

## 12.19 Electric Arc Welding

NOTE: Because of the many Source Classification Codes (SCCs) associated with electric arc welding, the text of this Section will give only the first 3 of the 4 SCC number fields. The last field of each applicable SCC will be found in Tables 12.19-1 and 12.19-2 below.

### 12.19.1 Process Description<sup>1-2</sup>

Welding is the process by which 2 metal parts are joined by melting the parts at the points of contact and simultaneously forming a connection with molten metal from these same parts or from a consumable electrode. In welding, the most frequently used methods for generating heat employ either an electric arc or a gas-oxygen flame.

There are more than 80 different types of welding operations in commercial use. These operations include not only arc and oxyfuel welding, but also brazing, soldering, thermal cutting, and gauging operations. Figure 12.19-1 is a diagram of the major types of welding and related processes, showing their relationship to one another.

Of the various processes illustrated in Figure 12.19-1, electric arc welding is by far the most often found. It is also the process that has the greatest emission potential. Although the national distribution of arc welding processes by frequency of use is not now known, the percentage of electrodes consumed in 1991, by process type, was as follows:

Shielded metal arc welding (SMAW) - 45 percent  
Gas metal arc welding (GMAW) - 34 percent  
Flux cored arc welding (FCAW) - 17 percent  
Submerged arc welding (SAW) - 4 percent

#### 12.19.1.1 Shielded Metal Arc Welding (SMAW)<sup>3</sup> -

SMAW uses heat produced by an electric arc to melt a covered electrode and the welding joint at the base metal. During operation, the rod core both conducts electric current to produce the arc and provides filler metal for the joint. The core of the covered electrode consists of either a solid metal rod of drawn or cast material or a solid metal rod fabricated by encasing metal powders in a metallic sheath. The electrode covering provides stability to the arc and protects the molten metal by creating shielding gases by vaporization of the cover.

#### 12.19.1.2 Gas Metal Arc Welding (GMAW)<sup>3</sup> -

GMAW is a consumable electrode welding process that produces an arc between the pool of weld and a continuously supplied filler metal. An externally supplied gas is used to shield the arc.

#### 12.19.1.3 Flux Cored Arc Welding (FCAW)<sup>3</sup> -

FCAW is a consumable electrode welding process that uses the heat generated by an arc between the continuous filler metal electrode and the weld pool to bond the metals. Shielding gas is provided from flux contained in the tubular electrode. This flux cored electrode consists of a metal sheath surrounding a core of various powdered materials. During the welding process, the electrode core material produces a slag cover on the face of the weld bead. The welding pool can be protected from the atmosphere either by self-shielded vaporization of the flux core or with a separately supplied shielding gas.

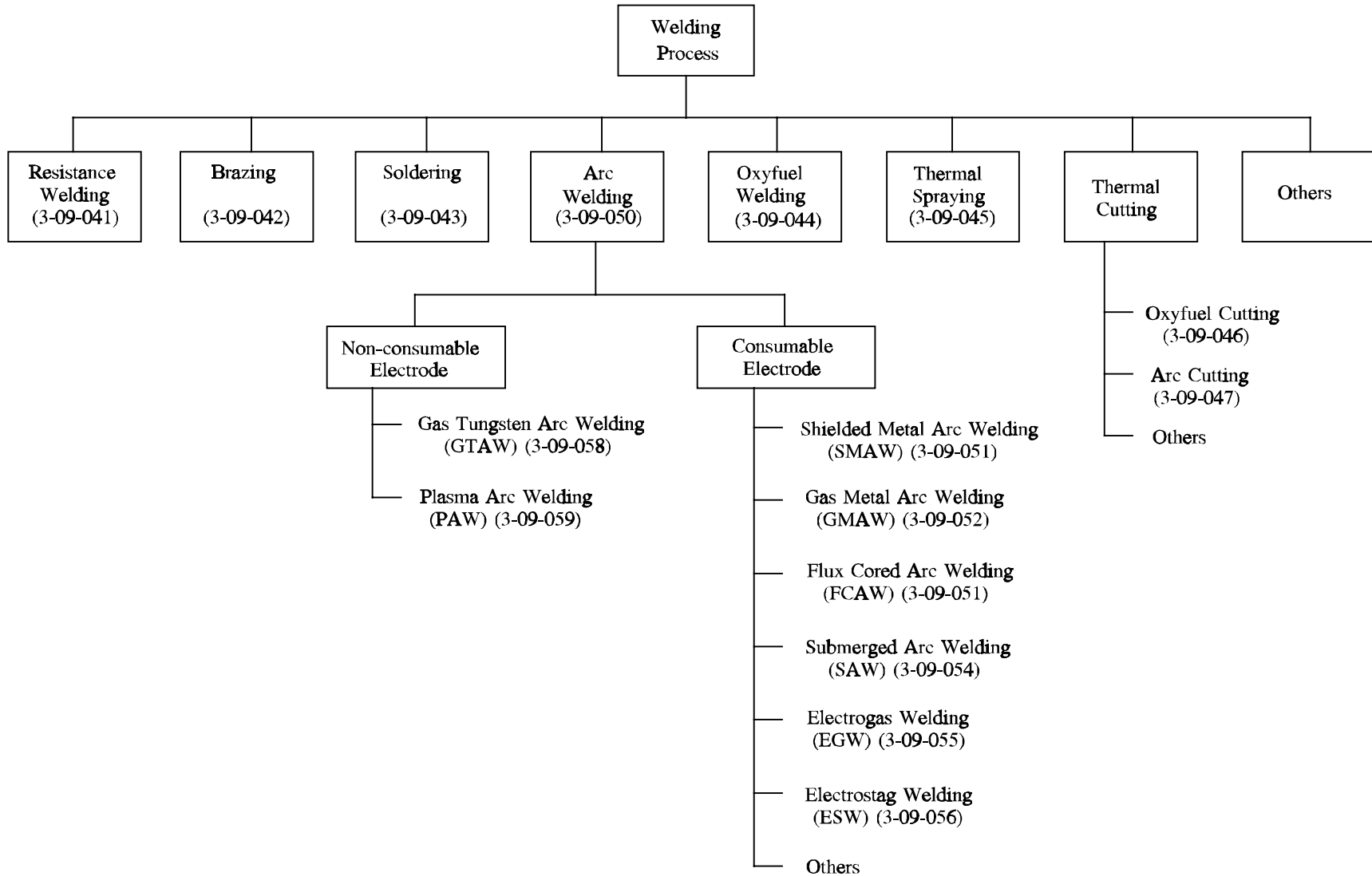


Figure 12.19-1. Welding and allied processes. (Source Classification Codes in parentheses.)

#### 12.19.1.4 Submerged Arc Welding (SAW)<sup>4</sup> -

SAW produces an arc between a bare metal electrode and the work contained in a blanket of granular fusible flux. The flux submerges the arc and welding pool. The electrode generally serves as the filler material. The quality of the weld depends on the handling and care of the flux. The SAW process is limited to the downward and horizontal positions, but it has an extremely low fume formation rate.

#### 12.19.2 Emissions And Controls<sup>4,8</sup>

##### 12.19.2.1 Emissions -

Particulate matter and particulate-phase hazardous air pollutants are the major concerns in the welding processes. Only electric arc welding generates these pollutants in substantial quantities. The lower operating temperatures of the other welding processes cause fewer fumes to be released. Most of the particulate matter produced by welding is submicron in size and, as such, is considered to be all PM-10 (i. e., particles # 10 micrometers in aerodynamic diameter).

The elemental composition of the fume varies with the electrode type and with the workpiece composition. Hazardous metals designated in the 1990 Clean Air Act Amendments that have been recorded in welding fume include manganese (Mn), nickel (Ni), chromium (Cr), cobalt (Co), and lead (Pb).

Gas phase pollutants are also generated during welding operations, but little information is available on these pollutants. Known gaseous pollutants (including "greenhouse" gases) include carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), and ozone (O<sub>3</sub>).

Table 12.19-1 presents PM-10 emission factors from SMAW, GMAW, FCAW, and SAW processes, for commonly used electrode types. Table 12.19-2 presents similar factors for hazardous metal emissions. Actual emissions will depend not only on the process and the electrode type, but also on the base metal material, voltage, current, arc length, shielding gas, travel speed, and welding electrode angle.

##### 12.19.2.2 Controls -

The best way to control welding fumes is to choose the proper process and operating variables for the given task. Also, capture and collection systems may be used to contain the fume at the source and to remove the fume with a collector. Capture systems may be welding booths, hoods, torch fume extractors, flexible ducts, and portable ducts. Collection systems may be high efficiency filters, electrostatic precipitators, particulate scrubbers, and activated carbon filters.

Table 12.19-1 (Metric And English Units). PM-10 EMISSION FACTORS FOR WELDING OPERATIONS<sup>a</sup>

Welding Process	Electrode Type (With Last 2 Digits Of SCC)	Total Fume Emission Factor (g/kg [lb/10 <sup>3</sup> lb] Of Electrode Consumed) <sup>b</sup>	EMISSION FACTOR RATING
SMAW <sup>c</sup> (SCC 3-09-051)	14Mn-4Cr (-04)	81.6	C
	E11018 (-08) <sup>h</sup>	16.4	C
	E308 (-12) <sup>j</sup>	10.8	C
	E310 (-16) <sup>k</sup>	15.1	C
	E316 (-20) <sup>m</sup>	10.0	C
	E410 (-24) <sup>n</sup>	13.2	D
	E6010 (-28)	25.6	B
	E6011 (-32)	38.4	C
	E6012 (-36)	8.0	D
	E6013 (-40)	19.7	B
	E7018 (-44)	18.4	C
	E7024 (-48)	9.2	C
	E7028 (-52)	18.0	C
	E8018 (-56) <sup>p</sup>	17.1	C
	E9015 (-60) <sup>q</sup>	17.0	D
	E9018 (-64) <sup>r</sup>	16.9	C
	ECoCr (-68) <sup>s</sup>	27.9	C
	ENi-CI (-72)	18.2	C
ENiCrMo (-76) <sup>t</sup>	11.7	C	
ENi-Cu (-80) <sup>u</sup>	10.1	C	
GMAW <sup>d,e</sup> (SCC 3-09-052)	E308L (-12) <sup>v</sup>	5.4	C
	E70S (-54) <sup>w</sup>	5.2	A
	ER1260 (-10)	20.5	D
	ER5154 (-26)	24.1	D
	ER316 (-20) <sup>x</sup>	3.2	C
	ERNiCrMo (-76) <sup>y</sup>	3.9	C
	ERNiCu (-80) <sup>z</sup>	2.0	C

Table 12.19-1 (cont.).

Welding Process	Electrode Type (With Last 2 Digits Of SCC)	Total Fume Emission Factor (g/kg [lb/10 <sup>3</sup> lb] Of Electrode Consumed) <sup>b</sup>	EMISSION FACTOR RATING
FCAW <sup>f,g</sup> (SCC 3-09-053)	E110 (-06) <sup>aa</sup>	20.8	D
	E11018 (-08)	57.0	D
	E308LT (-12) <sup>bb</sup>	9.1	C
	E316LT (-20) <sup>cc</sup>	8.5	B
	E70T (-54) <sup>dd</sup>	15.1	B
	E71T (-55) <sup>ee</sup>	12.2	B
	SAW <sup>g</sup> (SCC 3-09-054)	EM12K (-10) <sup>ff</sup>	0.05

<sup>a</sup> References 7-18. SMAW = shielded metal arc welding; GMAW = gas metal arc welding; FCAW = flux cored arc welding; SAW = submerged arc welding. SCC = Source Classification Code.

<sup>b</sup> Mass of pollutant emitted per unit mass of electrode consumed. All welding fume is considered to be PM-10 (particles ≤ 10 μm in aerodynamic diameter).

<sup>c</sup> Current = 102 to 229 A; voltage = 21 to 34 V.

<sup>d</sup> Current = 160 to 275 A; voltage = 20 to 32 V.

<sup>e</sup> Current = 275 to 460 A; voltage = 19 to 32 V.

<sup>f</sup> Current = 450 to 550 A; voltage = 31 to 32 V.

<sup>g</sup> Type of shielding gas employed will influence emission factor.

<sup>h</sup> Includes E11018-M

<sup>j</sup> Includes E308-16 and E308L-15

<sup>k</sup> Includes E310-16

<sup>m</sup> Includes E316-15, E316-16, and E316L-16

<sup>n</sup> Includes E410-16

<sup>p</sup> Includes E8018C3

<sup>q</sup> Includes E9015B3

<sup>r</sup> Includes E9018B3 and E9018G

<sup>s</sup> Includes ECoCr-A

<sup>t</sup> Includes ENiCrMo-4

<sup>u</sup> Includes ENi-Cu-2

<sup>v</sup> Includes E308LSi

<sup>w</sup> Includes E70S-3, E70S-5, and E70S-6

<sup>x</sup> Includes ER316I-Si and ER316L-Si

<sup>y</sup> Includes ENiCrMo-3 and ENi-CrMo-4

<sup>z</sup> Includes ERNiCu-7

<sup>aa</sup> Includes E110TS-K3

<sup>bb</sup> Includes E308LT-3

<sup>cc</sup> Includes E316LT-3

<sup>dd</sup> Includes E70T-1, E70T-2, E70T-4, E70T-5, E70T-7, and E70T-G

<sup>ee</sup> Includes E71T-1 and E71T-11

<sup>ff</sup> Includes EM12K1 and F72-EM12K2

Table 12.19-2. HAZARDOUS AIR POLLUTANT (HAP) EMISSION FACTORS FOR WELDING OPERATIONS<sup>a</sup>

Welding Process	Electrode Type (With Last 2 Digits Of SCC)	HAP Emission Factor ( $10^{-1}$ g/kg [ $10^{-1}$ lb/ $10^3$ lb] Of Electrode Consumed) <sup>b</sup>						EMISSION FACTOR RATING
		Cr	Cr(VI)	Co	Mn	Ni	Pb	
SMAW <sup>c</sup> (SCC 3-09-051)	14Mn-4Cr (-04)	13.9	ND	ND	232	17.1	ND	C
	E11018 (-08) <sup>h</sup>	ND	ND	ND	13.8	ND	ND	C
	E308 (-12) <sup>j</sup>	3.93	3.59	0.01	2.52	0.43	ND	D
	E310 (-16) <sup>k</sup>	25.3	18.8	ND	22.0	1.96	0.24	C
	E316 (-20) <sup>m</sup>	5.22	3.32	ND	5.44	0.55	ND	D
	E410 (-24) <sup>n</sup>	ND	ND	ND	6.85	0.14	ND	C
	E6010 (-28)	0.03	0.01	ND	9.91	0.04	ND	B
	E6011 (-32)	0.05	ND	0.01	9.98	0.05	ND	C
	E6012 (-36)	ND	ND	ND	ND	ND	ND	ND
	E6013 (-40)	0.04	ND	< 0.01	9.45	0.02	ND	B
	E7018 (-44)	0.06	ND	< 0.01	10.3	0.02	ND	C
	E7024 (-48)	0.01	ND	ND	6.29	ND	ND	C
	E7028 (-52)	0.13	ND	ND	8.4612	ND	1.62	C
	E8018 (-56) <sup>p</sup>	0.17	ND	ND	0.3	0.51	ND	C
	E9016 (-60)	ND	ND	ND	ND	ND	ND	ND
	E9018 (-64) <sup>q</sup>	2.12	ND	ND	7.83	0.13	ND	C
	ECoCr (-68)	ND	ND	ND	ND	ND	ND	ND
	ENi-Cl (-72)	ND	ND	ND	0.39	8.90	ND	C
	ENiCrMo (-76) <sup>r</sup>	4.20	ND	ND	0.43	2.47	ND	C
ENi-Cu-2 (-80) <sup>s</sup>	ND	ND	ND	2.12	4.23	ND	C	
GMAW <sup>d,e</sup> (SCC 3-09-052)	E308 (-12) <sup>t</sup>	5.24	ND	< 0.01	3.46	1.84	ND	C
	E70S (-54) <sup>u</sup>	0.01	ND	< 0.01	3.18	0.01	ND	A
	ER1260 (-10)	0.04	ND	ND	ND	ND	ND	D
	ER5154 (-26)	0.10	ND	ND	0.34	ND	ND	D
	ER316 (-20) <sup>v</sup>	5.28	0.10	ND	2.45	2.26	ND	D
	ERNiCrMo (-76) <sup>w</sup>	3.53	ND	ND	0.70	12.5	ND	B
	ERNiCu (-80) <sup>x</sup>	< 0.01	ND	ND	0.22	4.51	ND	C

Table 12.19-2 (cont.).

Welding Process	Electrode Type (With Last 2 Digits Of SCC)		HAP Emission Factor ( 10 <sup>-1</sup> g/kg [10 <sup>-1</sup> lb/10 <sup>3</sup> lb] Of Electrode Consumed) <sup>b</sup>					EMISSION FACTOR RATING	
			Cr	Cr(VI)	Co	Mn	Ni		Pb
FCAW <sup>f,g</sup> (SCC 3-09-053)	E110	(-06) <sup>y</sup>	0.02	ND	ND	20.2	1.12	ND	D
	E11018	(-08) <sup>z</sup>	9.69	ND	ND	7.04	1.02	ND	C
	E308	(-12)	ND	ND	ND	ND	ND	ND	ND
	E316	(-20) <sup>aa</sup>	9.70	1.40	ND	5.90	0.93	ND	B
	E70T	(-54) <sup>bb</sup>	0.04	ND	ND	8.91	0.05	ND	B
	E71T	(-55) <sup>cc</sup>	0.02	ND	< 0.01	6.62	0.04	ND	B
	SAW <sup>h</sup> (SCC 3-09-054)	EM12K	(-10)	ND	ND	ND	ND	ND	ND

<sup>a</sup> References 7-18. SMAW = shielded metal arc welding; GMAW = gas metal arc welding; FCAW = flux cored arc welding; SAW = submerged arc welding. SCC = Source Classification Code. ND = no data.

<sup>b</sup> Mass of pollutant emitted per unit mass of electrode consumed. Cr = chromium. Cr(VI) = chromium +6 valence state. Co = cobalt. Mn = manganese. Ni = nickel. Pb = lead. All HAP emissions are in the PM-10 size range (particles ≤ 10 μm in aerodynamic diameter).

<sup>c</sup> Current = 102 to 225 A; voltage = 21 to 34 V.

<sup>d</sup> Current = 275 to 460 A; voltage = 19 to 32 V.

<sup>e</sup> Type of shielding gas employed will influence emission factors.

<sup>f</sup> Current = 160 to 275 A; voltage = 22 to 34 V.

<sup>g</sup> Current = 450 to 550 A; voltage = 31 to 32 V.

<sup>h</sup> Includes E11018-M

<sup>j</sup> Includes E308-16 and E308L-15

<sup>k</sup> Includes E310-15

<sup>m</sup> Includes E316-15, E316-16, and E316L-16

<sup>n</sup> Includes E410-16

<sup>p</sup> Includes 8018C3

<sup>q</sup> Includes 9018B3

<sup>r</sup> Includes ENiCrMo-3 and ENiCrMo-4

<sup>s</sup> Includes ENi-Cu-2

<sup>t</sup> Includes E308LSi

<sup>u</sup> Includes E70S-3, E70S-5, and E70S-6

<sup>v</sup> Includes ER316I-Si

<sup>w</sup> Includes ERNiCrMo-3 and ERNiCrMo-4

<sup>x</sup> Includes ERNiCu-7

<sup>y</sup> Includes E110TS-K3

<sup>z</sup> Includes E11018-M

<sup>aa</sup> Includes E316LT-3

<sup>bb</sup> Includes E70T-1, E70T-2, E70T-4, E70T-5, E70T-7, and E70T-G

<sup>cc</sup> Includes E71T-1 and E71T-11

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