HEAT INPUT AND EFFICIENCY OF HEAT SOURCE

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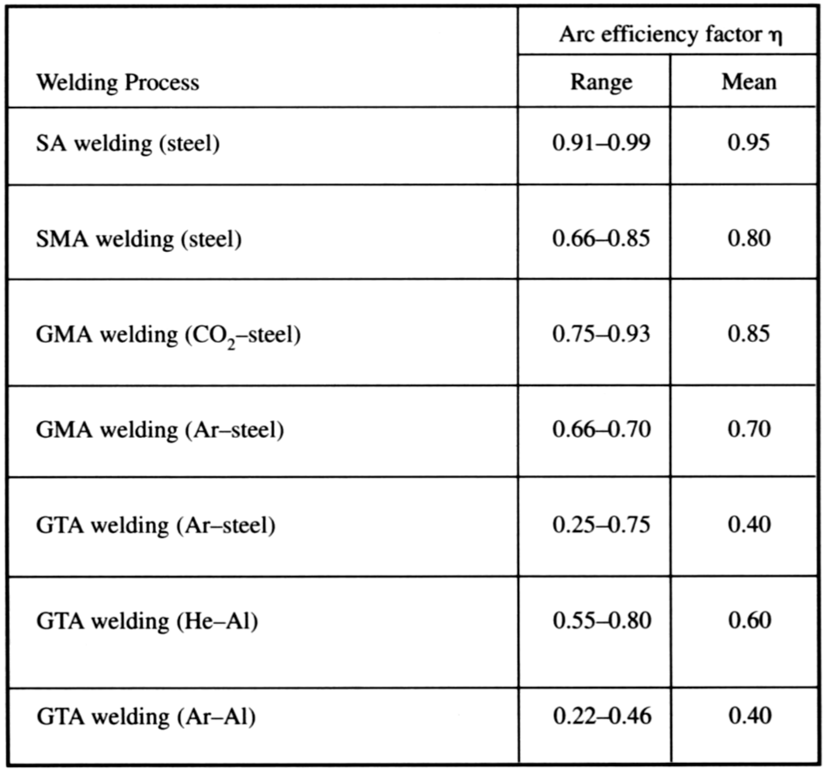
Heat Input

- Typically an “essential variable”
- Amount of energy per unit length
  - power/velocity
- Not all energy goes into the weld
  - Nominal heat input
    - energy spent at weld bead
    - easy to measure
  - Actual heat input
    - energy absorbed by bead
    - efficiency $\eta<100\%$
    - this is what actually matters

Heat Source Efficiencies



Welding Process	Arc efficiency factor η	
	Range	Mean
SA welding (steel)	0.91–0.99	0.95
SMA welding (steel)	0.66–0.85	0.80
GMA welding (CO_2–steel)	0.75–0.93	0.85
GMA welding (Ar–steel)	0.66–0.70	0.70
GTA welding (Ar–steel)	0.25–0.75	0.40
GTA welding (He–Al)	0.55–0.80	0.60
GTA welding (Ar–Al)	0.22–0.46	0.40

Grong, O., Metallurgical modelling of welding. 1st ed. 1994, Cambridge, Great Britain: The Institute of Materials.

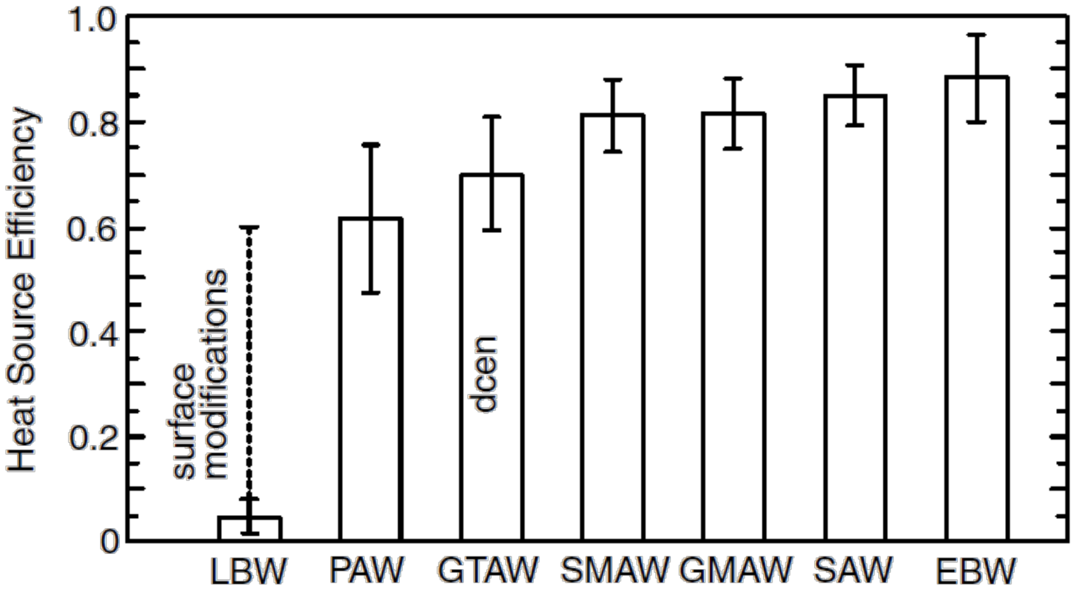


Figure 2.7 Heat source efficiencies in several welding processes.

Welding Metallurgy, S. Kou, 2nd Ed.

Heat Source Efficiencies

- EBW: high
  - few electrons bounce back
- LBW conduction: low
  - light reflects on molten metal
- LBW keyhole: higher
  - light is trapped in keyhole
- GTAW: low
  - energy into cathode and arc lost
- GMAW: high
  - energy into droplet recovered
  - energy into arc and evaporation lost
- SAW: very high
  - energy into droplet recovered
  - energy into arc and evaporation caught by slag
    - slag energy does not help penetration but can cause distortion

Nominal Heat Input in Arc Welding

- for CC

$$q'_n = \frac{VI \longleftarrow \text{power}}{U}$$

  - q'_n = nominal heat input (J/m)
  - V = voltage (V)
  - I = current (A)
  - U = travel velocity (m/s)

Nominal Heat Input in Arc Welding

- for waveform

$$q'_n = \frac{\int VI\,dt}{L}$$

given by power supply

  - q'_n = nominal heat input (J/m)
  - V = instant voltage (V)
  - I = instant current (A)
  - L = weld length (m)

Nominal Heat Input in Arc Welding

- typically: q'_n ~2 kJ/cm for sheet to ~10 KJ/cm for thick steels
- because WFS is proportional to current, and V does not vary much, the cross section of a weld is proportional to HI
- high heat input typically means
  - softer weld
  - easier to weld (welders love it)
  - less hydrogen problems
  - good penetration
  - more distortion
  - problems in stainless and high grade pipelines (above X65)
- low heat input means
  - harder weld
  - stringer beads
  - less room for error during welding
  - possible lack of penetration

Heat Input $q'_n = \frac{VI}{U}$

- Calculate the nominal heat input in the butt welding of 16 ga plate (1.5mm) using 0.030" wire. Express result in kJ/cm.

Welding Guidelines for Carbon and Low Alloy Steel
Short-Circuiting Transfer — Horizontal Fillets and Flat Butt Joints

CTWD[(1)] : 1/2" (13mm)
Gas: 100% CO_2
Gas flow: 25 to 35 cfh
(12 to 17 L/min.)

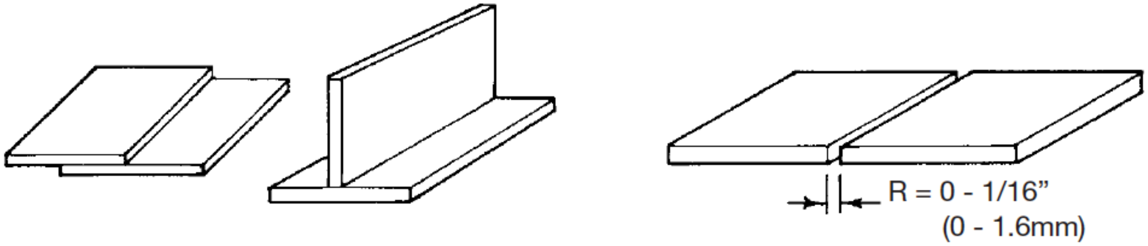


Plate Thickness - (mm)	24 ga (0.6)		20 ga (0.9)		16 ga (1.5)		14 ga (2)		12 ga (3)		10 ga (4)			3/16" (5)	1/4" (6)
Electrode Dia. - in. (mm)	0.025 (0.6)	0.030 (0.8)	0.030 (0.8)	0.035 (0.9)	0.030 (0.8)	0.035 (0.9)	0.030 (0.8)	0.035 (0.9)	0.030 (0.8)	0.035 (0.9)	0.030 (0.8)	0.035 (0.9)	0.045 (1.1)	0.045 (1.1)	0.045 (1.1)
WFS - in./min (M/min.)	100 (2.5)	75 (1.9)	125 (3.2)	100 (2.5)	175 (4.4)	150 (3.8)	225 (5.7)	175 (4.4)	275 (7.0)	225 (5.7)	300 (7.6)	250 (6.4)	125 (3.2)	150 (3.8)	200 (5.0)
Amps (Approximate)	35	35	55	80	80	120	100	130	115	160	130	175	145	165	200
Travel Speed - in./min (M/min.)	10 (0.25)	10 (0.25)	14 (0.35)	13 (0.33)	13 (0.33)	20 (0.50)	18 (0.45)	18 (0.45)	20 (0.50)	20 (0.50)	17 (0.43)	20 (0.50)	18 (0.45)	15 (0.38)	13 (0.33)
Voltage [(2)] (DC+)	17	17	18	18	19	19	20	20	21	21	22	22	18-20	19-21	20-22

(1) Contact Tip to Work Distance
(2) Decrease 2 volts for Argon/CO_2 blend.

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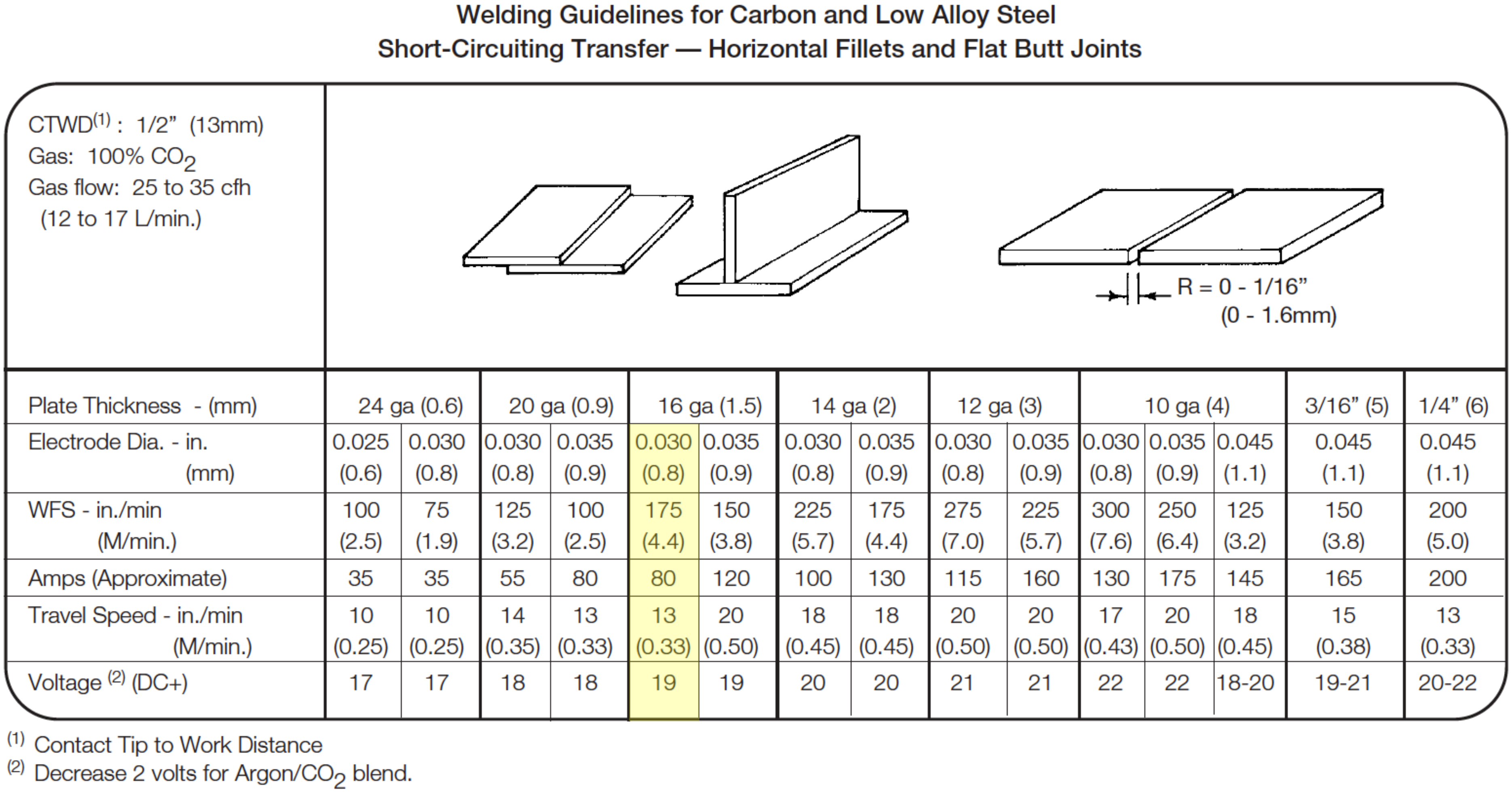

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Electrode Dia. - in.	0.025	0.030	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.045	0.045	0.045
(mm)	(0.6)	(0.8)	(0.8)	(0.9)	(0.8)	(0.9)	(0.8)	(0.9)	(0.8)	(0.9)	(0.8)	(0.9)	(1.1)	(1.1)	(1.1)
WFS - in./min	100	75	125	100	175	150	225	175	275	225	300	250	125	150	200
(M/min.)	(2.5)	(1.9)	(3.2)	(2.5)	(4.4)	(3.8)	(5.7)	(4.4)	(7.0)	(5.7)	(7.6)	(6.4)	(3.2)	(3.8)	(5.0)
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Travel Speed - in./min	10	10	14	13	13	20	18	18	20	20	17	20	18	15	13
(M/min.)	(0.25)	(0.25)	(0.35)	(0.33)	(0.33)	(0.50)	(0.45)	(0.45)	(0.50)	(0.50)	(0.43)	(0.50)	(0.45)	(0.38)	(0.33)
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$$HI = \frac{I \times V}{V_t} = \frac{80\,A \times 19\,V}{0.33 \frac{m}{min} \times \frac{1\,min}{60\,sec}} = 2.76 \times 10^5\ J/m$$

$$\boxed{HI = 2.76\ kJ/cm}$$

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(mm)	(0.6)	(0.8)	(0.8)	(0.9)	(0.8)	(0.9)	(0.8)	(0.9)	(0.8)	(0.9)	(0.8)	(0.9)	(1.1)	(1.1)	(1.1)
WFS - in./min	100	75	125	100	175	150	225	175	275	225	300	250	125	150	200
(M/min.)	(2.5)	(1.9)	(3.2)	(2.5)	(4.4)	(3.8)	(5.7)	(4.4)	(7.0)	(5.7)	(7.6)	(6.4)	(3.2)	(3.8)	(5.0)
Amps (Approximate)	35	35	55	80	80	120	100	130	115	160	130	175	145	165	200
Travel Speed - in./min	10	10	14	13	13	20	18	18	20	20	17	20	18	15	13
(M/min.)	(0.25)	(0.25)	(0.35)	(0.33)	(0.33)	(0.50)	(0.45)	(0.45)	(0.50)	(0.50)	(0.43)	(0.50)	(0.45)	(0.38)	(0.33)
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