Welding Processes

Flux Shielded Welding Processes

Flux Shielded Welding Processes

- Shielded Metal Arc Welding (SMAW)
- Flux Cored Arc Welding (FCAW)

Lecture 2

- Submerged Arc Welding (SAW)
- Electro Gas Welding (EGW)
- Electro Slag Welding (ESW)

Lecture 3

Lecture Scope

- Welding process fundamentals
- Applications
- Welding procedures
- Equipment
- Process capabilities and limitations

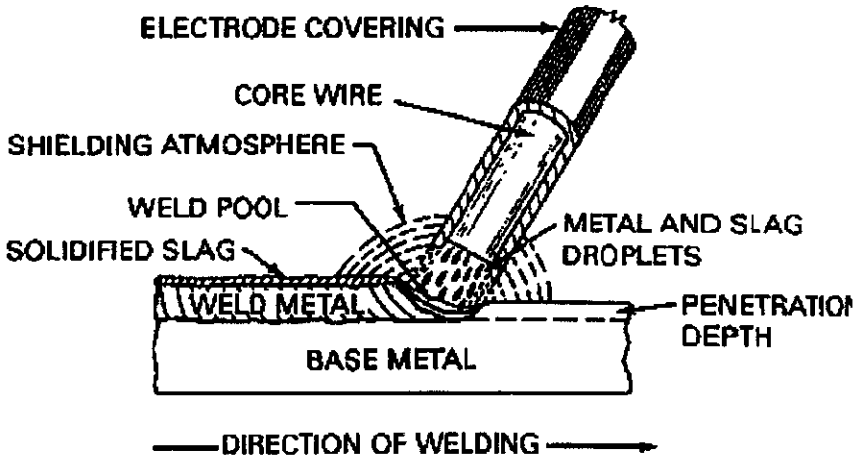
Shielded Metal Arc Welding (SMAW)

SMAW Process Fundamentals

- The heat source is an arc maintained between the tip of a covered electrode and the workpiece
- The tip of the electrode is moved along the joint, fusing the edges
- The electrode is consumed in the process
- The electrode supplies filler and materials that shield the weld and control weld metallurgy

SMAW

Process Fundamentals



SMAW Electrode Components

- The electrode consists of
  - the core
  - the covering

SMAW Electrode Core

- The functions of the core are:
  - conduct the electric current to the arc and
  - supply filler metal for the joint
- The core consists of:
  - a solid metal rod of drawn or cast material, or
  - a metallic sheath encasing metal powders

SMAW Electrode Covering

- The functions of the covering are:
  1. Provide gas and/or slag shielding
  2. Establish the electrical characteristics of the electrode
  3. Control the composition and metallurgy of the weld deposit
  4. Supply additional filler material
  5. Control weld bead shape
- The electrode covering consists of granular minerals, metals and binders extruded on the core rod

Electrode Covering Constituents

Covering Constituent	Arc Stabiliser	Slag Former	Reducing agent	Biinder	Coating strengther	Oxidising Agent	Gas Shield	Alloying
Gum/resin			B	A				
Cellulose			B		B		A	
Feldspar CaF2	B	A						
Clay (Al Silicates)	B	A						
Talc (Mg silicates)	B	A						
Rutile (Titania)	A	B						
Iron Oxides	B	A				A		
CaCO3	A	B				B	A	
Asbestos	B	A			A			
Ferro Manganese		A	A					B
Potassium Silicate	A	A		A				
Sodium Silicates	B	A		A				
Powedered Alloys								A

A=principal function B=minor function

AWS Electrode Classification

	Covering	Positions	Polarity
Exx10	Cellulosic	F,H,V,OH	DCEP
Exx11	Cellulosic	F,H,V,OH	AC, DCEP
Exx12	Rutile	F,H,V,OH	AC, DCEN
Exx13	Rutile	F,H,V,OH	AC or DC
Exx14	Rutile + iron powder	F,H,V,OH	AC or DC
Exx15	Basic	F,H,V,OH	DCEP
Exx16	Basic	F,H,V,OH	AC, DCEP
Exx18	Basic + iron powder	F,H,V,OH	AC or DC
Exx20	iron oxide/silicate	H-fillets	AC, DCEN
Exx24	Rutile + iron powder	H-fillets, F	AC or DC
Exx27	Iron oxide + iron powder	H-fillets, F	AC, DCEN
Exx28	Basic + 50% iron powder	H-fillets, F	AC, DCEP
Exx48	Similar to Exx20	F,H,OH,V-down	AC, DCEP

E 60xx	60,000 psi
E 70xx	70,000 psi
E 80xx	80,000 psi
E 90xx	90,000 psi
E100xx	100,000 psi

F	Flat
H	Horizontal
V	Vertical
OH	Overhead
H-Fillet	Horizontal Fillet

Electrode Types

Different electrode coatings suit different purposes. The four main types in use are:

1. Cellulosic
2. Rutile
3. Iron Oxide
4. Basic

Electrode Types

- Electrode Types
  1. Cellulosic
     - Covering has high cellulose content e.g. wood flour
     - Provides large quantities of H2 and CO2 gas shielding
     - Small volume of slag
     - Operate on DC electrode positive (DCEP)
     - Forceful penetrating arc
     - All positions

Electrode Types

- Electrode Types
  1. Cellulosic
  2. Rutile (titania)
     - Main constituent of coating is titanium dioxide (rutile)
     - Voluminous viscous slag covering which covers and supports the molten weld metal
     - Good for all-positional welding
     - DC electrode positive or negative (DCEP/DCEN) or AC
     - Smooth arc and medium penetration
     - Iron powder may be added to increase deposition rate

Electrode Types

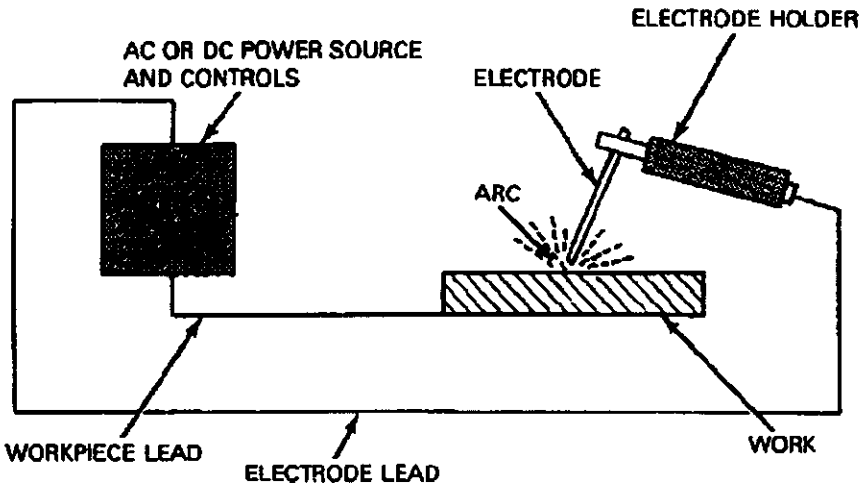
- Electrode Types
  1. Celluiosic
  2. Rutile (titania)
  3. Iron Oxide
     - Covering contains Fe, Mn oxides and silicates
     - Voluminous fluid slag giving smooth weld bead from which solidified slag is easily removed
     - Limited to flat "downhand" position
     - DCEP or alternating current (AC)
     - (AC is preferable from cost point of view)

Electrode Types

- Electrode Types
  1. Cellulosic
  2. Rutile (titania)
  3. Iron Oxide
  4. Basic
     - Coating contains CaCO3 and CaF2 with minerals having combined water kept to a minimum
     - Some iron powder may be added
     - Shielding by CO-CO2 (No H2) and a fluid "basic" slag
     - Produces weld metal of excellent ductility and toughness
     - All positions
     - DCEP/DECN (some types suitable for AC)
     - More difficult to use than rutile/cellulosic

SMAW Equipment

Typical Welding Circuit

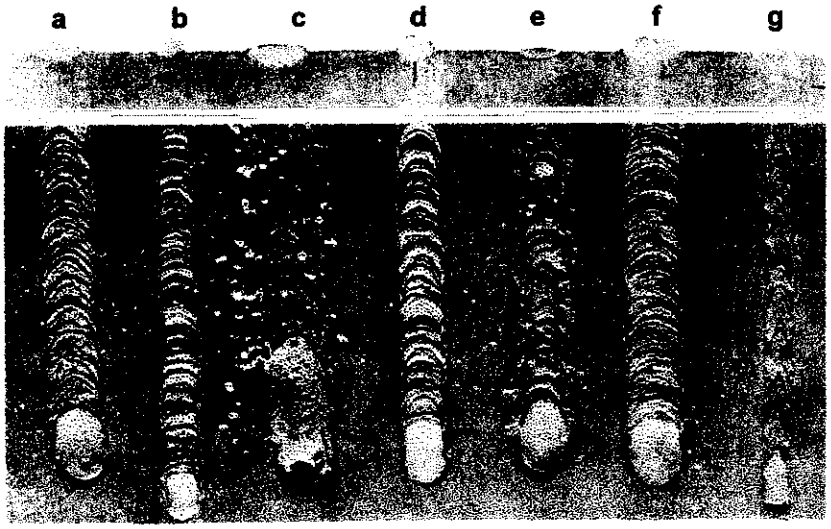


SMAW Welding Procedures

Variables that influence SMAW weld quality and productivity are:

- Electrode type and size
- Welding current, voltage, travel speed, technique
- Size of weld beads
- Material composition, thickness & joint geometry
- Surface condition
- Pre and post weld heat treatment
- Welder skill

SMAW Effects of Welding Variables



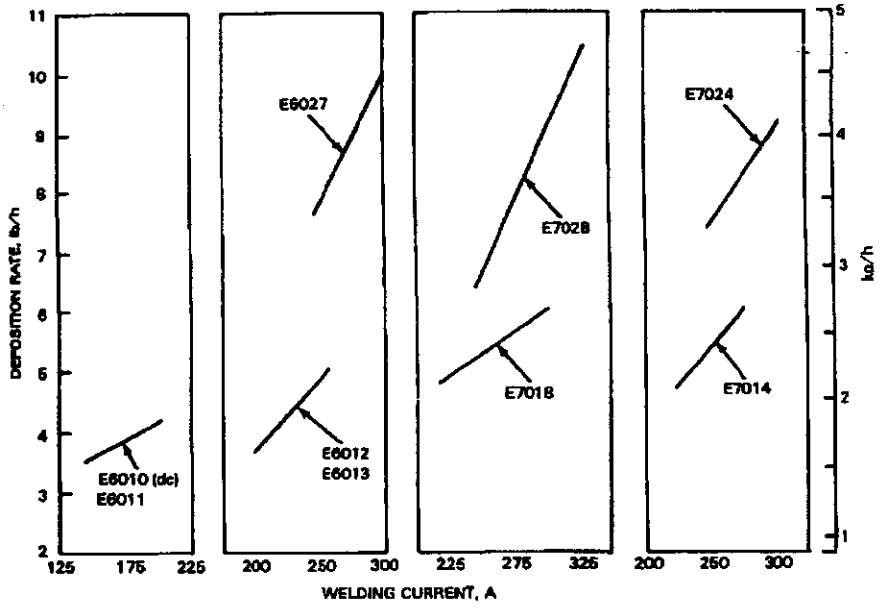
a)-OK; Current (b) too low, (c) too high; Arc Length (d) too short, (e) too long; Travel Speed (f) too slow, (g) too fast

SMAW Deposition Rates

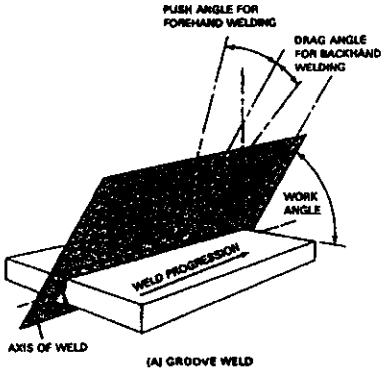
- Deposition rates depend mainly on electrode type and welding current
- Increased welding current increases deposition rate and speeds joint completion
- However, welding position, joint design and thickness, and metallurgy may limit the maximum useable current
- The highest deposition rates can be obtained in the flat position

SMAW Deposition Rates

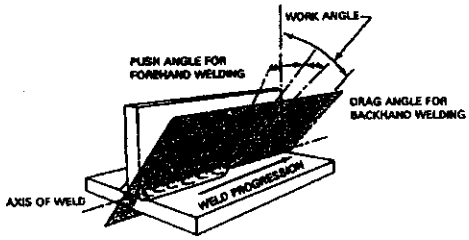
Various Electrode types



SMAW Electrode Orientation

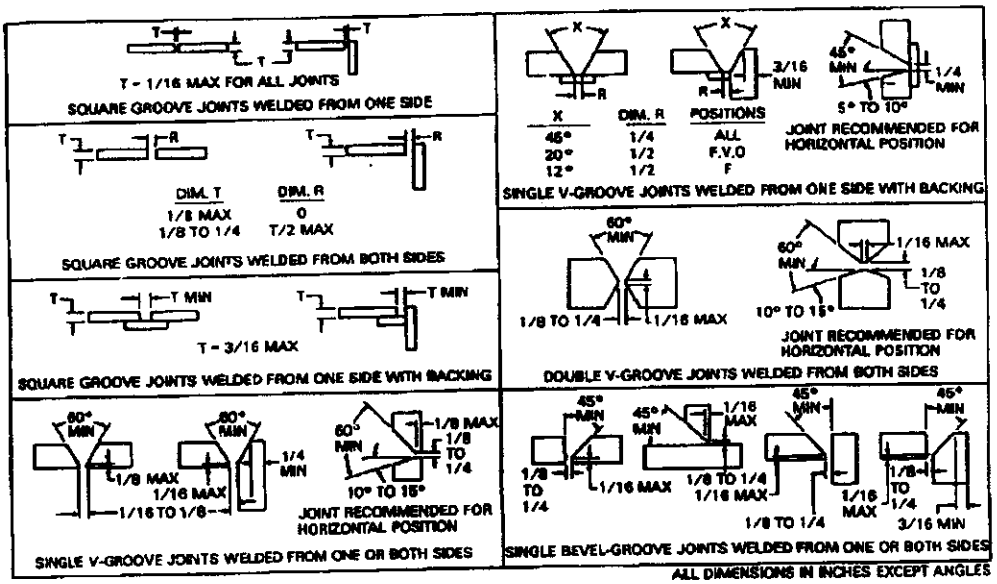


(A) GROOVE WELD



(B) FILLET WELD

SMAW Joint designs



SMAW Applications

SMAW Applications

- General steel construction
  - bridges, ships, plant and machinery
- High quality fabrication with requirements for strength, toughness and NDE quality
  - nuclear piping & pressure vessels
- Maintenance
  - hardfacing (e.g earthmover blades, materials handling equipment)
  - reclamation of defectiive or worn components
- All ferrous metals and nickel alloys, cast iron

Summary: SMAW Capabilities and Limitations

+ Low-cost, portable equipment and consumables adaptable to shop or field
+ All welding positions
+ High-quality welds with correct technique

– Low productivity
– Results depend on skill of manual operator
– Limited mainly to joining cast iron, steels and nickel alloys
– Slag removal

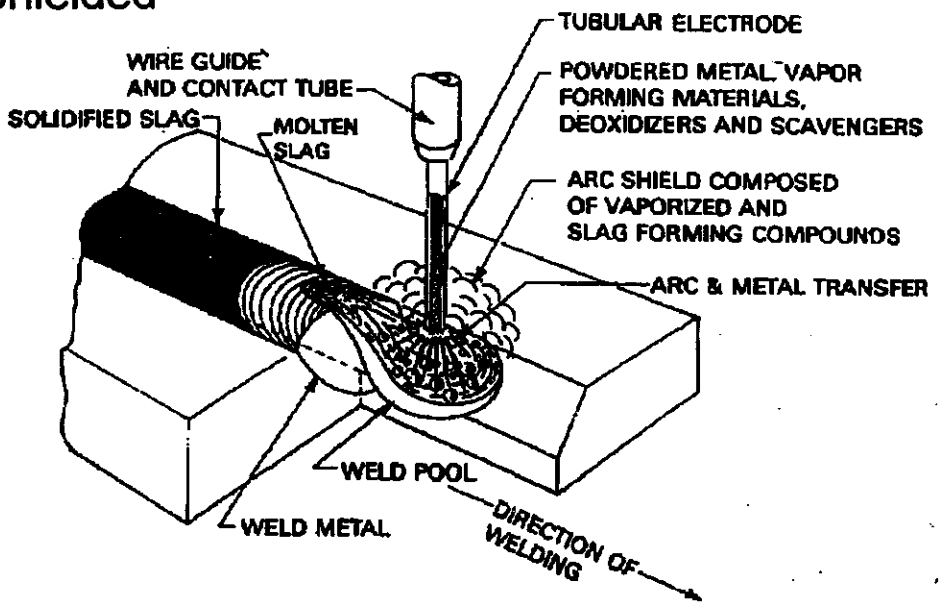
Flux Cored Arc Welding (FCAW)

FCAW Process Fundamentals

- The heat source is an arc maintained between a consumable electrode and the workpiece.
- The electrode is continuously fed into the arc as the weld head moves along the joint
- The arc and molten metal are shielded by granular flux contained in the tubular electrode (self shielded process)
- Shielding may be supplemented by an inert gas stream (gas shielded process)

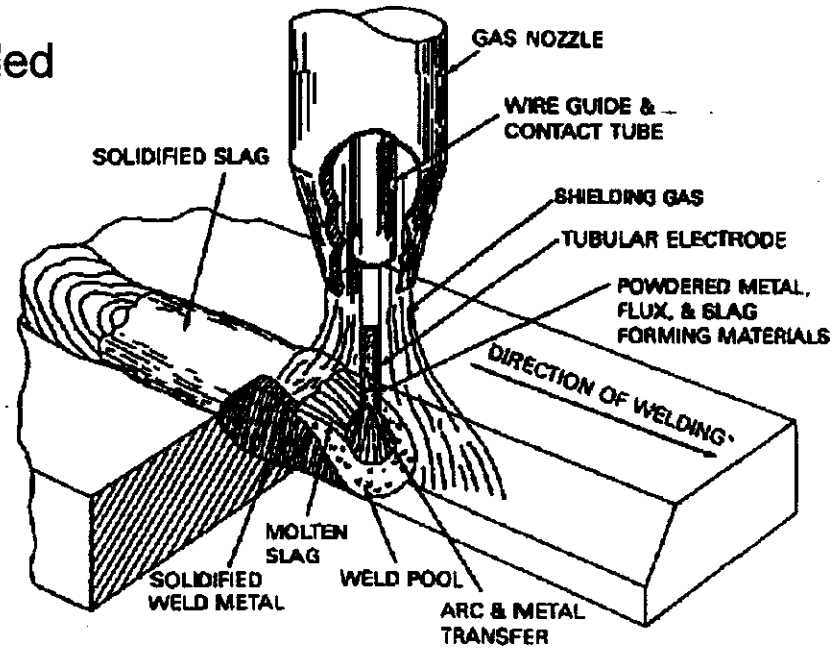
FCAW Process Fundamentals

Self-Shielded



FCAW Process Fundamentals

Gas Shielded

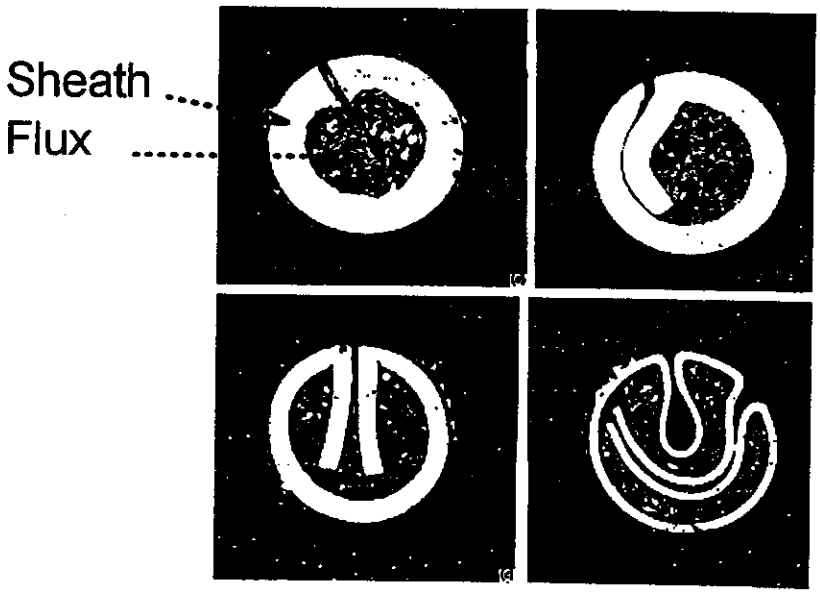


FCAW Electrodes

- The electrode consists of a metallic sheath which encases a mixture of granular flux and metal powders
- The functions of the electrode are
  - to supply electric current to the welding arc
  - to supply flux to the weld zone

FCAW Electrodes

Typical electrode cross-sections

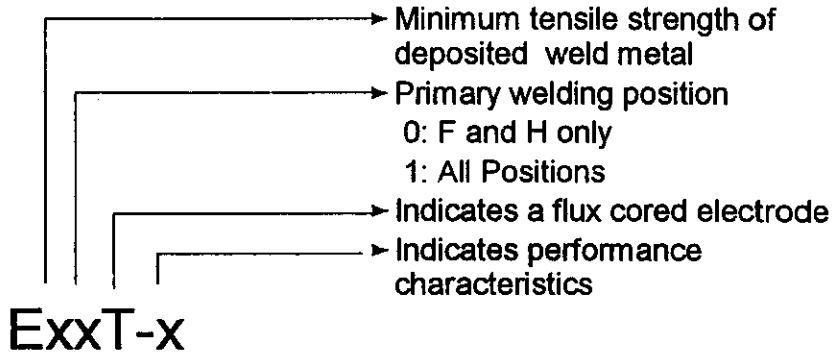


FCAW Electrodes

- The composition and functions of the flux in FCAW are similar to those of SMAW:
  - Provide gas and/or slag shielding of the weld zone and scavenge impurities
  - Establish the electrical characteristics of the electrode
  - Control the composition and metallurgy of the weld deposit
  - Supply additional filler material
  - Control weld bead shape

FCAW Electrode Classification

- AWS A5.20 classification for Mild Steel Tubular Electrodes:



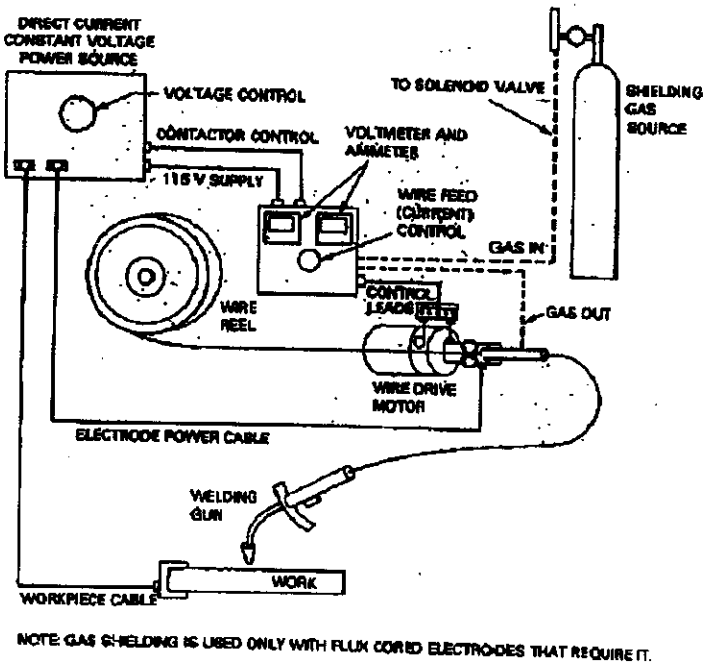
FCAW Mild Steel Electrodes

Type	Current	Shielding gas	Pos'n	Operating Characteristics
ExxT-1	DCEP	Ar-CO_2	All	Rutile type. Single or multi pass welds
ExxT-2	DCEP	Ar-CO_2	F, HF	Single pass welds on rimmed or scaled steel
ExxT-3	DCEP	self shield	F, HF	Single pass welds in sheet metal < 5mm thick
ExxT-4	DCEP	self shield	F, HF	Single or multi-pass; low penetration
ExxT-5	DCEP	Ar-CO_2	All	Single or multi pass welds with good notch toughness
ExxT-6	DCEP	self shield	F, HF	Single or multi pass welds, deep penetration with good notch toughness
ExxT-7	DCEN	self shield	All	Single or multi-pass welds
ExxT-8	DCEN	self shield	All	Single or multi-pass welds with good notch toughness
ExxT-10	DCEN	self shield	F, HF	Single pass welds at high speed
ExxT-11	DCEN	self shield	All	Single and multi pass welds, general purpose

Ar-CO_2: Carbon dioxide or argon-CO_2 mixtures
F: flat position; HF: horizontal fillet

FCAW Equipment

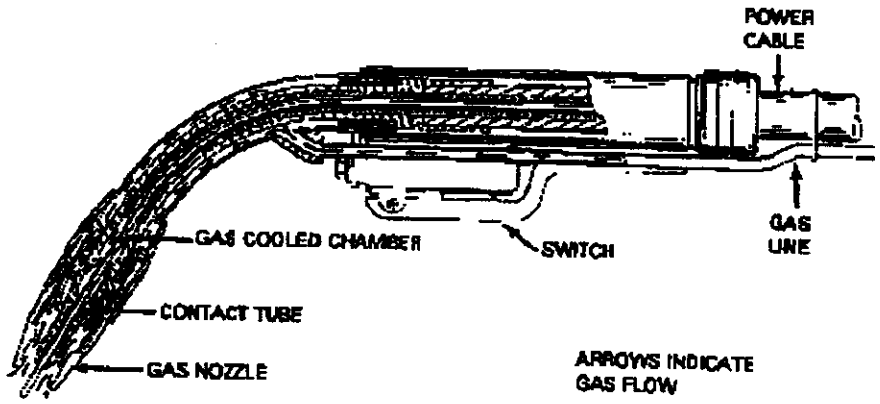
Typical semi-automatic



NOTE: GAS SHIELDING IS USED ONLY WITH FLUX CORED ELECTRODES THAT REQUIRE IT.

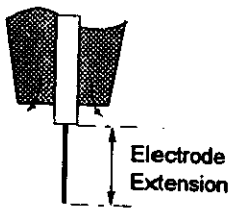
FCAW Equipment

Hand-held (semi automatic) gas-shielded welding gun



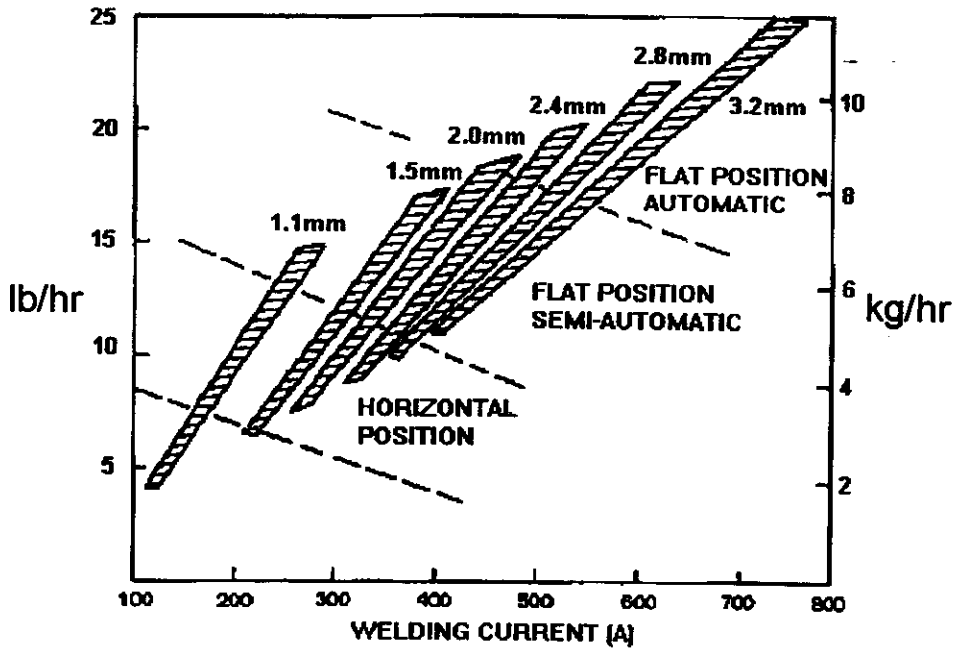
Process Variables

- The main variables that influence FCAW weld quality are:
  - Electrode type
  - Welding current
  - Arc voltage
  - Electrode extension ("stick-out")
  - Travel speed
  - Shielding gas flow
  - Electrode orientation

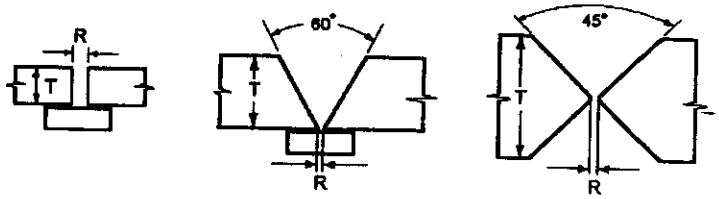


FCAW Deposition Rates

E70T-1 Electrodes with CO2 Shielding



Typical FCAW Welding Procedures



a b c

Flat Position

Joint Design	Thickness T (mm)	Root Opening R (mm)	No. Passes	Electrode Dia. (mm)	Welding Voltage (V)	Welding Current (A)	Wire Feed (mm/s)
a	5 - 10	3 - 6	1-2	2	30	425	116
b	10 - 25	0	2-6	2.4	30-32	480	95
c	25-50	0	6-14	2.4	32	450	80

Vertical Position

b	10-15	0	2-3	1.6	30-32	480	70

FCAW Applications

FCAW: Summary of Capabilities & Limitations

+ High deposition rates
+ Continuous electrode eliminates stub losses and stop/starts
+ Good tolerance to joint fit-up variations

– More costly equipment
– Complexity in setup and control
– Restricted distance from wire feeder
– Fume generation
– Slag removal