile, low penetration fillet welds and sealing runs in thin section material:

eg 170-180A, 24-25V, 450-550mm/min, operating with short 'stick-out'.

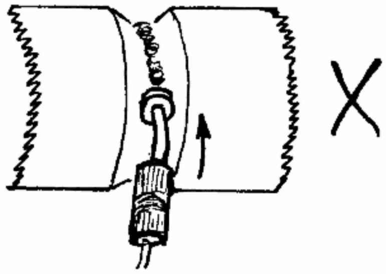
Standard CORMET and SUPERCORE 'P' Grade Wires: These wires are designed to meet requirements for welding structures, pipework and attachments in all positions. The fast-freeze slag coverage ensures controlled deposition of flat profile welds beads, with easy clean slag release.

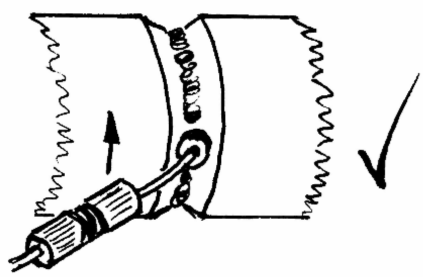
For butt joints in pipework, particularly in the challenging ASME 5G/6G, BS EN PF/H-L045 horizontal and inclined positions, minimum pipe dimensions for effective application can be defined:

- approximately 12-15mm minimum wall thickness
- 8" (200mm) minimum bore diameter, though 10" (250mm) to 12" (300mm) sizes ease demands on welder skills.

Reliable welding of small diameter pipework places increasing demands on the welder's ability to maintain consistent 'stick-out' and torch angle, under the relatively fast travel speed conditions involved with FCAW. Operating with the welding torch held approximately transverse to the weld seam enables the operator to maintain the requisite controlled movement more easily than when holding the torch in line with the seam.

Typical operating conditions: 155-175A, 25-27V

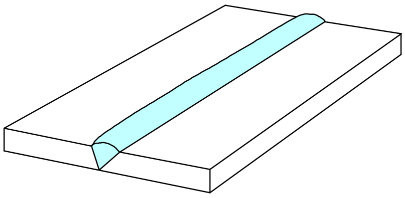




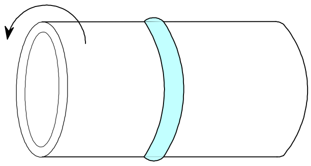
Welding Positions

According to ASME IX and (BS EN 287) specifications

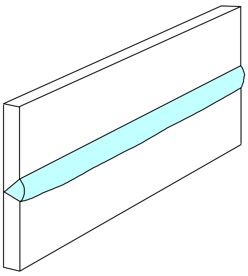
1G (PA)



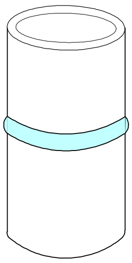
1G Rotated (PA)



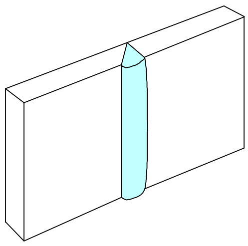
2G (PC)



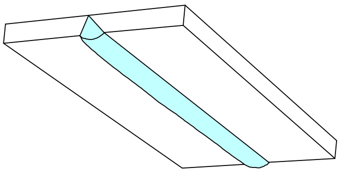
2G (PC)



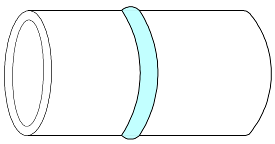
3G (PF)



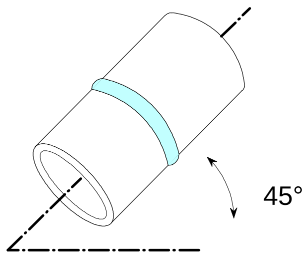
4G (PE)



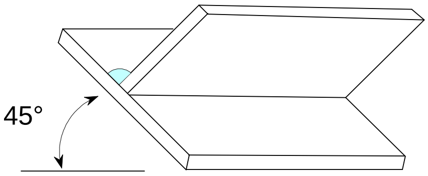
5G (PF)



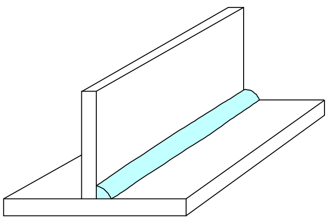
6G (H-LO45)



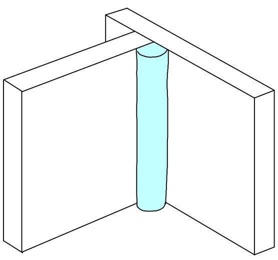
1F (PA)



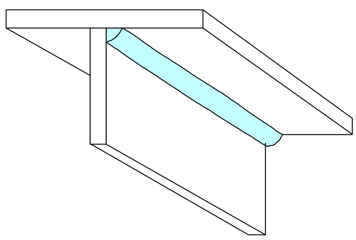
2F (PB)



3F (PF)



4F (PD)



Welding Techniques: 3

Root Pass

The viable application of FCW's for root pass welding operations is subject to a number of requirements;

1. Double-side V and J-butts

Provided that joint alignment can be maintained, an initial joint-sealing run can be deposited without encountering excessive penetration and need for extensive back-grinding prior to back-filling. Typical open or closed joint configurations would involve:

Root face: 2 ± 0.5mm Root gap: 2 ±1mm

2. Single-side V and J-butts

To achieve consistently uniform, fully penetrating root beads, joint gap and alignment maintenance is essential. Typical joint configurations would involve:

Root face: 1.5 – 2.0mm Root gap: 2.5 ± 0.5mm

The slag shielded root underbead surface does not require additional inert gas protection.

It is recommended that FCAW in this context is confined to those joints in pipework or small vessels where the thin layer of underbead slag is acceptable, or, can be adequately flushed away.

3. Single-side welding on to ceramic backing

This higher productivity approach to single or double-sided V-butts, welding on to hard baked ceramic tiles that fuse to support and mould the weld underside, can be applied effectively to alloy FCAW, producing uniformly smooth weld profiles. Typical joint configurations would involve:

Root face: 1.0 ± 0.5mm Root gap: 6 – 8mm

4. Single-side welding on to solid steel backing

Single bead root pass welding into this type of 'blind' joint configuration is not recommended. Full penetration and fusion of the joint corners and backing bar may be prevented by slag trapped at the root of the joint.

The alternative, a 2-bead root layer - involves excessive joint opening, eg a 12mm wide root gap, and overall joint volume.

It is recommended that the typical 5mm wide root gap joint is welded, initially, using an 'Ultramet B' grade basic coated type SMAW (MMA) electrode, to secure reliable fusion and freedom from entrapped slag.

Operational Recommendations

Wire Feed System

Supercore and Cormet wires operate effectively on both single and double drive roll systems. Extreme wire feed roll pressure must be avoided, to prevent distortion of the tubular sheath, potential flux losses and interference with overall wire feeding smoothness. It is recommended that roll pressure adjustment during setting up is just sufficient to ensure that feeding can positively overcome finger gripping of wire exiting from the contact tip.

The guide tube, which steers wire from the feed rolls into the welding torch liner, should be fitted very close to the drive roll exit, to ensure that wire delivery is fully supported, and breakout, 'birdsnesting', problems are prevented.

Use matching sized coiled steel liner for the wire diameter involved, to maintain positive wire feeding.

Whilst in many cases both 1.2 and 1.6mm ø wire sizes are available, with stainless steel fabrication, the 1.2mm size is the most popular, by virtue of:

- suitably wide ~140 – 270A operating range, which adequately covers the general thicknesses of stainless steels welded.

- faster melt-off / deposition rate than the larger cross-section 1.6mm size.

The 1.6mm diameter wires generally fit those situations which can take advantage of higher current/voltage operating conditions, eg mechanised welding applications.

Welding Procedure

Joint surfaces to be welded should be free from excessive oxide, grease and/or paint, to promote bead 'toe' wetting, general profile uniformity, and effective slag release.

Select wire feed speed (welding current) to suit welding position or material thickness to be joined.

Select appropriate arc voltage as indicated by the 'power band' of the Operability Tolerance Box.

Wire tip trimming will ensure effective explosion-free arc striking and a smooth weld start.

Set gas shield flow rate to appropriate level, adjust gas nozzle such that the contact tip is recessed ~5mm inside.

Operating with a typical 15mm 'stick-out', trim the wire feed speed to optimise arc length and achieve a smooth, spatter-free, spray arc condition. (See 'Arc Voltage', page 5.)

Welding with a 'pulling' (backhand) technique similar to MMA (SMAW), is recommended for maximum overall welding performance in the downhand / horizontal-vertical positions. (See 'Welding Techniques', page 12.)

Arc extinction, via welding back over the weld pool, 'feeds' the final crater and yields a crack-free weld finish.

Machine Maintenance

Whilst FCAW is characteristically a low weld spatter process, efficient application to high productivity fabrication will benefit from routine machine maintenance to minimise unnecessary downtime:

- cleaning of wire feed roll system, to remove any build-up of debris,
- removal of any spatter deposited, in the gas shield nozzle, to ensure continued effectiveness of weld pool protection
- worn contact tips, which ultimately impede smooth wire feeding and can cause 'burn-back', should be regularly inspected and replaced, to avoid delays more costly than a new tip. Use contact tip size designated for the wire diameter.

Wire Protection

Wire reels on the machine should, preferably, be provided with some form of protective covering, to avoid unnecessary exposure to the airborne contamination and moisture levels associated with workshop environments. Under these conditions wire reels can be expected to remain in satisfactory condition on the machine over several days. However, conditions of unprotected exposure on the machine, and especially in a closed, cold, workshop over the weekend, risk the possibility of moisture pick-up on the wire surface/seam and subsequent weld porosity. In these circumstances, spools should be removed from the machine and stored in a warm, dry cupboard or enclosure.

Welding Fume Control

Welding fumes generated during fabrication of austenitic stainless steels in particular - eg type 304L/316L – are an important aspect of working environment control.

The rate of fume emission per kilo of deposited weld metal is significantly lower than that of rutile coated MMA (SMAW) electrodes. However, in view of the comparatively higher deposition rate achieved using the FCAW process:

eg @ 200A	Supercore 316L	1.2mm ø	3.6 kg/h arc time
	Supermet 316L	5mm ø	2.2 kg/h arc time

the levels of fume generated per unit time, by both MMA and FCW, are broadly similar.

In general, in view of the higher operating duty cycles possible using the FCAW process, control of welding fume levels, via the use of local fume extraction, is strongly recommended, especially with welding in confined or poorly ventilated work areas.

For more detailed information on welding fumes, see the appropriate Metrode FCW Data Sheet, and the Welding Manufacturers' Association publication No 236 "The Arc Welder At Work".

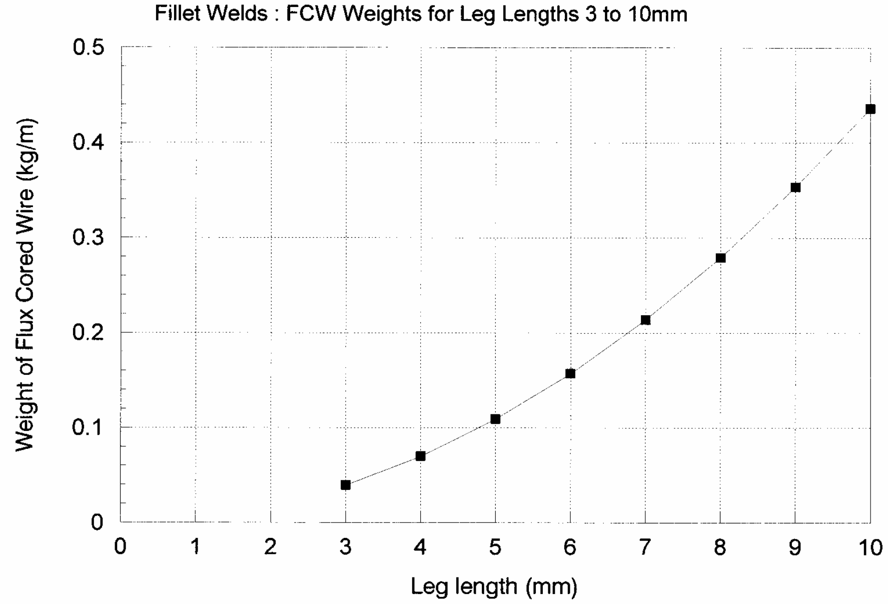
Estimating FCW Requirements

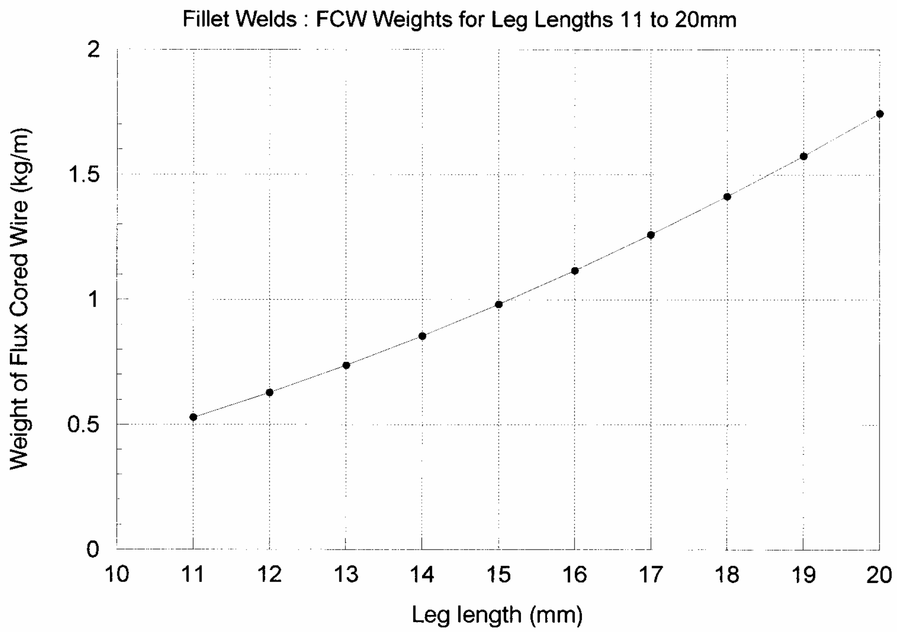
The following charts, based on:

- mitre profile, equi-leg length horizontal-vertical fillet welds'
- single-side 69° V-butt joints, with a 3mm root gap, and 1.5mm root face, to produce a 2mm high root underbead & weld cap reinforcement

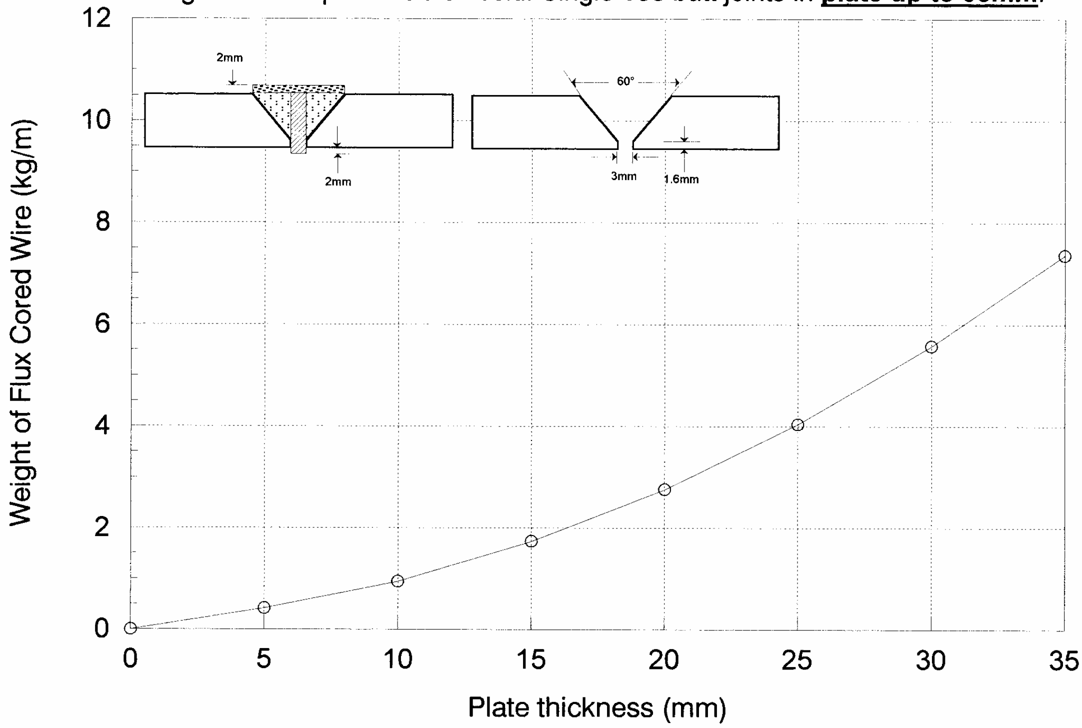
enable the quantity of FCW, for a range of joint sizes, to be directly read off the vertical axis.

Estimations have taken into account the 90% recovery of weld metal, from weight of wire consumed, but do not include any shopfloor wastage losses.





Weight of FCW per metre of weld. Single-vee butt joints in **plate up to 35mm**.



Weight of FCW per metre of weld. Single-vee butt joints in **plate 35 to 70mm**.