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Estimating Welding Costs

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Chapter 5

Welding Costs

Topics

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Overview

Estimating the costs of depositing weld metal can be a difficult task because of the many variables involved. Design engineers must specify the type and size of weld joint to withstand the loads that the weldment must bear. The welding engineer must select the welding process, and type of filler metal that will provide the required welds at the least possible cost. With the cost of operations rising, selection of the process that deposits weld metal most expediently must be carefully considered. Labor and overhead account for approximately 85% of the total welding cost. Power costs usually account for less than 1%; therefore, approximately 14% of the cost of the job is related to the welding process selected.

This chapter will help you understand why certain processes are selected and how the calculations are derived.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Explain the comparisons of welding costs.

Prerequisites

None

1.0.0 COMPARISONS of WELDING COSTS

This chapter will cover cost estimating for steel weldments produced by the four most common arc welding processes in use today: shielded metal arc welding, gas metal arc welding, flux cored arc welding and gas tungsten arc welding. The GTAW process is a relatively costly method of depositing weld metal, and is usually chosen for weld quality or material thickness and composition limitations, rather than economy.

Welding costs may be divided into two categories; the “fixed” costs involved regardless of the filler metal or welding process selected, and those related to a specific welding process. Fixed costs entail material handling, joint preparation, fixturing, tacking, preheating, weld clean-up, and inspection. Although some of these items will be affected by the specific process and filler metal chosen, they are a necessary part of practically all welding operations. Calculating these costs will depend upon your workers’ capabilities and the equipment you use.

The cost of actually depositing the weld metal will vary considerably with the filler metal and welding process selected. This cost element will be influenced by your labor and overhead rates, the deposition rate and efficiency of the filler metal, your operating factor, and the cost of materials and power.

1.1.0 Cost of Shielded Metal Arc Welding

The cost of welding for a specific application is one of the most important factors for determining whether shielded metal arc welding should be used. The calculation methods used in this chapter can also be used to compare the costs of this welding process with other welding processes.

Shielded metal arc welding is a very low initial investment cost, however, its moderate deposition rates and low operator factors may be outweighed by other considerations.

The cost of this welding process consists of three major items. These are (1) the labor and overhead cost, (2) electrode cost, (3) electric power cost.

1.1.1 Labor Cost

The labor and overhead costs are usually combined in cost calculations, which is common practice in many metal working industries. Overhead usually includes items such as services, taxes, facilities maintenance, and the depreciation of the equipment. The hourly rate and the overhead rate vary from plant to plant and the actual hourly rates for each plant should be used for this calculation.

The operator factor is the percentage of time that the welder is actually welding. Since a large amount of time goes into set-up, preheating, slag removal, and changing electrodes, the operator factor for this process is relatively low. It can range from as low as 10% to as high as 50%, but it is usually in the area of 20-40%. The operator factor varies from plant to plant and for different types of weldments.

The deposition rates of the electrodes affect the labor and overhead costs because the rate at which the electrode is deposited affects productivity. The travel speeds for the shielded metal arc welding process are often low.

The equation for determining the labor and overhead cost per foot of weld is:

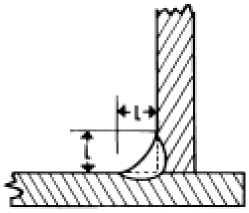
$$\frac{Labor\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{Labor\ and\ Overhead\ Costs}{Hour} X \frac{Pounds\ of\ Weld\ Deposit}{Foot\ of\ Weld}}{Deposition\ Rate\ X\ Operating\ Factor} \right)$$

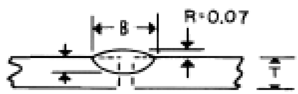
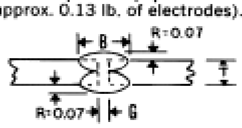
1.1.2 Electrode Cost

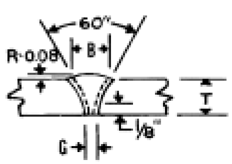
The cost of the electrode per foot of weld is determined by several factors. The first is the weight of electrodes deposited per foot of weld. This is dependent on the size of the weld to be made. The second is the cost per pound of the electrode. The third is the deposition efficiency of the electrode. The deposition efficiency is the percentage of the total weight of the electrode that is actually deposited in the weld. This varies from electrode to electrode and for the calculations we will be using, a 2 in. (51 mm) stub loss is assumed. Some of the weight is lost to spatter, slag, and some of the electrode becoming gas. *Table 5-1* shows the electrode consumption for different sizes and types of welds. The equation for the cost of the electrode per foot of weld is:

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{Pounds\ of\ Weld\ Deposit}{Foot\ of\ Weld} X \frac{Cost\ of\ Electrode}{Pound}}{Deposition\ Efficiency} \right)$$

Table 5-1 — Calculation of Electrode Consumption

	Size of Fillet L (in inches)	Pounds of Electrodes required per linear foot of weld* (approx)	Steel Deposited per linear foot of weld (in pounds)
HORIZONTAL FILLET WELD 	1/8	.048	.027
	3/16	.113	.063
	1/4	.189	.106
	5/16	.296	.166
	3/8	.427	.239
	1/2	.760	.425
	5/8	1.185	.663
	3/4	1.705	.955
	1	3.030	1.698

	Joint Dimensions (in inches)			Pounds of Electrodes required per linear foot of weld* (approx)		Steel deposited per linear foot of weld	
	MTL. Thick T	Bead Width B	Root Open G	Without reinforcement	With reinforcement**	Without reinforcement (lbs)	With reinforcement ** (lbs)
SQUARE GROOVE BUTT JOINTS . . . welded one side 	3/16	3/8	0	-	.16	-	.088
			1/16	.04	.20	.020	.109
	1/4	7/16	1/16	.05	.23	.027	.129
			3/32	.07	.26	.039	.143
	5/16	1/2	1/16	.06	.27	.033	.153
			3/32	.09	.30	.050	.170
. . . welded two sides If root of top weld is chipped or flame gouged and welded, add 0.07 lb. to steel deposited (equivalent to approx. 0.13 lb. of electrodes). 	1/8	1/4	0	-	.21	-	.119
			1/32	.03	.24	.013	.132
	3/16	3/8	1/32	.04	.36	.020	.199
			1/16	.07	.39	.040	.218
	1/4	7/16	1/16	.10	.47	.053	.261
			3/32	.14	.53	.080	.288

	Joint Dimensions			Pounds of Electrodes required per linear foot of weld* (approx)		Steel deposited per linear foot of weld	
	MTL. Thick T	Bead Width B	Root Open G	Without reinforcement	With reinforcement**	Without reinforcement (lbs)	With reinforcement ** (lbs)
"V" GROOVE BUTT JOINT 	1/4	.207	1/16	.15	.25	.085	.143
	5/16	.311	3/32	.31	.46	.173	.258
	3/8	.414	1/8	.50	.70	.282	.394
	1/2	.558	1/8	.87	1.15	.489	.641
	5/8	.702	1/8	1.35	1.68	.753	.942
	3/4	.847	1/8	1.94	2.35	1.088	1.320
	1	1.138	1/8	3.45	4.00	1.930	2.240

1.1.3 Electric Power Cost

The cost of the electric power is a relatively minor cost factor, but it can become important when large amounts of welding are required on a certain job. The cost of electric power used is dependent on the amount of welding current, welding voltage, the efficiency of the power source, welding time, and the cost per kilowatt-hour. The power source efficiency will be assumed for this calculation. This is the same equation used for all of the welding processes. The equation for estimating the electric power cost is:

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{Welding\ Current\ X\ Welding\ Voltage}{Power\ Source\ Efficiency}\right) X \begin{pmatrix} Power \\ Cost \end{pmatrix} X \begin{pmatrix} Welding \\ Time \end{pmatrix}$$

1.1.4 Examples

Table 5-2 shows a cost comparison of several different electrode types. The following are sample calculations: (Values taken from Table 5-2) E6011, 3/16" Electrode, 1/4" Fillet Weld.

$$\frac{Labor\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{Labor\ and\ Overhead\ Costs}{Hour}\ X\ \frac{Pounds\ of\ Weld\ Deposit}{Foot\ of\ Weld}}{Deposition\ Rate\ X\ Operating\ Factor}\right)$$

$$\frac{Labor\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{\$18.00}{Hour}\ X\ \frac{.106\ Pounds}{Foot}}{\frac{4.5\ Pounds}{Hour}\ X\ .35}\right) = \frac{\$1.211}{Foot}$$

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{Pounds\ of\ Weld\ Deposit}{Foot\ of\ Weld}\ X\ \frac{Cost\ of\ Electrode}{Pound}}{Deposition\ Efficiency}\right)$$

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{.106\ Pounds}{Foot}\ X\ \frac{\$.45}{Pound}}{.69}\right) = \frac{\$.069}{Foot}$$

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{Welding\ Current\ X\ Welding\ Voltage}{Power\ Source\ Efficiency}\right) X \begin{pmatrix} Welding \\ Time \end{pmatrix} X \begin{pmatrix} Power \\ Cost \end{pmatrix}$$

Use the following formula to figure *Welding Time,* which is an additional calculation you need to determine *Electric Power Costs per Foot of Weld*.

$$\frac{Welding\ Time}{Foot\ of\ Weld} = \left(\frac{\dfrac{Pounds\ of\ Weld\ Metal\ Deposited}{Foot}}{\dfrac{Deposition\ Rate}{Hour}} \right)$$

$$\frac{Welding\ Time}{Foot\ of\ Weld} = \left(\frac{\dfrac{.106\ Pounds}{Foot}}{\dfrac{4.5\ Pounds}{Hour}} \right) = \frac{.024\ Hour}{Foot}$$

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{180\ Amps\ X\ 26\ Volts}{.50} \right) X\ (.24\ hr)\ X\ \left(\frac{\$.35}{kw-hr} \right) X \left(\frac{1\ kw}{1000\ w} \right) = \frac{\$.008}{Foot}$$

When you have your labor, electrode, and power costs calculated, you can determine your total costs per foot of weld.

SMAW example

$$\frac{Total\ Costs}{Foot\ of\ Weld} = \left(\frac{Labor\ + Electrode + Electric\ Power}{\$1.211 + \quad \$.069 \quad + \quad \$.008} \right) = \frac{\$1.288}{Foot\ of\ Weld}$$

1.1.5 Cost Comparison of Different Sizes of Diameter Electrodes Used for Making Different Weldments

Table 5-2 shows the different costs associated with different electrodes.

Table 5-2 — Cost Comparison of Different 3/16" Diameter Electrodes Used For Making a 1/4" Fillet Weld.

Electrode Type	E6011	E6013	E7014	E7018	E7024
Deposition Rate (lbs/hr)	4.5	4.2	5.3	4.8	9.5
Welding Current (amps)	180	220	240	250	280
Welding Voltage (volts)	26	22	26	25	33
Operating Factor (%)	35	35	35	35	35
Labor + Overhead Cost ($/hr)	18	18	18	18	18
Welding Time (min)	4.1	4.4	3.5	3.8	1.9
Weight of Deposit Per Foot (lb/ft)	0.106	0.106	0.106	0.106	0.106
Deposition Efficiency (%)	69	63	66	72	67
Electrode Cost Per Pound ($/lb)	0.45	0.44	0.45	0.45	0.45
Electric Power Cost ($/kw-hr)	0.035	0.035	0.035	0.035	0.035
Power Source Efficiency (%)	50	50	50	50	50
Labor + Overhead Cost/Foot of Weld ($/ft)	1.211	1.298	1.029	1.136	0.574
Electrode Cost/Foot of Weld ($/ft)	0.069	0.074	0.072	0.066	0.071
Electric Power Cost/Foot of Weld ($/ft)	0.008	0.008	0.01	0.01	0.008
Total ($/ft)	**1.288**	**1.38**	**1.111**	**1.212**	**0.653**

1.2.0 Cost of Gas Tungsten Arc Welding

Gas tungsten arc welding is expensive and not very economical to use on thick metal, but on many other applications, it will be the best method. Because this process can be used to weld very thin metal, dissimilar metals, and a wide variety of non-ferrous metals, it is often chosen for its capabilities with less consideration given to cost factors. In some cases, it is the only usable welding process. The following cost calculation methods can be used to compare the cost of this welding process with other welding processes.

The initial investment cost for this process can vary widely depending on the complexity of the equipment required. This can range from a high frequency current and inert gas attachment added to a shielded metal arc-welding machine, up to a fully automatic welding head and a programmable power source. There are also many possibilities that exist between these extremes. The type of equipment used depends on the type of application.

Manual gas tungsten arc welding generally produces moderate deposition rates and low operator factors compared to other arc welding processes. Automatic operations will generally give higher deposition rates and higher operator factors.

The cost of consumables can also vary widely because of the price differences for the different shielding gases and filler metals. For some applications, no filler metal is used and for the welding of some of the more exotic metals, filler wire can be very expensive. Technically, the tungsten electrode is non-consumable, but tungsten electrodes have to be replaced after a period of use. The frequency at which electrodes must be replaced depends on conditions such as the welder skill and the amount of welding current. A good approximation of the cost of the tungsten electrode is 4% of the shielding gas cost. The torch nozzles may also have to be replaced from time to time, depending on the type of nozzle and the care they are given by the welder.

The cost of this welding process is similar to SMAW but it has additional factors to consider in the shielding gas and the wear on the tungsten electrode. It consists of four major items including (1) the labor and overhead cost, (2) the filler metal cost, (3) the shielding gas cost, (4) the electric power cost, and one minor item, wear on the electrode.

1.2.1 Labor Cost

As discussed earlier, the labor and overhead costs are often combined in cost calculations; this is usually the largest cost factor in welding.

The operator factor in percentage is about the same for GTAW as for SMAW, but for different reasons. With GTAW, while little or no slag is produced, more time is needed for setup, preheating, and changing filler rods. However, because this process can be used manually and automatically, the operator factor can vary widely depending on which process you use.

For manual welding, the operator factor is relatively low and may range from about 10% to as high as 50%, but is normally in the range of 20% to 40%. Automatic welding generally gives high operator factors because it can usually proceed to completion without interruption. Operating factors for this can rise as high as 80% or more, depending on the specific application.

The deposition rates and travel speeds affect the labor and overhead costs because the rate at which the weld can be completed affects the productivity; travel speeds used with this process are often fairly low.

The equation for determining the labor and overhead cost per foot of weld is the same as SMAW:

$$\frac{Labor\ Cost}{Foot\ of\ Weld} = \left(\frac{\dfrac{Labor\ and\ Overhead\ Costs}{Hour}\ X\ \dfrac{Pounds\ of\ Weld\ Deposit}{Foot\ of\ Weld}}{Deposition\ Rate\ X\ Operating\ Factor} \right)$$

The equation for determining your total labor cost is:

$$Total\ Labor\ Cost = (Total\ Welding\ Time)\ X \left(\frac{Labor\ and\ Overhead\ Costs}{Hour} \right)$$

1.2.2 Filler Metal Cost

Filler metal costs are made up of the same three factors that affect SMAW: 1) weight of electrodes deposited per foot of weld dependent on the size of the weld to be made, 2) cost per pound of the electrode, and 3) deposition efficiency of the electrode. However, the deposition efficiency is nearly 100% for most GTAW welding operations because little or no filler metal is lost through spatter, vaporization, or stub end loss. For the calculations to be used for GTAW, a deposition efficiency of 100% will be assumed. Refer to *Tables 5-3 and 5-4* for filler metal weights and consumption. The equations used for determining the cost of the filler metal are as follows:

For manual welding:

$$Filler\ Metal\ Cost = \left(\begin{matrix} Length\ of \\ Wire\ Used \end{matrix}\right) X \left(\begin{matrix} Deposition \\ Efficiency \end{matrix}\right) X \left(\begin{matrix} Wire\ Rate\ Per \\ Unit\ of\ Length \end{matrix}\right) X \left(\frac{Wire\ Cost}{Pound}\right)$$

Alternatively, for manual welding you can use:

$$Filler\ Metal\ Cost = \left(\frac{(Weight\ of\ Deposit)\ X\ (Filler\ Metal\ Costs)}{Deposition\ Efficiency}\right)$$

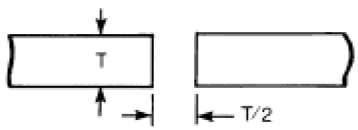
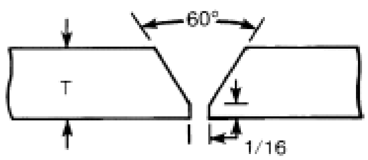
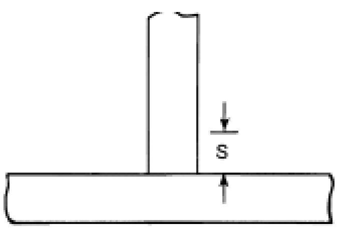
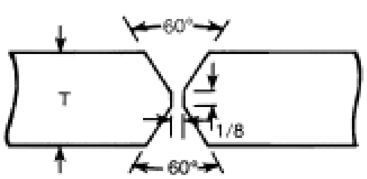
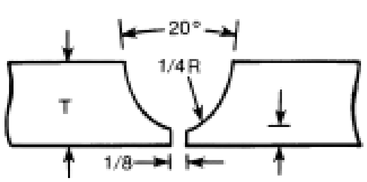
For automatic welding:

$$Filler\ Metal\ Cost = \left(\begin{matrix} Arc \\ Time \end{matrix}\right) X \left(\begin{matrix} Wire\ Feed \\ Rate \end{matrix}\right) X \left(\begin{matrix} Wire\ Rate\ Per \\ Unit\ of\ Length \end{matrix}\right) X \left(\frac{Wire\ Cost}{Pound}\right)$$

Table 5-3 — Inches Per Pound of Filler or Bare Electrode Wire.

Wire Diameter		Metal or Alloy								
Decimal Inches	**Fraction Inches**	**Aluminum**	**Bronze, Alum. 10%**	**Bronze, Silicon**	**Copper (deox.)**	**Copper Nickel**	**Magnesium**	**Nickel**	**Steel, Mild**	**Steel Stainless**
0.02		32400	11600	10300	9800	9950	50500	9900	11100	10950
0.025		22300	7960	7100	6750	6820	34700	6820	7680	7550
0.03		14420	5150	4600	4360	4430	22400	4400	4960	4880
0.035		10600	3780	3380	3200	3260	16500	3240	3650	3590
0.04		8120	2900	2580	2450	2490	12600	2480	2790	2750
0.045	3/64	6410	2290	2040	1940	1970	9990	1960	2210	2170
0.062	1/16	3382	1120	1070	1020	1040	5270	1030	1160	1140
0.078	5/64	2120	756	675	640	650	3300	647	730	718
0.093	3/32	1510	538	510	455	462	2350	460	519	510
0.125	1/8	825	295	263	249	253	1280	252	284	279
0.156	5/32	530	189	169	160	163	825	162	182	179
0.187	3/16	377	134	120	114	116	587	115	130	127
0.25	1/4	206	74	66	62	64	320	63	71	70

Table 5-4 — Filler Metal Consumption for Different Sizes and Types of Welds Made With Different Types of Base and Filler Metal.

Type of Weld	Weight of Deposit (Lbs/ft)					
	T or S (in)	T or S (mm)	Steel* Stainless Steel	Nickel* Copper Phosphor Bronze	Aluminum	Magnesium
	1/16	1.6	.02	.03	.01	>.01
	1/8	3.2	.05	.06	.02	.01
	3/16	4.8	.10	.11	.03	.02
	1/4	6.4	.16	.18	.05	.04
	3/8	9.6	.32	.37	.11	.07
	1/4	6.4	.19	.22	.07	.04
	5/16	7.9	.27	.31	.09	.06
	3/8	9.5	.37	.42	.13	.08
	7/16	11.1	.48	.55	.16	.11
	1/2	12.7	.61	.70	.21	.14
	5/8	15.9	.91	1.04	.31	.20
	3/4	19.1	1.28	1.47	.44	.29
	1/8	3.2	.03	.03	.01	>.01
	3/16	4.8	.06	.07	.02	.01
	1/4	6.4	.11	.12	.04	.02
	5/16	7.9	.17	.19	.06	.04
	3/8	9.5	.24	.27	.08	.05
	1/2	12.7	.43	.49	.15	.09
	5/8	15.9	.66	.76	.23	.15
	3/4	19.1	.96	1.09	.33	.21
	1	25.4	1.70	1.94	.58	.38
	5/8	15.9	.70	.80	.24	.16
	3/4	19.1	.92	1.05	.32	.21
	7/8	22.2	1.18	1.35	.40	.26
	1	25.4	1.46	1.67	.50	.33
	5/8	15.9	1.04	1.19	.36	.23
	3/4	19.1	1.37	1.57	.47	.31
	7/8	22.2	1.73	1.98	.59	.39
	1	25.4	2.14	2.45	.73	.48

*Note: The metals within these two categories do not all have exactly the same density but are close enough to give a good approximation.

These figures are based on an 1/16 inch (1.6 mm) reinforcement and a 100% deposition efficiency. For manual welding, approximately a 5% increase should be added to these figures.

1.2.3 Shielding Gas Cost

The calculation for the cost of shielding gas is the same for GTAW, GMAW, and FCAW. The cost of the shielding gas depends on the gas flow rate, the arc time, and the cost for the type of shielding gas. Helium costs much more than argon per cubic foot and higher flow rates must be used with helium that can make it much more expensive than argon. The equation for determining the shielding gas cost is:

$$\frac{Shielded\ Gas\ Cost}{Foot\ of\ Weld} = \left(\frac{Arc}{Time}\right) X \left(\frac{Gas\ Flow}{Rate}\right) X \left(\frac{Cost\ of\ Gas}{Cubic\ Foot}\right)$$

1.2.4 Electric Power Cost

Electric power costs are the same in all the welding processes. The equation for the electric power cost is:

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{Welding\ Current\ X\ Welding\ Voltage}{Power\ Source\ Efficiency}\right) X \left(\frac{Arc}{Time}\right) X \left(\frac{Power\ Cost}{kw-hr}\right)$$

To determine arc time per foot of weld, use:

$$\frac{Arc\ Time}{Foot\ of\ Weld} = \left(\frac{Length\ of\ Weld}{Travel\ Speed}\right)$$

For example:

$$\frac{Arc\ Time}{Foot\ of\ Weld} = \left(\frac{12\ inch}{10\ in/\min}\right) X \left(\frac{1\ hour}{60\min}\right) = \frac{.020\ hr}{Foot\ of\ Weld}$$

Then include your operator factor to calculate total welding time per foot of weld.

$$\frac{Total\ Welding\ Time}{Foot\ of\ Weld} = \left(\frac{Length\ of\ Weld}{Travel\ Speed\ X\ Operating\ Factor}\right)$$

For example:

$$\frac{Total\ Welding\ Time}{Foot\ of\ Weld} = \left(\frac{12\ inch}{10\ in/\min\ X\ .35}\right) X \left(\frac{1\ hour}{60\min}\right) = \frac{.057\ hr}{Foot\ of\ Weld}$$

Or

$$\frac{Total\ Welding\ Time}{Foot\ of\ Weld} = \left(\frac{Arc\ Time}{Operating\ Factor}\right)$$

For example:

$$\frac{Total\ Welding\ Time}{Foot\ of\ Weld} = \left(\frac{.020\ hr}{.35}\right) = .057$$

1.2.5 Examples

Now you are ready to calculate your total costs per foot of weld. *Table 5-5* shows the figures used for the cost calculations of both manual and automatic gas tungsten arc welding. The following is a sample calculation of the manual method of welding (values taken from *Table 5-5*).

$$\frac{Total\ Labor\ Cost}{Foot\ of\ Weld} = (Total\ Welding\ Time)\ X\ \left(\frac{Labor\ and\ Overhead\ Costs}{Hour}\right)$$

$$\frac{Total\ Labor\ Cost}{Foot\ of\ Weld} = (.057)\ X\ \left(\frac{\$18.00}{Hour}\right) = \$1.026$$

$$\frac{Filler\ Metal\ Cost}{Foot\ of\ Weld} = \left(\frac{(Weight\ of\ Deposit)\ X\ (Filler\ Metal\ Costs)}{Deposition\ Efficiency}\right)$$

$$\frac{Filler\ Metal\ Cost}{Foot\ of\ Weld} = \left(\frac{(.037)\ X\ (\$1.60)}{1.00}\right) = \$.059$$

$$\frac{Shielded\ Gas\ Cost}{Foot\ of\ Weld} = \left(\begin{matrix} Arc \\ Time \end{matrix}\right) X \left(\begin{matrix} Gas\ Flow \\ Rate \end{matrix}\right) X \left(\frac{Cost\ of\ Gas}{Cubic\ Foot}\right)$$

$$\frac{Shielded\ Gas\ Cost}{Foot\ of\ Weld} = (.020\ hr)\ X\ (30\ ft^3/hr)\ X \left(\frac{\$.06}{ft^3}\right) = \$.036$$

For this example of a calculation, assume a tungsten electrode cost at 4% of the cost of the shielding gas.

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = (.04)\ X\ (\$.36) = \$.001$$

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{Welding\ Current\ X\ Welding\ Voltage}{Power\ Source\ Efficiency}\right) X \left(\begin{matrix} Arc \\ Time \end{matrix}\right) X \left(\frac{Power\ Cost}{kw-hr}\right)$$

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{240\ Amps\ X\ 25\ Volts}{.50}\right) X\ (.020\ hr)\ X \left(\frac{\$.035}{kw-hr}\right) X \left(\frac{1\ kw}{1000\ w}\right) = \$.008$$

GTAW example

$$\frac{Total\ Costs}{Foot\ of\ Weld} = \left(\begin{matrix} Labor & +\ Filler\ Metal & +\ Shielding\ Gas & +\ Electrode & +\ Electric\ Power \\ \$1.026 & +\ \$.059 & +\ \$.036 & +\ \$.001 & +\ \$.008 \end{matrix}\right) = \$1.130$$

1.2.6 Cost Comparison of Manual vs. Automatic

Table 5-5 — Cost comparison of Manual vs. Automatic welding

Method of Welding	Manual	Automatic
Welding Current (amps)	240	300
Welding Voltage (volts)	25	30
Travel Speed (in/min)	10	15
Gas Flow (f^3/hr)	30	40
Welding Time (hr)	0.057	0.022
Arc Time (hr)	0.02	0.013
Labor + Overhead Cost ($/hr)	18	18
Operator Factor (%)	35	60
Weight of Deposit (Ibs)	0.037	0.037
Filler Wire Cost ($/Ib)	1.6	1.6
Deposition Efficiency (%)	100	100
Gas Cost ($/$f^3$)	0.06	0.06
Gas Used (f^3)	0.6	0.53
Electric Power Cost ($/kw-hr)	0.035	0.035
Power Source Efficiency (%)	50	50
Labor + Overhead Cost ($/ft)	1.026	0.396
Filler Wire Cost ($/ft)	0.059	0.059
Shielding Gas Cost ($/ft)	0.036	0.032
Electrode Cost ($/ft)	0.001	0.001
Electric Power Cost ($/ft)	0.008	0.008
Total Cost ($/ft)	**1.130**	**0.496**

1.3.0 Cost of Gas Metal Arc Welding

Gas metal arc welding can be used to weld many thicknesses and types of metals as economically as possible. It is usually selected because it is the least expensive process that can be used for many applications.

The initial investment for the equipment can vary depending on the complexity and size of the equipment used. The equipment for a semiautomatic welding station is much less expensive than the equipment required for a fully automatic set-up. The type of equipment depends on the type of application. Semiautomatic gas metal arc welding produces higher deposition rates and operator factors when compared to manual shielded metal arc welding.

The level of welder skill for gas metal arc welding is generally less than that required for shielded metal arc welding and gas tungsten arc welding. This helps to develop welds with a more consistent quality. Semiautomatic welding often competes against manual processes such as oxyacetylene welding, shielded metal arc welding, and gas tungsten arc welding for many applications. This process will generally produce higher deposition rates and operator factors than these other manual processes.

Automatic gas metal arc welding operations will give higher deposition rates and operator factors. The cost of electrode wires and shielding gases can vary widely because of price differences between different types and sizes of electrodes and different types of shielding gas. The cost of electric power consumed will depend on the type of machine, amount of welding, and the welding currents being used.

The cost of this welding process consists of four major items: labor and overhead, electrode, shielding gas, and electric power.

1.3.1 Labor Cost

GMAW can be used semiautomatically and automatically, which means the operator factor can vary widely. Operator factors for semiautomatic welding usually range from about 25% to as high as 60%. These operator factors are low compared to machine and automatic welding, where operator factors can range up to 80% or more depending on the application. The machine and automatic welding operations give higher operator factors because the welding can proceed to completion without interruption. The deposition rates and travel speeds affect the labor and overhead costs because the rate at which the electrode wire is deposited affects the productivity. The deposition rates and travel speeds used will be affected by the size of the electrode wire, the welding current, the thickness of the base metal, and the type of base metal.

The equation for determining the labor and overhead costs is:

$$\frac{Labor\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{Labor\ and\ Overhead\ Costs}{Hour}\ X\ \frac{Pounds\ of\ Weld\ Deposit}{Foot\ of\ Weld}}{Deposition\ Rate\ X\ Operating\ Factor} \right)$$

Or

$$Total\ Labor\ Cost = (Total\ Welding\ Time)\ X \left(\frac{Labor\ and\ Overhead\ Costs}{Hour} \right)$$

1.3.2 Electrode Cost

As previously discussed, the cost of the electrode wire per weld is determined by several factors: the weight of the weld deposited, the cost per pound of the filler metal, and the deposition efficiency of the filler metal. Refer to *Tables 5-3 and 5-4* which show the inches per pound and the filler metal consumption for different sizes and types of welds. The small diameter solid electrode wires used for this process cost more per pound than larger diameter solid electrode wires and covered electrodes. Electrode wire is less expensive per pound when supplied in a reel or large coil, as compared to a small coil. The total amount of wire purchased also affects the cost. Large shipments of wire will generally cost less per pound than small shipments.

The deposition efficiency is about 95% for most welding operations. Some of the electrode wire is lost to spatter and vaporization. This will vary slightly depending on the type of shielding gas. Argon will generally give higher deposition efficiencies than carbon dioxide due to the fact that less spatter is produced by spray transfer. The lowest deposition efficiencies are obtained when using the globular transfer mode because larger amounts of spatter are created.

The equations used for determining the cost of the electrode/filler metal are:

$$\frac{Electrode\,Cost}{Foot\,of\,Weld} = \left(\frac{Arc}{Time}\right) X \left(\frac{Wire\,Feed}{Rate}\right) X \left(\frac{Wire\,Rate\,Per}{Unit\,of\,Length}\right) X \left(\frac{Wire\,Cost}{Pound}\right)$$

Or

$$\frac{Electrode\,Cost}{Foot\,of\,Weld} = \left(\frac{(Weight\,of\,Deposit)\,X\,(Filler\,Metal\,Costs)}{Deposition\,Efficiency}\right)$$

1.3.3 Shielding Gas Cost

Remember, the calculation for GTAW, GMAW, and FCAW is the same

The equation for determining the shielding gas cost is:

$$\frac{Shielded\,Gas\,Cost}{Foot\,of\,Weld} = \left(\frac{Arc}{Time}\right) X \left(\frac{Gas\,Flow}{Rate}\right) X \left(\frac{Cost\,of\,Gas}{Cubic\,Foot}\right)$$

1.3.4 Electric Power Cost

Remember, the calculation for SMAW, GTAW, GMAW, and FCAW is the same**.**

The equation for electric power cost is:

$$\frac{Electric\,Power\,Cost}{Foot\,of\,Weld} = \left(\frac{Welding\,Current\,X\,Welding\,Voltage}{Power\,Source\,Efficiency}\right) X \left(\frac{Arc}{Time}\right) X \left(\frac{Power\,Cost}{kw - hr}\right)$$

1.3.5 Examples

Table 5-6 shows the figures used for cost calculations of semiautomatic and automatic gas metal arc welding and a comparison with shielded metal arc welding. In equations where arc time is necessary, it can be determined from the following equations:

$$\frac{Arc\,Time}{Foot\,of\,Weld} = \left(\frac{Length\,of\,Weld}{Travel\,Speed}\right)$$

Or

$$\frac{Arc\,Time}{Foot\,of\,Weld} = \left(\frac{Weight\,of\,Deposit}{Deposition\,Rate}\right)$$

$$\frac{Arc\,Time}{Foot\,of\,Weld} = \left(\frac{.106\,lbs/ft}{6.3\,lbs/hr}\right) = .017\,hr$$

The total welding time can then be determined by the equation:

$$\frac{Total\ Welding\ Time}{Foot\ of\ Weld} = \left(\frac{Arc\ Time}{Operating\ Factor}\right)$$

$$\frac{Total\ Welding\ Time}{Foot\ of\ Weld} = \left(\frac{.017\ hr}{.50}\right) = .034\ hr$$

The following is a sample calculation for making a ¼ in. (6.4mm) fillet weld with semiautomatic gas metal arc welding using the figures from Table 5-6.

$$\frac{Labor\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{Labor\ and\ Overhead\ Costs}{Hour}\ X\ \frac{Pounds\ of\ Weld\ Deposit}{Foot\ of\ Weld}}{Deposition\ Rate\ X\ Operating\ Factor}\right)$$

$$\frac{Labor\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{\$18.00}{Hour}\ X\ \frac{.106\ lbs}{Foot}}{6.3\ lbs/hr\ X\ .50}\right) = \$.606$$

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\frac{(Weight\ of\ Deposit)\ X\ (Filler\ Metal\ Costs)}{Deposition\ Efficiency}\right)$$

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\frac{(.106\ lbs/ft)\ X\ (\$.60/lb)}{.95}\right) = \$.067$$

Or

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\begin{matrix}Arc\\ Time\end{matrix}\right) X \left(\begin{matrix}Wire\ Feed\\ Rate\end{matrix}\right) X \left(\begin{matrix}Wire\ Rate\ Per\\ Unit\ of\ Length\end{matrix}\right) X \left(\frac{Wire\ Cost}{Pound}\right)$$

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\frac{.017\ hr}{ft}\right) X \left(\frac{240\ in}{\min}\right) X \left(\frac{60\ \min}{1\ hr}\right) X \left(\frac{1\ lb}{2210\ in}\right) X \left(\frac{\$.60}{Pound}\right) = \$.067$$

$$\frac{Shielded\ Gas\ Cost}{Foot\ of\ Weld} = \left(\begin{matrix}Arc\\ Time\end{matrix}\right) X \left(\begin{matrix}Gas\ Flow\\ Rate\end{matrix}\right) X \left(\frac{Cost\ of\ Gas}{Cubic\ Foot}\right)$$

$$\frac{Shielded\ Gas\ Cost}{Foot\ of\ Weld} = \left(\frac{.017\ hr}{ft}\right) X \left(\frac{25\ ft^3}{hr}\right) X \left(\frac{\$.03}{ft^3}\right) = \$.013$$

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{Welding\ Current\ X\ Welding\ Voltage}{Power\ Source\ Efficiency}\right) X \left(\frac{Arc}{Time}\right) X \left(\frac{Power\ Cost}{kw-hr}\right)$$

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{200\ Amps\ X\ 73 Volts}{.8}\right) X\ (.017\ hr)\ X\ \left(\frac{\$.035}{kw-hr}\right) X \left(\frac{1 kw}{1000\ w}\right) = \$.003$$

GMAW example

$$\frac{Total\ Costs}{Foot\ of\ Weld} = \left(\frac{Labor\ + Electrode\ + Shielding\ Gas + Electric\ Power}{\$.606\ \ + \$.067\ \ + \$.013\ \ + \$.003}\right) = \$.689$$

1.3.6 Cost Comparison of Manual (SMAW) vs. Semiautomatic (GMAW) and Automatic (GMAW)

Table 5-6 — Cost Comparison of Manual Shielded Metal Arc Welding vs. Semiautomatic and Automatic Gas Metal Arc Welding for Making a 1/4 in. (6.4 mm) Fillet Weld.

Process Method of Welding	SMAW Manual	GMAW Semiautomatic	GMAW Automatic
Electrode Diameter (in)	3/16	0.045	1/16
Welding Current (amps)	250	200	350
Welding Voltage (volts)	25	23	24
Travel Speed (in/min)	9	15	25
Gas Flow (ft^3/hr)		25	35
Welding Time (hr)	0.063	0.033	0.01
Arc Time (hr)	0.022	0.017	0.008
Wire Feed Speed (in/min)		240	270
Labor + Overhead Cost ($/hr)	18	18	18
Operator Factor (%)	35	50	80
Weight of Deposit (lbs)	0.106	0.106	0.106
Electrode Cost ($/lbs)	0.45	0.6	0.55
Deposition Efficiency (%)	72	95	95
Deposition Rate (lbs/hr)	4.8	6.3	13.2
Gas Cost ($/$ft^3$)		0.03	0.03
Gas Used (ft^3)		0.33	0.29
Electric Power Cost ($/kw/hr)	0.035	0.035	0.035
Power Source Efficiency (%)	50	80	80
Labor + Overhead Cost ($/ft)	1.136	0.606	0.181
Electrode Cost ($/ft)	0.066	0.067	0.061
Shielding Gas Cost ($/ft)		0.013	0.008
Electric Power Cost ($/ft)	0.01	0.003	0.003
Total Cost ($/ft)	**1.212**	**0.689**	**0.253**

1.4.0 Cost of Flux Cored Arc Welding

Flux cored arc welding has advantages over other processes which make it the most economical welding method for many different applications. To select a welding process for your project or task, you should compare factors such as deposition rates, welding speeds, joint preparation time, operator factors, and welding material costs.

Like GMAW, the initial investment for the equipment can vary considerably depending on the size and complexity of the equipment used, and the equipment used is often the same as for gas metal arc welding. Because of the higher current levels used in flux cored arc welding, larger power sources may be needed. With the self-shielding electrode wires, a gas shielding system is not needed, which simplifies and reduces the overall cost of the equipment. In some cases where gas metal arc welding equipment is available, a change to flux cored arc welding would require almost no new equipment. The equipment for semiautomatic welding is much less expensive than equipment for automatic welding.

An advantage of flux cored arc welding over the manual welding processes is that a lower degree of welder skill is needed. A welder skilled in gas metal arc welding would have very little trouble learning to weld with flux cored arc welding. This process generally has good welder appeal. This is particularly true when compared to gas metal arc welding at the higher current levels.

Another example is the comparison to semiautomatic submerged arc welding where it is more difficult to weld because the weld puddle is not visible. Semiautomatic flux cored arc welding usually competes with shielded metal arc welding, gas metal arc welding and submerged arc welding. Automatic flux cored arc welding usually competes against automatic gas metal arc welding and submerged arc welding. In flux cored arc welding, the costs of materials will vary depending on the electrode and whether or not shielding gas is required. The electric power cost will depend on the machine and the welding parameters.

The cost of this process consists of four major items that are labor and overhead, electrodes, shielding gas and electric power. The cost calculation methods used in this chapter can be used to compare the cost of flux cored arc welding to the other processes.

1.4.1 Labor Cost

Because this process is applied semiautomatically and automatically, the operator factor can vary widely. Operator factors for semiautomatic welding usually range from 25% to as high as 60%. When compared to gas metal arc welding, operator factors are usually slightly lower with flux cored arc welding because more time is spent removing slag. Since flux cored arc welding uses a continuously fed electrode wire, operator factors are much higher than shielded metal arc welding, where much time is spent changing electrodes. Operator factors for machine and automatic welding can range up to 80% or more, depending on the application.

The equation for determining the labor and overhead costs is:

$$\frac{Labor\ Cost}{Foot\ of\ Weld} = \left(\frac{\dfrac{Labor\ and\ Overhead\ Costs}{Hour}\ X\ \dfrac{Pounds\ of\ Weld\ Deposit}{Foot\ of\ Weld}}{Deposition\ Rate\ X\ Operating\ Factor} \right)$$

Or

$$Total\ Labor\ Cost = (Total\ Welding\ Time)\ X \left(\frac{Labor\ and\ Overhead\ Costs}{Hour}\right)$$

1.4.2 Electrode Cost

The deposition efficiency of flux cored wire is lower than that of solid wires because the flux core provides shielding gas and a slag covering. Self-shielding flux cored wires typically have a deposition efficiency of about 75-80%, which is much higher than obtained from covered electrodes. Gas shielded electrode wires have deposition efficiencies ranging from 80-90%. These are higher than self-shielding wires because less of the core becomes shielding gas and slag. With both types of flux cored wires, some wire is lost to spatter and vaporization. Spatter is generally higher with self-shielding electrodes that also contributes to the lower deposition efficiencies. The type of shielding gas used will have an effect on the deposition efficiency. Carbon dioxide will produce higher spatter levels than argon-carbon dioxide and argon-oxygen mixtures.

The equations used for determining the cost of an electrode wire are:

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\frac{Arc}{Time}\right) X \left(\frac{Wire\ Feed}{Rate}\right) X \left(\frac{Wire\ Rate\ Per}{Unit\ of\ Length}\right) X \left(\frac{Wire\ Cost}{Pound}\right)$$

Or

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\frac{(Weight\ of\ Deposit)\ X\ (Filler\ Metal\ Costs)}{Deposition\ Efficiency}\right)$$

For the first equation, the wire weight per unit of length is needed. This figure will vary depending on the type of electrode wire used. Some flux-cored electrodes contain more core elements than others do. This is true of the self-shielding wires when compared to gas shielded wires. A good approximation of the percent fill or amount of flux in a tubular wire for cost calculations is about 16% by weight. This gives inches of wire per pound as shown in *Table 5-7*.

Table 5-7 — Inches of wire needed to make one pound.

Electrode Diameter in.	Inches of wire per pound
.045	2375
1/16	1230
5/64	996
3/32	640
7/64	469
1/8	346
3/32	225

1.4.3 Shielding Gas Cost

If you do not use self-shielded flux cored wire you will have to determine shielding gas costs.

The equation for determining the shielding gas cost is:

$$\frac{Shielded\ Gas\ Cost}{Foot\ of\ Weld} = \left(\frac{Arc}{Time}\right) X \left(\frac{Gas\ Flow}{Rate}\right) X \left(\frac{Cost\ of\ Gas}{Cubic\ Foot}\right)$$

1.4.4 Electric Power Cost

The equation for electric power cost is:

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{Welding\ Current\ X\ Welding\ Voltage}{Power\ Source\ Efficiency}\right) X \left(\frac{Arc}{Time}\right) X \left(\frac{Power\ Cost}{kw-hr}\right)$$

1.4.5 Examples

Table 5-8 shows the figures used for a cost calculation comparison of shielded metal arc welding, gas metal arc welding, flux cored arc welding using a self-shielding wire, flux cored arc welding using a gas-shielded wire, and submerged arc welding. The examples given are typical but the exact data should be obtained from the manufacturer's data sheets and the actual welding conditions. In equations where arc time is necessary, it can be determined from the following equation.

$$\frac{Arc\ Time}{Foot\ of\ Weld} = \left(\frac{(Length\ of\ Weld)\ X\ (Number\ of\ Passes)}{Travel\ Speed}\right)$$

Or

$$\frac{Arc\ Time}{Foot\ of\ Weld} = \left(\frac{Weight\ of\ Deposit}{Deposition\ Rate}\right)$$

The total welding time can then be determined by the equation:

$$\frac{Total\ Welding\ Time}{Foot\ of\ Weld} = \left(\frac{Arc\ Time}{Operating\ Factor}\right)$$

The following sample calculation is for making a ½ inch (12.7 mm) fillet weld in the horizontal position using semiautomatic flux cored arc welding with a gas-shielded electrode.

$$\frac{Labor\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{Labor\ and\ Overhead\ Costs}{Hour}\ X\ \frac{Pounds\ of\ Weld\ Deposit}{Foot\ of\ Weld}}{Deposition\ Rate\ X\ Operating\ Factor}\right)$$

$$\frac{Labor\ Cost}{Foot\ of\ Weld} = \left(\frac{\frac{\$18.00}{Hour} X \frac{.425\,lbs}{Foot}}{17\,lbs/hr\ X\ .45} \right) = \$1.001$$

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\frac{(Weight\ of\ Deposit)\ X\ (Filler\ Metal\ Costs)}{Deposition\ Efficiency} \right)$$

$$\frac{Electrode\ Cost}{Foot\ of\ Weld} = \left(\frac{(.425\,lbs/ft)\ X\ (\$.75/lb)}{.90} \right) = \$.345$$

$$\frac{Shielded\ Gas\ Cost}{Foot\ of\ Weld} = \left(\frac{Arc}{Time} \right) X \left(\frac{Gas\ Flow}{Rate} \right) X \left(\frac{Cost\ of\ Gas}{Cubic\ Foot} \right)$$

$$\frac{Arc\ Time}{Foot\ of\ Weld} = \left(\frac{Weight\ of\ Deposit}{Deposition\ Rate} \right)$$

$$\frac{Arc\ Time}{Foot\ of\ Weld} = \left(\frac{.425\,lbs/ft}{17.0\,lbs/hr} \right) = .0250\,hr$$

$$\frac{Shielded\ Gas\ Cost}{Foot\ of\ Weld} = \left(\frac{.0250\,hr}{ft} \right) X \left(\frac{35\ ft^3}{hr} \right) X \left(\frac{\$.025}{ft^3} \right) = \$.022$$

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{Welding\ Current\ X\ Welding\ Voltage}{Power\ Source\ Efficiency} \right) X \left(\frac{Arc}{Time} \right) X \left(\frac{Power\ Cost}{kw-hr} \right)$$

$$\frac{Electric\ Power\ Cost}{Foot\ of\ Weld} = \left(\frac{475\ Amps\ X\ 29\,Volts}{.8} \right) X\ (.0250)\ X \left(\frac{\$.04}{kw-hr} \right) X \left(\frac{1\,kw}{1000\,w} \right) = \$.017$$

FCAW example

$$\frac{Total\ Costs}{Foot\ of\ Weld} = \left(\frac{Labor\ +Electrode\ +Shielding\ Gas + Electric\ Power}{\$1.001\ \ +\ \$.345\ \ +\$.022\ \ +\$.017} \right) = \$1.384$$

1.4.6 Cost Comparison of Between (SMAW), (GMAW) and (FCAW)

Table 5-8 — Cost Comparisons Between SMAW, GMAW, FCAW, and Submerged Arc Welding of 1/2 in. (12.7 mm) Fillet Weld in the Horizontal Position.

Process **Method of Application** **Electrode Type**	**SMAW** **Manual** **E7024**	**GMAW** **Semiautomatic** **E70S-3**	**FCAW** **Semiautomatic** **E70T-4**	**FCAW** **Semiautomatic** **E70T-1**	**SAW** **Semiautomatic** **EM 12K**
Electrode Diameter (in.)	1/4	1/16	3/32	3/32	3/32
Welding Current (amps)	380	350	375	475	550
Welding Voltage (volts)	33	25	28	29	33
Travel Speed (in./min.)	11-3	18-3	--	15	12
Gas Flow (f^3/hr.)	--	45	--	35	--
Total Welding Time (hr.)	0.0995	0.8654	0.0587	0.0556	0.0605
Arc Time (hr.)	0.0348	0.0327	0.0264	0.025	0.0272
Wire Feed Speed (in./min.)	--	270	215	200	120
Labor and Overhead Cost ($/hr.)	18	18	18	18	18
Operator Factor (%)	35	50	45	45	45
Weight of Deposit (Ibs.)	0.425	0.425	0.425	0.425	0.425
Electrode Cost ($/Ib.)	0.5	0.6	0.6	0.75	0.52
Deposition Efficiency (%)	67	93	80	90	100*
Deposition Rate (Ibs./hr.)	12.2	13	16.1	17	15.6
Gas Cost ($/$f^3$)	--	0.025	--	0.025	--
Gas Used (f^3)	--	--	--	--	--
Flux Cost ($/Ib.)	--	--	--	--	0.5
Flux Used (Ibs.)	--	--	--	--	0.53
Electric Power Cost ($/kw-hr.)	0.04	0.04	0.04	0.04	0.04
Power Source Efficiency (%)	50	80	80	80	80
Labor and Overhead Cost ($/ft.)	1.71	1.177	1.057	1.001	1.09
Electrode Cost ($/ft.)	0.317	0.274	0.318	0.354	0.221
Shielding Gas Cost ($/ft.)	--	0.037	--	0.022	--
Flux Cost (#/ft.)	--	--	--	--	0.266
Electric Power Cost ($/ft.)	0.035	0.014	0.014	0.017	0.024
Total Cost ($/ft.)	**2.143**	**1.502**	**1.389**	**1.384**	**1.601**

Summary

This chapter discussed how to determine the welding costs of multiple processes.