Estimating Welding Cost

1. COST FACTORS

There are several methods which may be used to study welding cost, and these depend on the need for such a study. For example, is it needed to estimate a new job for bidding? Or, it is needed to compare one procedure against another? Or, is the chief need one of determining the amount of electrode to order?

A good method of cost estimating should give the final cost quickly; yet indicate what portion of the operation is more expensive, i.e. where the welding dollar is really being spent.

The final cost includes at least these items: a) labor and overhead for plate preparation, assembling, welding, cleaning, and sometimes stress-relieving; b) electrode, flux, and gas; and c) electric power.

Table 1 includes a number of useful formulas for determining various cost components.

Unfortunately there is no one all-inclusive formula by which all types of welding jobs may be studied. The simplest type of cost estimation is a job that requires a long, single-pass fillet or groove weld. Next comes the long, multi-pass weld, where a different procedure may be used for each pass. In both examples, it is sufficient to assume a reasonable operating factor due to the downtime between electrodes consumed and to apply this to the actual arc time. This downtime is affected by the weldor, as well as the job. A more complicated weld may require a handling time factor. This handling time is affected more by the job, than by the welding.

Three items which are difficult to tie down, yet greatly affect the cost of a weld, are these:

1. The amount of filler weld metal required; this varies with size of weld, size of root opening or fit up, amount of reinforcement, included angle of groove, etc.

2. The operating factor used, i.e. the ratio of actual arc time to the over-all welding time.

3. The amount of handling and cleaning time.

This section includes various tables and nomographs which are helpful in making true cost estimates. No estimating system, however, is satisfactory without the estimator applying his good judgment and perception.

2. COST OF WELD METAL

The cost of welding is directly affected by the amount of weld metal required. Very few people realize the great increase in weld metal and cost that results from a slight increase in weld size.

The cross-sectional area of a weld generally varies as the square of the weld size. For example, making a $\frac{5}{16}''$ leg size fillet weld when a $\frac{1}{4}''$ weld is desired, increases the leg by 25% but the area is increased by 56%. The amount of reinforcement is difficult to specify and control; yet the range of its variance can substantially affect the amount of weld metal required. A slight increase in root opening increases the amount of weld metal for the entire thickness and length of the weld. The resulting percentage increase in weld metal is usually surprising.

Computing Weld Weight

Designers or associated personnel frequently have to compute the weight of weld metal required on a particular job, as a matter of either cost estimating or determining the amount of material to be ordered for a particular job. Sometimes these computations must be based on the size and configuration of the joint. The normal procedure to follow in such a case is to compute the cross-sectional area of the joint in square inches and then convert this into pounds per linear foot by multiplying by the factor 3.4. To simplify these computations, Table 2 (weight in lbs/linear ft) has been developed; its use is illustrated in Problem 1.

Tables 3, 4, and 5 provide precalculated weights for specific joints and read directly in lbs per foot of joint. Table 6 is a similar table for AWS prequalified joints. Tables for the direct reading of weld metal for partial-penetration groove or fillet welds are included in Section 3.6, "Fabrication of Built-Up Columns."

For estimating the weight of manual electrode required, roughly add another 50% to this amount of weld metal.

In order to arrive at the labor cost per foot of joint, it is necessary to know the speed at which the joint can be welded. This may be found in prepared data on standard welding procedures, both for manual welding as well as the submerged-arc process. For special joints for which no information is available, the deposition rate (lbs/hr) may be determined from tables and charts for given welding currents. The joint speed is then found by dividing this deposition rate by the amount of weld metal required (lbs/linear ft.).

TABLE 1—Useful Welding Cost Formulas

SPEED	TIME	JOINT SPEED
$\frac{ft}{hr} = 5\,\frac{in}{min}$	$\frac{min}{ft} = \frac{60}{ft/hr} = \frac{12}{in/min}$	$S = \dfrac{1}{\frac{1}{S_1} + \frac{1}{S_2} + \frac{1}{S_3}}$

JOINT SPEED	ROD MELTED PER FOOT	ROD MELTED PER HOUR
$\frac{ft}{hr} = \frac{60\ D}{J}$	$\frac{\text{lb rod melted}}{\text{ft weld}} = \frac{1200\ M}{N\ L_m\ S}$	$\frac{\text{lb rod melted}}{hr} = \frac{6000\ M\ (OF)}{N\ L_m}$

ROD MILEAGE	ROD CONSUMED PER FOOT	ROD CONSUMED PER HOUR
$\frac{\text{in of weld}}{\text{one rod}} = L_w = \frac{L_m\ S}{M}$	$\frac{\text{lb rod consumed}}{\text{ft weld}} = \frac{1200\ M}{N\ L_m S}$	$\frac{\text{lb rod consumed}}{hr} = \frac{6000\ M\ (OF)}{N\ L_m}$

APPROXIMATE MELT OFF RATE $= \frac{E(\text{arc volts})\ I(\text{welding current})}{1000} = \frac{\text{lb rod melted}}{hr}$

APPROXIMATE COST OF SUBMERGED ARC AUTOMATIC WELD $= \frac{¢}{ft} = \frac{.0065\ I\ (F+W) + 20\ L}{S}$

WELD COST	per foot of each pass	per lb of deposit
LABOR OVERHEAD	$\frac{¢}{ft} = \frac{20\ L}{S\ (OF)}$	$\frac{¢}{lb} = \frac{5\ L}{3\ D\ (OF)}$
MANUAL ELECTRODE	$\frac{¢}{ft} = \frac{1200\ M\ W}{N\ L_m\ S}$	$\frac{¢}{lb} = \frac{W}{E_2}$
AUTOMATIC WIRE & FLUX	$\frac{¢}{ft} = \frac{12\ m\ (W+RF)}{S} = \frac{J\ (W+RF)}{E_2}$	$\frac{¢}{lb} = \frac{W+RF}{E_2}$
GAS	$\frac{¢}{ft} = \frac{20\ G}{S}$	$\frac{¢}{lb} = \frac{5\ G}{3\ D}$

L = labor + overhead ($/hr)
W = wire or rod cost (¢/lb)
F = flux cost (¢/lb)
G = gas cost ($/hr)
R = ratio of flux to wire
D = (lb weld deposited/min)
M = (in rod melted/min) = L_m/T
C = (lb rod consumed/min) with stub
m = (lb rod melted/min) no stub
W_r = weight one rod with stub (lbs) = 100/N
W_s = weight of one stub (lbs)
E_1 = deposition efficiency $\frac{\text{lb weld deposited}}{\text{lb rod melted}} = \frac{D}{m}$
E_2 = overall deposition efficiency $\frac{\text{lb weld deposited}}{\text{lb rod consumed}} = \frac{D}{C} = E_1 E_3$
E_3 = melting efficiency $\frac{\text{lb rod melted}}{\text{lb rod consumed}} = \frac{m}{C} = \frac{W_r - W_s}{W_r}$

N = number rods/100 lbs
I = welding current (amperes)
S = (in weld/min) = L_w/T
T = time to melt one rod (min)
L_m = (in rod melted/rod)
L_w = (in weld/rod)
J = (lb weld/ft of joint)
OF = operating factor

TABLE 2—Weight of Weld Metal
(Pounds Per Foot of Joint)
Based on Joint Design

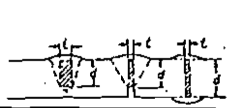
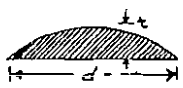
"d" or "r"	Segment of Weld Bead	BUTT WELDS																FILLET WELDS		
																		 flat	convex	concave leg size Increased 10%
Dimension		"t" Dimension						"t" Dimension					Included Angle					Values below are for leg size 10% oversize, consistent with normal shop practices.		
		1/16"	1/8"	3/16"	1/4"	3/8"	1/2"	1/16"	1/8"	3/16"	1/4"		14°	20°	60°	45° (1/2 of 90°)	70°			
1/16"												.021								
1/8"		.027	.053	.080	.106	.159	.212					.083	.0065	.0094	.031	.027	.037	.032	.039	.037
3/16"		.040	.080	.119	.159	.239	.318	.027				.188	.0147	.021	.069	.060	.084	.072	.087	.083
1/4"		.053	.106	.159	.212	.318	.425	.035				.334	.026	.037	.123	.106	.149	.129	.155	.147
5/16"		.066	.133	.199	.265	.390	.531	.044				.531	.041	.059	.192	.166	.232	.201	.242	.230
3/8"		.080	.159	.239	.318	.478	.637	.053	.106			.750	.059	.084	.276	.239	.334	.289	.349	.331
7/16"		.091	.186	.279	.371	.557	.743	.062	.124	.186		1.02	.080	.115	.376	.326	.456	.394	.475	.451
1/2"		.106	.212	.318	.425	.637	.849	.071	.142	.212		1.33	.104	.150	.491	.425	.595	.514	.620	.589
9/16"		.119	.239	.358	.478	.716	.955	.080	.159	.239			.132	.190	.621	.538	.753	.651	.785	.745
5/8"		.133	.265	.398	.531	.796	1.06	.089	.177	.266			.163	.234	.766	.664	.930	.804	.970	.920
11/16"		.146	.292	.438	.584	.876	1.17	.097	.195	.292	.389		.197	.283	.927	.804	1.13			
3/4"		.159	.318	.478	.637	.955	1.27	.111	.212	.318	.424		.234	.337	1.11	.956	1.34	1.16	1.40	1.32
13/16"		.172	.345	.517	.690	1.04	1.38	.114	.230	.345	.460		.275	.396	1.30	1.12	1.57			
7/8"		.186	.371	.557	.743	1.11	1.49	.124	.248	.372	.490		.319	.459	1.50	1.30	1.82	1.58	1.90	1.80
15/16"		.199	.398	.597	.796	1.19	1.59	.133	.266	.398	.530		.367	.527	1.73	1.50	2.07			
1"		.212	.425	.627	.849	1.25	1.70	.142	.282	.418	.566		.417	.599	1.96	1.70	2.38	2.06	2.48	2.36
1-1/16"		.226	.451	.677	.902	1.35	1.80	.150	.301	.451	.602		.471	.676	2.22	1.92	2.68			
1-1/8"		.239	.478	.716	.955	1.43	1.91	.159	.318	.477	.637		.528	.758	2.48	2.15	3.02	2.60	3.14	2.98
1-3/16"		.252	.504	.756	1.01	1.51	2.02	.168	.336	.505	.672		.588	.845	2.77	2.40	3.36			
1-1/4"		.265	.531	.796	1.06	1.59	2.12	.177	.354	.531	.706		.651	.936	3.07	2.66	3.72	3.21	3.88	3.68
1-5/16"		.279	.557	.836	1.11	1.67	2.23	.186	.372	.557	.743		.718	1.03	3.38	2.93	4.10			
1-3/8"		.292	.584	.876	1.17	1.75	2.34	.195	.389	.584	.777		.789	1.13	3.71	3.21	4.50	3.89	4.69	4.45
1-7/16"		.305	.610	.915	1.22	1.83	2.44	.203	.407	.610	.814		.836	1.24	4.05	3.51	4.91			
1-1/2"		.318	.637	.955	1.27	1.91	2.55	.212	.425	.636	.849		.938	1.35	4.42	3.82	5.36	4.62	5.58	5.30
1-9/16"		.332	.664	.995	1.33	1.99	2.65	.221	.442	.664	.884		1.02	1.46	4.79	4.15	5.81			
1-5/8"		.345	.690	1.04	1.38	2.07	2.76	.230	.460	.690	.920		1.10	1.58	5.18	4.49	6.29	5.43	6.55	6.22
1-11/16"		.358	.716	1.07	1.43	2.15	2.87	.239	.477	.716	.956		1.19	1.71	5.59	4.84	6.80			
1-3/4"		.371	.743	1.11	1.49	2.23	2.97	.249	.495	.741	.990		1.28	1.84	6.01	5.20	7.29	6.29	7.59	7.21
1-13/16"		.385	.769	1.15	1.54	2.31	3.08	.257	.511	.770	1.03		1.37	1.97	6.45	5.58	7.81			
1-7/8"		.390	.796	1.19	1.59	2.39	3.18	.266	.531	.796	1.06		1.47	2.10	6.90	5.97	8.36	7.21	8.72	8.28
1-15/16"		.411	.822	1.23	1.65	2.47	3.29	.274	.549	.823	1.10		1.56	2.25	7.36	6.38	8.94			
2"		.425	.849	1.27	1.70	2.55	3.40	.283	.566	.849	1.13		1.67	2.40	7.85	6.80	9.52	8.23	9.93	9.43

TABLE 3—Weight of Weld Metal (lbs/ft of Joint)

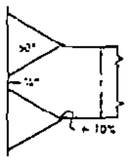
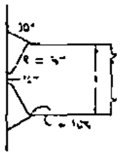
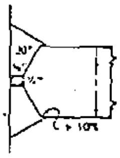
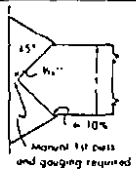
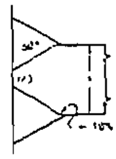
↓ Plate thickness									
	30° reinforcement	20° reinforcement	30° reinforcement	20° reinforcement	30° reinforcement	20° reinforcement	30° reinforcement	20° reinforcement	30° reinforcement
5/8	.456	.364	.544	.452	2.53	1.96	1.33	1.11	.427
3/4	.811	.649	.735	.626	3.02	2.40	1.71	1.43	.616
7/8	1.26	1.01	1.01	.830	3.54	2.86	2.14	1.79	.901
1	1.82	1.46	1.33	1.06	4.07	3.34	2.61	2.19	1.09
1 1/8	2.48	1.99	1.62	1.30	4.63	3.84	3.13	2.64	1.39
1 1/4	3.24	2.60	1.93	1.56	5.19	4.35	3.70	3.12	1.71
1 3/3	4.11	3.28	2.26	1.83	5.80	4.89	4.30	3.63	2.07
1 1/2	5.07	4.06	2.62	2.13	6.41	5.45	4.96	4.19	2.46
1 5/8	6.14	4.91	3.01	2.45	7.06	6.02	5.66	4.78	2.89
1 3/4	7.30	5.84	3.41	2.79	7.72	6.62	6.40	5.41	3.35
2	9.94	7.94	4.29	3.52	9.11	7.85	8.03	6.79	4.38
2 1/8	11.4	9.12	4.75	3.91	9.85	8.51	8.91	7.54	4.94
2 1/4	13.0	10.4	5.25	4.32	10.6	9.18	9.83	8.32	5.54
2 3/8	14.7	11.7	5.77	4.75	11.4	9.87	10.8	9.14	6.18
2 1/2	16.4	13.1	6.31	5.20	12.2	10.6	11.8	10.0	6.85
2 5/8	18.3	14.7	6.88	5.67	13.0	11.4	12.9	10.9	7.55
2 3/4	20.3	16.2	7.46	6.16	13.8	12.1	14.0	11.8	8.28
3	24.6	19.6	8.71	7.20	15.5	13.6	16.3	13.8	9.85

TABLE 4—Weight of Weld Metal (lbs/ft of Joint)

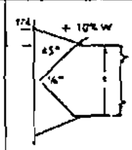
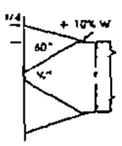
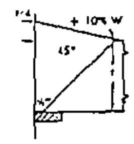
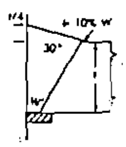
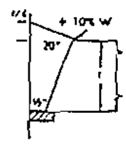
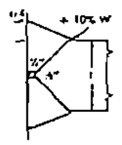
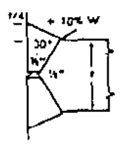
↓ Plate thickness							
5/8	.854	.501	1.45	1.39	1.52	1.09	1.15
3/4	1.15	.805	1.95	1.79	1.89	1.45	1.49
7/8	1.48	1.18	2.50	2.22	2.29	1.99	1.85
1	1.86	1.63	3.13	2.70	2.72	2.30	2.23
1 1/8	2.28	2.14	3.83	3.22	3.17	2.79	2.63
1 1/4	2.74	2.73	4.59	3.76	3.55	3.31	3.06
1 3/8	3.24	3.39	5.42	4.26	4.15	3.88	3.52
1 1/2	3.78	4.12	6.31	4.99	4.67	4.49	3.99
1 5/8	4.36	4.92	7.28	5.56	5.22	5.14	4.49
1 3/4	4.99	5.80	8.32	6.36	5.80	5.83	5.02
2	6.35	7.76	10.6	7.90	7.02	7.33	6.14
2 1/8	7.10	8.85	11.8	8.73	7.67	8.05	6.74
2 1/4	7.88	9.99	12.1	9.58	8.33	9.00	7.35
2 3/8	8.73	11.3	14.5	10.5	9.04	9.91	8.00
2 1/2	9.60	12.5	15.9	11.4	9.66	10.9	8.66
2 5/8	10.5	13.9	17.5	12.4	10.5	11.8	9.35
2 3/4	11.5	15.3	19.0	13.4	11.3	12.8	10.1
3	13.5	18.4	22.4	15.6	12.9	15.0	11.6

TABLE 5—Weight of Weld Metal
(lbs/ft of Joint)
Reinforcement: 10% W, Width of Joint

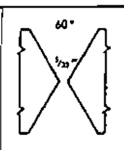
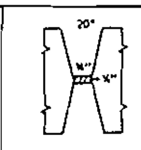
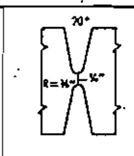
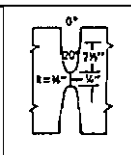
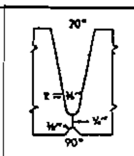
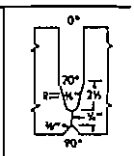
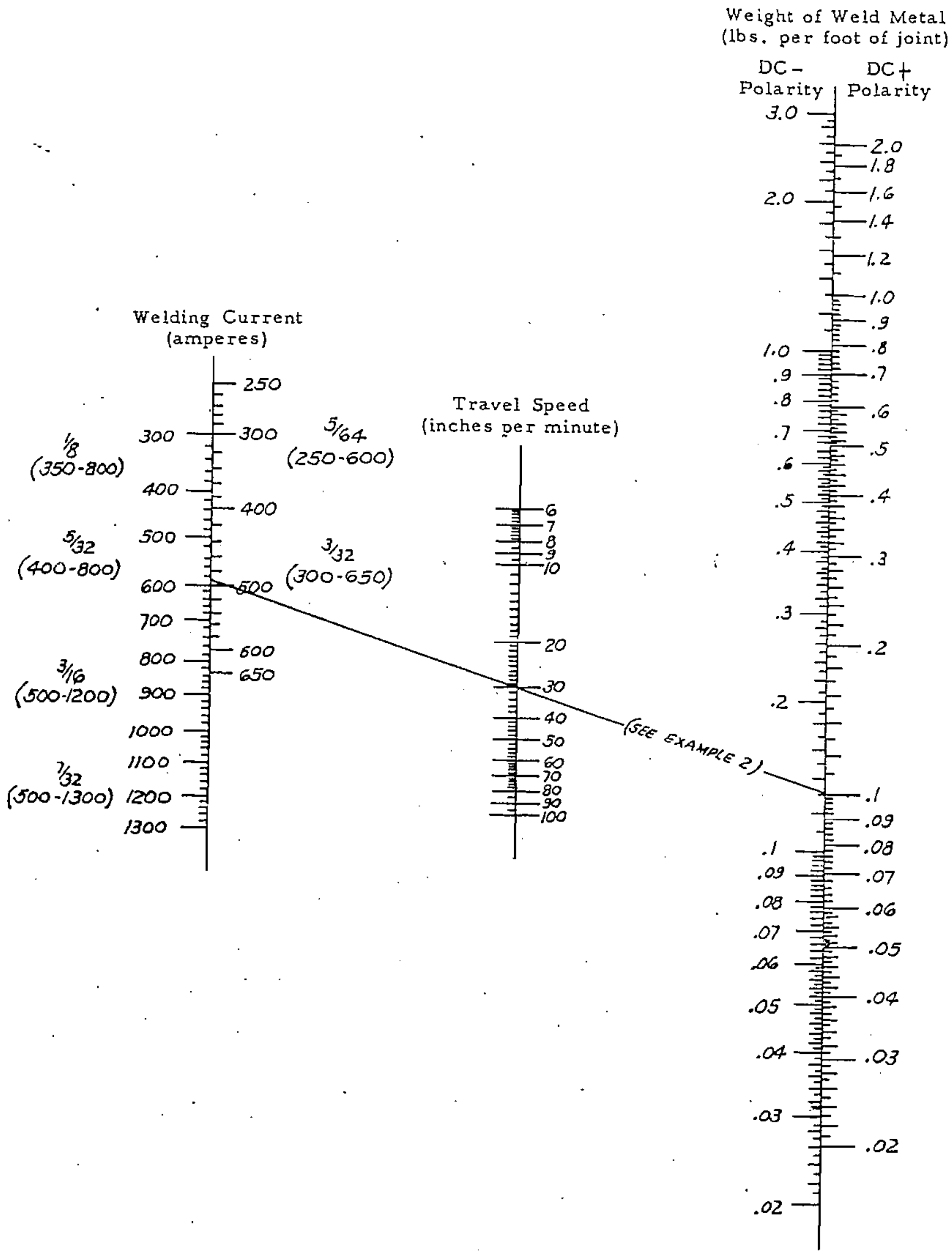
Plate thickness ↓						
1	1.81	2.24	1.82		1.54	
1 1/8	2.17	2.61	2.17		1.89	
1 1/4	2.61	2.99	2.52		2.27	
1 3/8	3.09	3.37	2.88		2.65	
1 1/2	3.57	3.76	3.27		3.07	
1 5/8	4.12	4.18	3.65		3.50	
1 3/4	4.67	4.59	4.05		3.94	
2	5.93	5.44	4.87		4.91	
2 1/8	6.58	5.88	5.28		5.40	
2 1/4	7.32	6.34	5.72		5.94	
2 3/8	8.05	6.80	6.16		6.50	
2 1/2	8.87	7.28	6.63		7.06	
2 5/8	9.67	7.76	7.10		7.65	
2 3/4	10.5	8.26	7.57		8.25	
3	12.4	9.27	8.55		9.54	
3 1/8	13.3	9.80	8.90		10.2	10.2
3 1/4	14.5	10.3	9.40		10.8	10.8
3 1/2	16.5	11.2	10.6		12.3	12.1
3 3/4	18.8	12.5	11.6		13.8	13.3
4	21.2	13.7	12.9		15.4	14.7
4 1/2	26.4	16.2	15.2		18.9	17.2
5	32.3	18.8	17.8		22.6	19.8
5 1/2	38.7	21.6	20.5	20.4	26.7	22.3
6	45.7	24.6	23.4	23.0	31.0	25.0
6 1/2	53.3	27.8	26.4	25.4	35.6	27.0
7	61.4	30.4	29.6	28.1	40.5	30.1
7 1/2	70.0	34.3	32.9	30.6	46.0	32.8
8	79.5	37.9	36.4	33.3	51.7	35.3
9	99.9	45.5	43.9	38.4	63.9	40.4
10	122.6	53.8	52.0	43.5	77.4	45.6

FIG. 1—Weight of Weld Metal
(lbs/ft of Joint)
Based on Procedures, Using Submerged-Arc Process



Problem 1

Computing the Weight of Weld Metal Based on Joint Design

With Table 2, computations based on joint design are easy. Essentially, it is a matter of dividing the cross-section of the area to be filled with weld metal, into standard geometric areas. The contributions of the individual areas can be found in the chart. Totaling these, gives the pounds of weld metal per foot required by the joint. For example, consider the following joint design (Fig. 2):

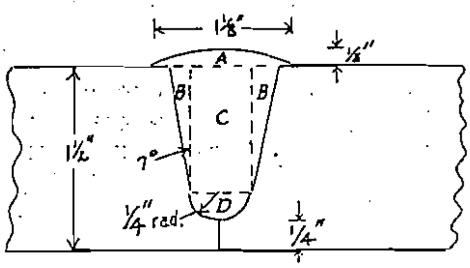
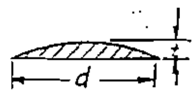


FIGURE 2

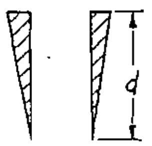
This joint can be broken into component areas A, B, C and D. Referring to Table 2, the contribution of each of these component areas to the total weight of weld metal required by the joint is simply picked off the chart as follows (Fig. 3):

(A)



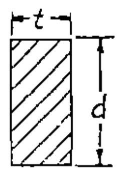
Since t = ⅛" and d = 1⅛" read from Table 2:
.318 lbs/ft

(B)



Since included angle is 14° and d = 1" read from Table 2:
.417 lbs/ft

(C)



Since t = ½" and d = 1" read from Table 2:
1.7 lbs/ft

(D)

Since r = ¼" read from Table 2:
.334 lbs/ft

FIGURE 3

Adding these, the total weight becomes 2.77 lbs of weld metal per foot of joint.

Problem 2

Computing the Weight of Weld Metal Based on Welding Procedures

When the welding procedures for a particular job are known, it is a simple matter to determine the weight of weld metal that will be deposited per foot of joint through the use of the nomograph for submerged arc welding Figure 1. Simply line up a straight-edge through the point on the left scale that represents the welding current being used and the point on the middle scale that represents the travel speed being used. Where the straight-edge intersects the right scale, read the amount of weld metal per foot of joint.

There is one note of caution. Be sure to use the proper side of the *Welding Current* scale, depending on the size of electrode used, and the correct side of the *Weight of Weld Metal* scale, depending on the polarity used.

As an example, the line drawn on the nomograph represents the procedure which uses 590 amps on ⅛" electrode at a travel speed of 30 in./min. The resultant weight of weld metal is .10 lbs per foot of joint if DC positive polarity is used, or .13 lbs if DC negative polarity is used.

Problem 3

Adjusting Procedures to Provide the Required Amount of Weld Metal

For some types of joints, there are no established welding procedures. When such is the case, the normal method is to find an established procedure for a similar joint and alter it slightly to accommodate the desired joint. The nomograph for submerged-arc welding, Figure 1, can eliminate a lot of hit-and-miss approaches to the selection of the proper procedure.

For example, consider the following submerged-arc automatic joint (Fig. 4):

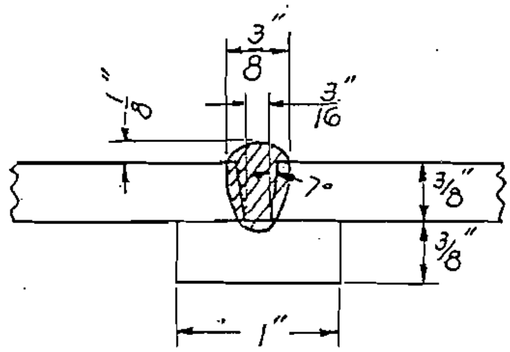


FIGURE 4

There are no established procedures for this joint. Probably the closest is that for the following joint (Fig. 5):

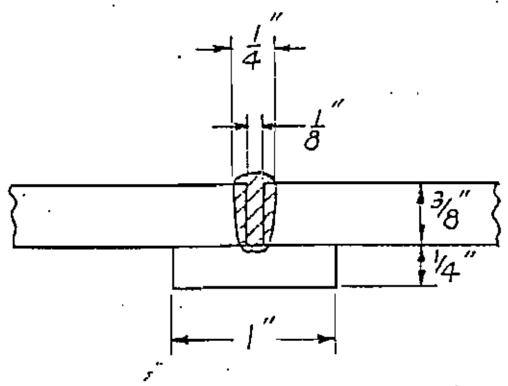


FIGURE 5

Power:	DC+
Amperes:	670
Volts:	29
Electrode Size:	5/32"
Travel Speed:	16"/min.

In adjusting this procedure to the new joint, it is reasonable to assume that the 670 amps would be about right and, therefore, the simplest thing to do would be to slow down the welding speed enough to provide the amount of fill required. To do this, first determine the amount of weld metal required to fill the new joint in the manner outlined in Problem 1. In this case, it is determined to be .404 lbs/ft of joint.

Then, use the nomograph to determine the proper speed setting as follows.

Locate 670 amps on the left-hand side of the welding scale (for 5/32" electrode) and .404 lbs/ft on the DC+ polarity side of the weld metal scale. Draw a straight line between them. This intersects the travel speed line at 9"/min, which is an estimate of the speed which should be used to provide adequate fill in the joint. With this much of the procedure fixed, it is a simple matter to adjust the voltage to provide the desired bead shape.

* * * *

3. OPERATING FACTOR

The selection of a proper operating factor (OF) is difficult, and yet affects the final cost more than any other single item. Even though some difficulty is encountered in obtaining this value, it is necessary to establish an approximately true value rather than to simply ignore it or assume it to be 100%. Consider the following:

METHOD A	METHOD B
¼" electrode A @ 20¢/lb	¼" electrode B @ 14¢/lb
uses ¼ # rod/ft of weld	uses ¼ # rod/ft of weld
speed is 18 in./min	speed is 16 in./min
labor & overhead, $6.00/hr	labor & overhead, $6.00/hr
Total cost of welding using 100% operating factor: 11.7 ¢/ft	Total cost of welding using 100% operating factor: 10.9 ¢/ft

This indicates that, with 100% operating factor, electrode B would have the least cost, and would save 6.6%.

Total cost of welding using 30% operating factor 27.2 ¢/ft	Total cost of welding using 30% operating factor 28.4 ¢/ft

This indicates that, with 30% operating factor, electrode A would have the least cost and would save 4.1%.

In other words, the operating factor does affect the welding cost sufficiently to be considered.

Since one might question the practice of assuming the same operating factor for various electrodes and procedures, consider the following example.

A welding engineer is interested in replacing his present E-6012 electrode on a certain job with the iron powder E-6024 electrode. The following is his cost study:

E-6012 ELECTRODE	E-6024 ELECTRODE
5/16" leg fillet .30# rod/ft	5/16" leg fillet .30# rod/ft
5/16" E-6012 rod @ 375 amps AC	5/16" E-6024 rod @ 375 amps AC
melt-off rate M = 7¾ in./min	melt-off rate M = 10.2 in./min
speed S = 9 in./min	speed S = 13 in./min
length rod melted L_m = 16"	length rod melted L_m = 16"
time T = 2.06 min/rod	time T = 1.57 min/rod

Assume a 50% operating factor (OF)
and \$6.00/hr labor and overhead (L)

labor cost	labor cost
$\frac{20L}{S\,(OF)} = \frac{(20)(6)}{(9)(50\%)} = 26.7$ ¢/ft	$\frac{20\,L}{S\,(OF)} = \frac{(20)(6)}{(13)(50\%)} = 18.5$ ¢/ft

or a saving in labor of 30.7% by using the iron powder electrode E-6024.

But this analysis reveals the following: The arc time for the E-6012 electrode per rod is 2.06 minutes; using a 50% operating factor, this represents a downtime of 2.06 minutes per rod. This downtime between electrodes includes time to lift up the helmet, clean the slag off the weld, insert a new electrode into the holder, etc. On the same basis the arc time for the E-6024 electrode would be 1.57 minutes per rod; and using the same operating factor of 50%, this means a downtime of only 1.57 minutes per rod.

It might appear at first that simply substituting the E-6024 electrode into the holder would decrease the downtime; i.e. the operator can lift up his helmet faster, knock off the slag faster, pick up and insert the next electrode faster, etc. Of course this is not true.

A more accurate method would be to use a fixed downtime, adjusting the operating factor accordingly. Re-examine this cost study, using an average downtime between electrodes of 2.06 minutes:

E-6012 ELECTRODE	E-6024 ELECTRODE
operating factor = 50%	operating factor $= \frac{1.57}{(1.57) + (2.06)} = 43.5\%$
labor cost	labor cost
$\frac{20\,L}{S\,(OF)} = \frac{(20)(6)}{(9)(50\%)} = 26.7$ ¢/ft	$\frac{20\,L}{S\,(OF)} = \frac{(20)(6)}{(13)(43.5\%)} = 21.2$ ¢/ft

or a saving in labor cost of 21% by using the E-6024 electrode.

Assume $E = \frac{\text{lbs rod melted}}{\text{lbs rod consumed}} = 90\%$

rod cost	rod cost
$\frac{1200\,M\,W}{N\,L_m\,S\,E_3} = \frac{(1200)(7\ 3/4)(14.9)}{(219)(16)(9)(90\%)} = 4.9$ ¢/ft	$\frac{1200\,M\,W}{N\,L_m\,S\,E_3} = \frac{(1200)(10.2)(16.9)}{(218)(16)(13)(90\%)} = 5.1$ ¢/ft
Total 26.7 + 4.9 = 31.6 ¢/ft	Total 21.2 + 5.1 = 26.3 ¢/ft

or a total saving in labor and rod cost of 16.8% by using the E-6024 electrode.

Note that the decreased arc time with the E-6024 results in a slightly lower operating factor, 43.5% instead of 50%, although the joint does cost less.

One might further suggest using a downtime per electrode and a handling time per foot of weld. These figures, if available, would give a more true picture of the welding cost, but it would mean making a time study of the job, which we are trying to avoid.

The nomograph, Figure 6, may be used to quickly read the labor and overhead cost per foot of weld.

4. COST PER HOUR

As a matter of interest, consider the cost per hour for these two procedures:

E-6012 ELECTRODE	E-6024 ELECTRODE
<u>rod consumed per hr</u>	<u>rod consumed per hr</u>
$\frac{6000\,M\,(OF)}{N\,L_m\,E_3} = \frac{(6000)(7\ 3/4)(50\%)}{(219)(16)(90\%)}$	$\frac{6000\,M\,(OF)}{N\,L_m\,E_3} = \frac{(6000)(10.2)(43.5\%)}{(218(16)(90\%)}$
= 7.37 lbs/hr	= 8.49 lbs/hr
<u>rod cost</u>	<u>rod cost</u>
7.37 x 14.9 ¢/lb = $1.10/hr	8.49 x 16.9 ¢/lb = $1.44/hr
<u>labor cost</u> = 6.00	<u>labor cost</u> = 6.00
Total = $7.10/hr	Total = $7.44/hr

It can be expected then that the cost per hour for making the same size weld will increase slightly with faster procedures. Obviously the increase equals the difference in cost of electrode consumed. Of course the number of units turned out per hour is greater, so the unit cost is less.

5. ESTIMATING ACTUAL WELDING TIME

After the length and size of the various welds have been determined, there are three ways to estimate the actual welding time:

1. Convert these values into weight of weld metal per linear foot, and total for the entire job. Determine the deposition rate from the given welding current, and from this find the arc time. This method is especially useful when there is no standard welding data for the particular joint.

2. If standard welding data is available in tables, giving the arc travel speeds for various types and sizes of welds, in terms of inches per minute, apply this to the total lengths of each type and size of weld on the job.

3. Time the actual weld or job.

Most welding procedures are based on good welding conditions. These assume a weldable steel, clean smooth edge preparation, proper fit-up, proper position of plates for welding, sufficient accessibility so the welding operator can easily observe the weld and place the electrode in the proper position, and welds sufficiently long so the length of crater is not a factor in determining weld strength. Under these standard conditions, the weld should have acceptable appearance. Failure to provide these conditions requires a substantial reduction in welding current and immediately increases cost.

It is impossible to put a qualitative value on these factors, therefore the designer or engineer must learn to anticipate such problems and, by observation or consulting with shop personnel or other engineers who have actual welding experience, modify his estimate accordingly.

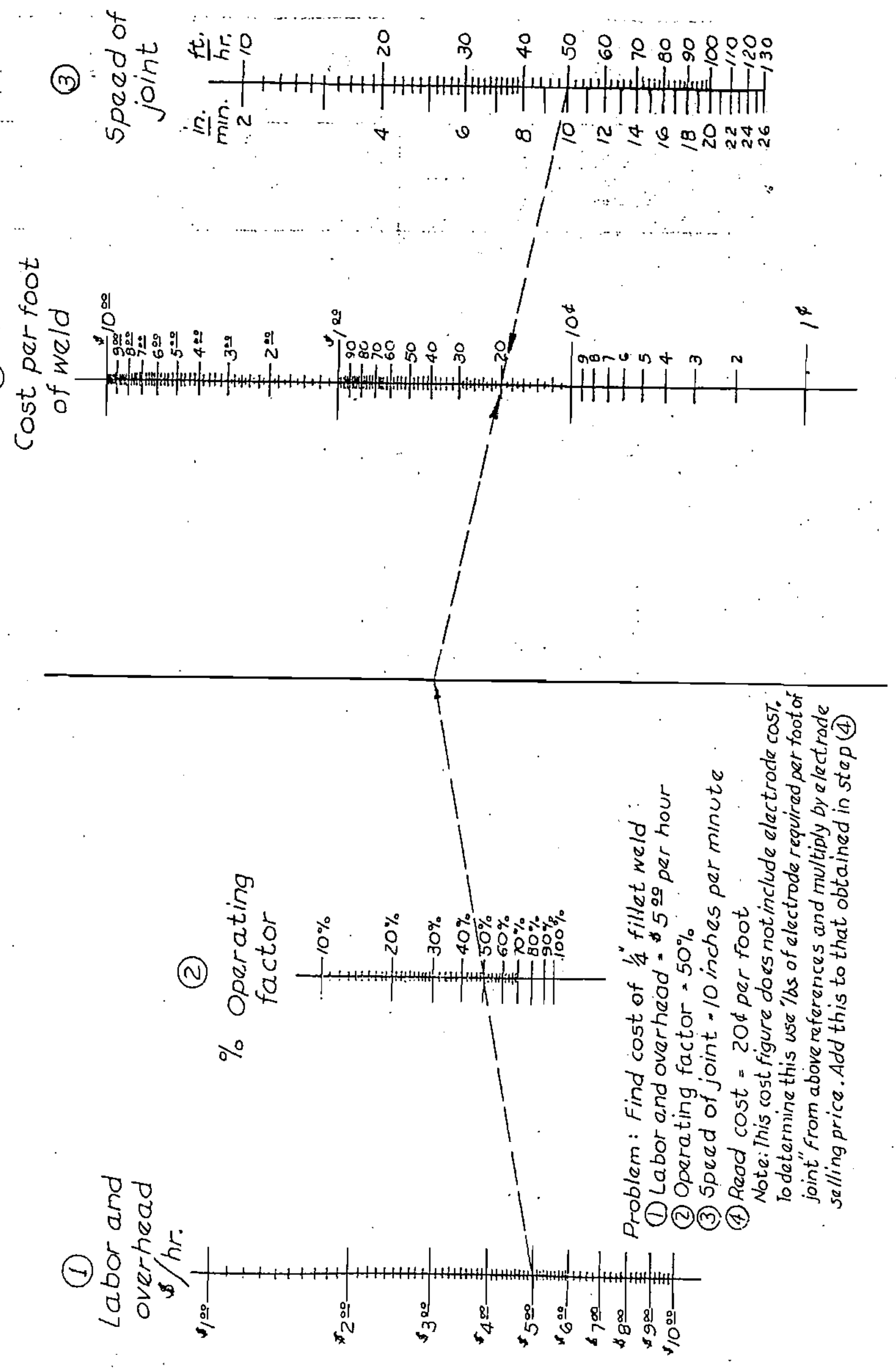
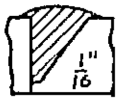
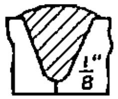
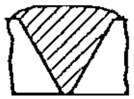
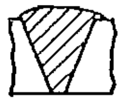
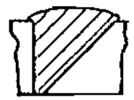
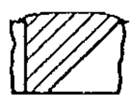
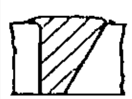


FIG. 6—Welding Cost Estimator
(Does Not Include Cost of Filler Metal)

TABLE 6—Weight of Weld Metal (lbs/ft of Joint)

Plate Thickness	Unlimited † Flat and Overhead 30°  1/16"	Unlimited † All Positions 45°  1/16"	Unlimited † Flat and Overhead 20°  1/8"	Unlimited † All Positions 45°  1/8"	Unlimited † Double V* / Max. 3/4" † Single V* 60°  1/8"	Unlimited † All Positions 45°  1/4"	Unlimited † Flat and Overhead 30°  3/8"	Unlimited † Flat and Overhead 20°  1/2"	Unlimited † Double Bevel* / Max. 3/4" † Single Bevel* 45°  1/8"	Unlimited † All Positions 45°  1/4"	Unlimited † Flat and Overhead 30°  3/8"
1/2"	.58	.65	.68	.67	.84	.89	.98	1.12	.74	1.00	1.01
3/4"	.90	1.40	1.27	1.35	1.70	1.60	1.60	1.80	1.52	1.87	1.65
1"	1.78	2.32	1.96	2.23	2.83	2.57	2.41	2.50	2.47	2.97	2.51
1 1/4"	2.40	3.65	2.60	3.32	4.27	3.67	3.35	3.30	3.70	4.35	3.45
1 1/2"	3.54	4.99	3.37	4.60	5.98	5.03	4.35	4.18	5.17	5.93	4.55
1 3/4"	4.65	6.70	4.20	6.06	7.93	6.55	5.55	5.17	6.87	7.80	5.80
2"	5.87	8.64	5.20	7.76	10.32	8.31	6.75	6.20	8.85	9.87	7.12
2 1/4"	7.20	10.80	6.23	9.35	12.90	10.23	8.15	7.32	11.10	12.20	8.60
2 1/2"	8.74	13.27	7.34	11.71	15.81	12.37	9.67	8.50	13.57	14.79	10.22
2 3/4"	10.40	15.90	8.60	14.00	19.00	14.70	11.37	9.85	16.30	17.75	12.00
3"	12.20	18.93	9.87	16.50	22.48	17.20	13.08	11.15	19.17	20.69	13.87

* All Positions
A.W.S. Highway and R.R. Bridge 1956—Prequalified Joints 9-5-57