PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

Fecha	Duración	Tema	Profesor
Junio 11	18 a 21 h	SIDERURGIA DEL ACERO	Ing. Rodolfo Hernández Sánchez
Junio 13, 15 y 18	18 a 21 h c/d.	NOCIONES DE METALURGIA	Ing. Oscar de Buen López de Heredía.
Junio 20	18 a 21 h	ACEROS ESTRUCTURALES	Ing. Rúal Granados Granados
Junio 22	18 a 21 h	PRINCIPALES MEDIOS DE UNION	Ing. José Luis Sánchez Martínez
Junio 25	18 a 21 h	SOLDADURAS : PROCEDIMIENTOS, SOLDADURA DEL ARCO ELECTRICO, TIPOS DE LECTRODO, ELECCION DEL MAS ADECUADO.	Ing. José Luis Sánchez Martínez
Junio 27	18 a 21 h	TRANSMISION DE INFORMACION: PLANOS Y ESPECIFICACIONES.	Ing. Rodolfo Hernández Sánchez
Junio 29 y Julio 2	18 a 21 h y 18 a 19:30 h	FABRICACION: HABILITADO DEL MATERIAL, ENDEREZADO, PUNZONADO, SOLDADURA, PINTURA.	Ing. Vicente Villaseñor Bianchi
Julio 2	19:30 a 21 h	TRANSPORTE Y COLOCACION EN OBRA	Ing. José Antonio Fernández Paz
Julio 4	18 a 21 h	MONTAJE	Ing. José Antonio Fernández Paz
Julio 6 y 9	18 a 21 h c/día	SUPERVISION Y CONTROL DE CALIDAD (ANTES, DURANTE Y DESPUES DE LA FABRICACION Y DURANTE EL MONTAJE).	Ing. Rául Granados Granados
Julio 11	18 a 21 h	ASPECTOS ECONOMICOS Y CONTRACTUALES	Ing. José Antonio Fernández Paz

DIRECTORIO DE PROFESORES DEL CURSO

PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO 1979.

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PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

ACEROS ESTRUCTURALES

ING. RAUL GRANADOS

JUNIO, 1979.

ACEROS ESTRUCTURALES

Las ventajas de las estructuras y construcciones de acero se derivan de las características del material.

Las propiedades mecánicas del acero dependen fundamentalmente de su composición química, proceso de laminación y tratamientos térmicos. También influyen en las propiedades del material, las técnicas empleadas en las pruebas, tales como la rapidez de carga en la muestra, la geometría, la temperatura y el estado de esfuerzos.

Algunas de las principales características de los aceros se derivan del ensaye de una probeta a tensión. Esta prueba se realiza en acero debido a la sencillez con que se puede reproducir.

Un diagrama típico esfuerzo-deformación para un acero estructural es el que se muestra en las figuras siguientes.

Las principales propiedades del acero se enumeran a continuación:

1).- Límite de fluencia (Fy). Se define como el esfuerzo para el cual la deformación presenta un gran incremento, sin que exista aumento en el esfuerzo. Esto corresponde en la gráfica a la porción horizontal de la misma, denominada zona de comportamiento plástico.

2).- Resistencia de fluencia. Algunos aceros no muestran la zona de comportamiento plástico, característica de los aceros estructurales, es decir no tienen límite de fluencia bien definido. Por lo tanto en este caso es necesario definir esta característica en forma convencional, según se muestra en la figura siguiente, obteniéndose un punto de la curva esfuerzo-deformación, denominado resistencia de fluencia.

3).- Resistencia a la tensión. Se define como la relación entre la tensión axial máxima aplicada sobre la probeta, y el área de la sección transversal original.

4).- Límite de proporcionalidad. Es el máximo esfuerzo para el que existe una relación lineal entre esfuerzos y deformaciones.

5).- Ductilidad. Es la habilidad del material para alargarse sin rotura. Generalmente se expresa en porcentaje y va acompañada de una reducción en la sección transversal de la probeta.

6).- Módulo de elasticidad. Se define como la relación entre esfuerzos y deformaciones en la zona elástica, es decir, es la pendiente de la porción recta de la gráfica y su valor para todos los aceros se considera igual a 2×10^6 Kg/cm^2.

7).- Módulo tangente. Es la pendiente de la tangente a la curva esfuerzo - deformación, en cualquier punto situado arriba del límite de proporcionalidad.

8).- Módulo de endurecimiento por deformación. La pendiente de la tangente a la curva en la zona de endurecimiento se denomina módulo de endurecimiento por deformación y su valor máximo se tiene en el inicio de esa zona y se considera igual a 49000 Kg/cm^2.

9).- Relación de Poisson. Se define como la relación entre la deformación unitaria transversal y la deformación unitaria longitudinal. Para el acero varía entre 0.25 y 0.33 dentro del rango elástico y se designa con μ.

10).- Módulo de elasticidad en cortante. Se define como la relación del esfuerzo cortante a la deformación unitaria por cortante en el rango elástico y puede determinarse con la expresión $G = \frac{E}{2(1+\mu)}$ y para el acero tiene un valor aproximado de 800000 Kg/cm^2.

11).- Soldabilidad. Es la capacidad del acero para aceptar los procesos de soldadura sin afectar a las propiedades mecánicas. Varía para los -

aceros en función de su composición química y el proceso de soldadura.

12).- Maquinabilidad. Es la facilidad que presentan ciertos acéros para ser sometidos a procesos de roscado sin afectar sus propiedades.

13).- Formabilidad. Es la propiedad que exhiben ciertos aceros para doblarse sin agrietamientos.

14).- Resistencia a la corrosión y durabilidad. Con la adición de ciertos elementos a la composición química, se puede aumentar su resistencia a la corrosión y por lo tanto su durabilidad.

15).- Resistencia a la fatiga. Es la habilidad del acero para soportar aplicaciónes repetidas de carga o esfuerzo.

16).- Resistencia al impacto. Es la capacidad del material para soportar aplicaciones súbitas de carga.

17).- Tenacidad. Es la capacidad del acero para absorber energía y se determina por medio del área bajo la curva esfuerzo - deformación. Por lo tanto depende tanto de la resistencia como de la ductilidad.

18).- Resistencia a la falla frágil. Bajo determinadas condiciones de esfuerzo, temperatura y presencia de muescas o grietas, el acero puede perder su característica de ductilidad. La resistencia a la falla frágil -

será pues la capacidad del material para conservar su ductilidad bajo esos efectos adversos.

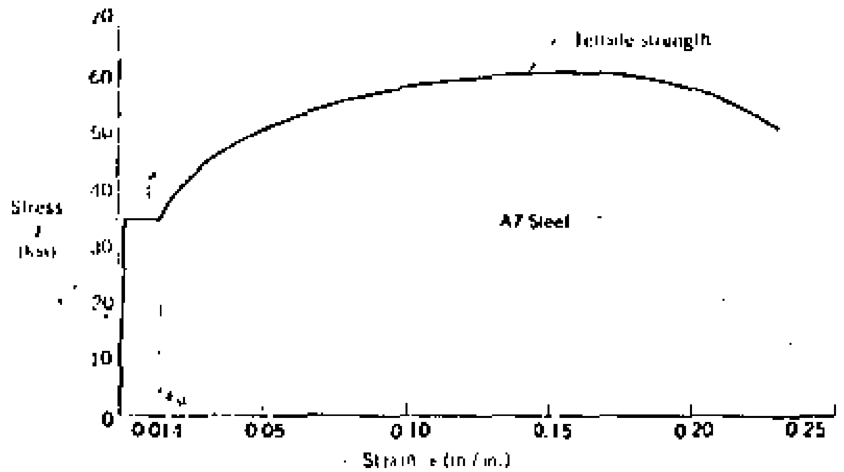


Fig. 2.1 Complete Tensile Stress-Strain Diagram for Structural Carbon Steel

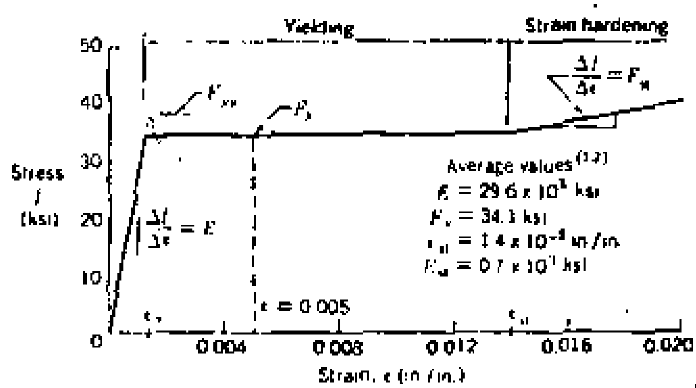


Fig. 2.2 Portion of Stress-Strain Diagram for A7 Steel

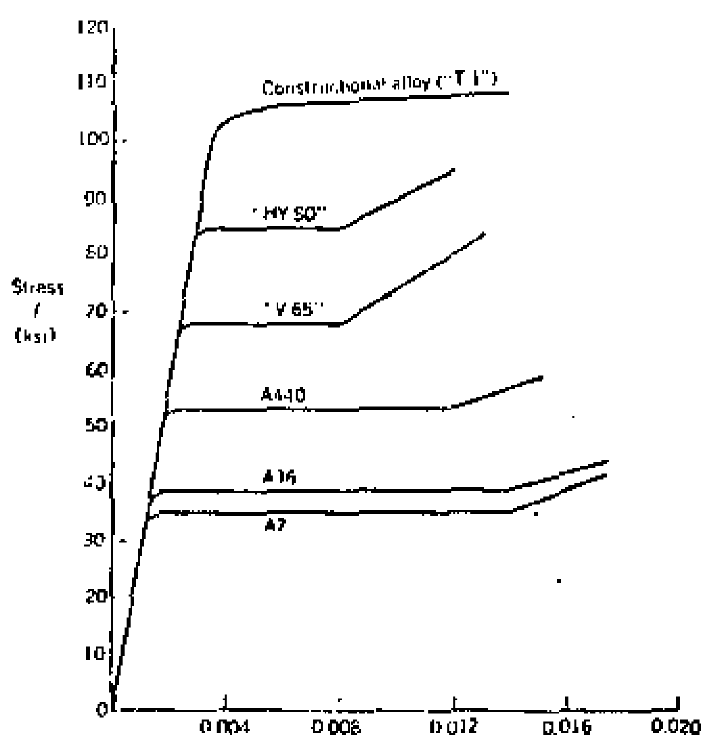
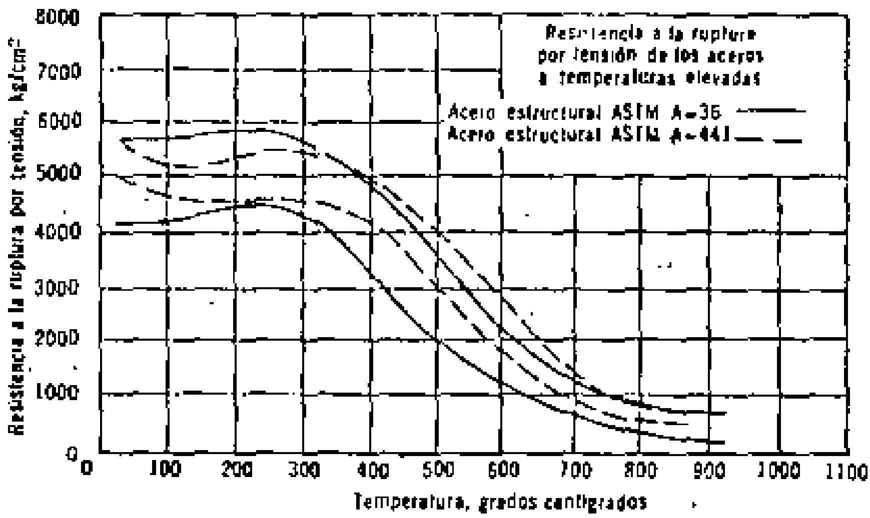


Fig. 2.12 Stress-Strain Curves for Various Steels



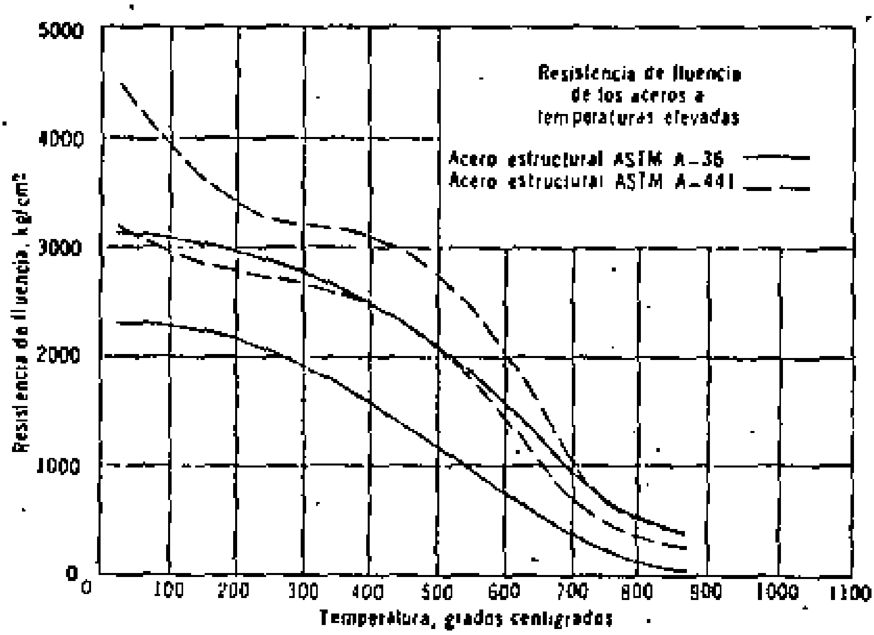


Fig. 2-1 Resistencia de tensión y de cedencia a temperaturas elevadas (Cortesía de la *Applied Research Laboratory, United States Steel Corp.*)

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Tabla 2-1 Propiedades mecánicas de los aceros estructurales al carbono

Tipo ASTM	Espesor, pulgs	Punto de fluencia mínimo Kg/cm²	Resistencia a la tensión Kg/cm²
A7		2320	4220-5275
A373	hasta 4	2250	4050-5275
A36	hasta 8	2530	4050-5625

Table 2.2 Chemical Requirements for Structural Carbon Plates[1,1]

Type	Thickness (in.)	C (max. %)	Mn (%)	Si (%)
A7	—	—	—	—
A36	¾ and under	.28	—	—
	Over ¾ to 1½	.28	.80-1.10	—
	Over 1½ to 4	.28	.80-1.10	.15-.30
A373	½ and under	.26	—	—
	Over ½ to 1	.25	.50-.90	—
	Over 1 to 2	.26	.50-.90	.15-.30
	Over 2 to 4	.27	.50-.90	.15-.30

Table 2-2 Propiedades mecánicas de los aceros de alta resistencia y baja aleación

Tipo ASTM	Espesor, pulgs	Punto de fluencia mín Kg/cm²	Resistencia a la tensión Kg/cm²
A242, A440	¾ y menores	3515	4920
y A441	¾ a 1½	3235	4710
	1½ a 4	2955	4430
A572-42	hasta 4	2955	4220
45	hasta 1½	3165	4220
50	hasta 1½	3515	4570
55	hasta 1½	3865	4920
60	hasta 1	4220	5275
65	hasta ½	4570	5625

Table 2.3 Chemical Requirements for High-Strength Steels[1,1]

Element	A440 (%)	A441 (%)	A242 (%)
Carbon	.28	.22	.22
Manganese	1.10-1.60	1.25	1.25
Phosphorus	.40	.04	—
Sulfur	.05	.05	.05
Silicon	.30	.30	—
Copper	.20	.20	—
Vanadium	—	.02	—

Tabla 2-3 Propiedades mecánicas de los aceros de aleación templados y revenidos

Tipo ASTM	Espesor, pulgs.	Punto de fluencia en mm Kg/cm²	Resistencia a la tensión Kg/cm²
A514	hasta ¾ incl.	7030	8085-9490
A514	más de ¾ a 2½ incl.	7030	8085-9490
A514	más de 2½ a 4 incl.	6330	7385-9400

Tabla 2-1 Propiedades mecánicas de los aceros estructurales de calibre delgado

Designación Comercial	Designación ASTM	Grado	Espesor plgs.	Punto de fluencia o Resistencia de fluencia mín Kg/cm²	Resistencia última Kg/cm²	Elongación mín en 2 plgs., por ciento
Láminas de acero al carbono de calidad estructural laminadas en plano	A245	A	0.0449	1 760	3 160	23-27
		B	hasta	2 110	3 450	21-25
		C	0.2299	2 320	3 660	18-23
		D		2 810	3 870	15-20
Tiras de acero al carbono de calidad estructural laminadas en caliente	A303	A	0.0255	1 760	3 160	19-27
		B	hasta	2 110	3 450	18-25
		C	0.2299	2 320	3 660	17-23.5
		D		2 810	3 870	15-21
Láminas y tiras de acero de alta resistencia y baja aleación, laminadas en frío	A374		0.2499 y menores	3 160	4 570	20-22
Láminas y tiras de acero de alta resistencia y baja aleación, laminadas en caliente	A375		0.0710 hasta 0.2299	3 520	4 920	22
Láminas de acero de calidad estructural recubiertas de cinc	A446	A	0.1756	2 320	3 370	20
		B		2 600	3 660	18
		C	y	2 810	3 870	16
		D		3 520	4 570	12
		E	menores	5 620	5 770	1.5

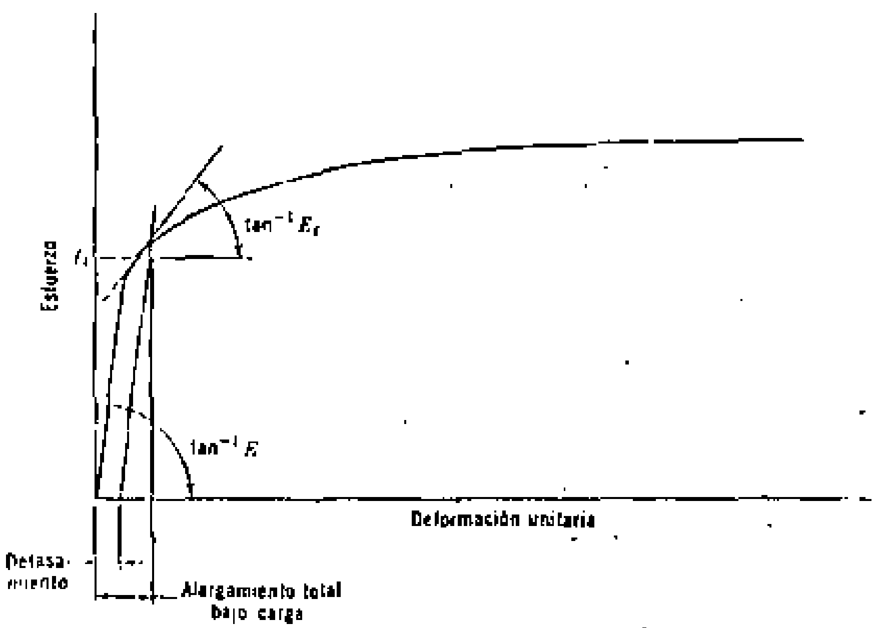

Fig. 2.5 Curva esfuerzo-deformación típica para láminas y tiras de acero.

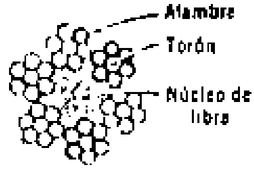

Fig. 2-7 Sección transversal de un cable de alambre.

Tabla 2-5 Alambre galvanizado para puentes: Resistencia de fluencia, resistencia a la tensión y elongación

Recubrimiento, Clase	*Diámetro plgs.*	*Resistencia mín. a la tensión, Kg/cm²*	*Resistencia mín. de fluencia a 0.7 % de extensión bajo carga*	*Elongación total mín en 10 plgs., por ciento*
A	0.041 y mayores	15 470	11 250	4.0
B	Todos los diámetros	14 770	10 550	4.0
C	Todos los diámetros	14 060	9 840	4.0

Tabla 2-6 Alambre galvanizado para puentes: Pesos mínimos de recubrimiento

Diámetro del alambre recubierto plgs	*Peso mínimo de recubrimiento en onzas por pie cuadrado de superficie de alambre sin recubrir* Clase A	B	C
De 0.041 a 0.061	0.40	0.80	1.20
Más de 0.061 a 0.079	0.50	1.00	1.50
Más de 0.079 a 0.092	0.60	1.20	1.80
Más de 0.092 a 0.103	0.70	1.40	2.10
Más de 0.103 a 0.119	0.80	1.60	2.40
Más de 0.119 a 0.142	0.85	1.70	2.55
Más de 0.142 a 0.187	0.90	1.80	2.70
Más de 0.187	1.00	2.00	3.00

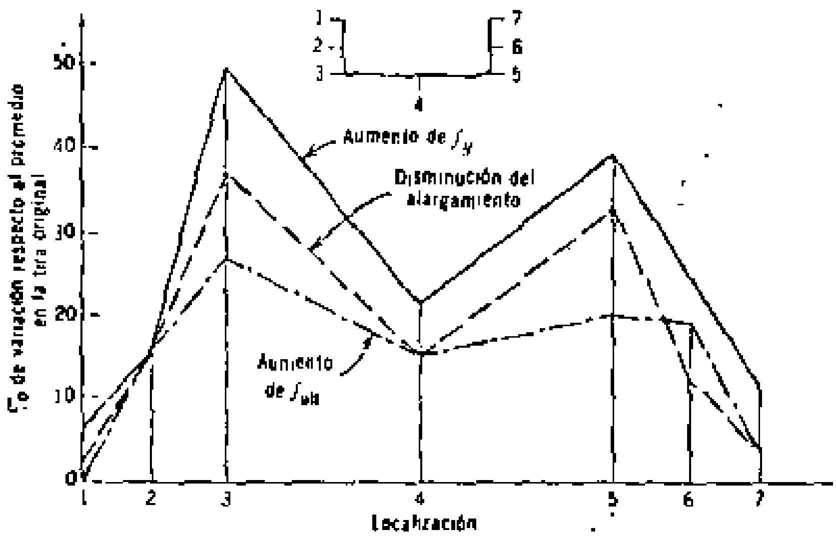

Fig. 2.6 Comparación de las propiedades mecánicas del material original y de la sección conformada, en siete localizaciones específicas indicadas.[4]

Tabla 2-7 Propiedades mecánicas de los torones para puentes recubiertos de zinc

Normas establecidas por la "Wire Rope Technical Board"

Diámetro nominal pulg.	*Resistencia mínima de ruptura en toneladas métricas* — Clase "A" recubrimiento completo	Clase "B" recubrimiento en los alambres interiores. Clase "A" recubrimiento en los alambres exteriores.	Clase "C" recubrimiento en los alambres interiores. Clase "A" recubrimiento en los alambres exteriores.	Área metálica aproximada en cm²	Peso aproximado en Kg./m
1/2	13.6	13.2	12.9	0.97	0.77
9/16	17.2	16.7	16.4	1.23	0.98
5/8	21.8	21.1	20.7	1.51	1.22
11/16	26.3	25.5	24.9	1.83	1.47
3/4	30.8	29.9	29.3	2.18	1.76
13/16	36.3	35.2	34.5	2.55	2.07
7/8	41.7	40.5	39.6	2.96	2.40
15/16	50.0	47.5	46.5	3.40	2.75
1	55.3	53.7	52.5	3.87	3.13
1 1/16	62.6	60.7	59.4	4.37	3.53
1 1/8	70.8	68.7	67.2	4.90	3.96
1 3/16	78.0	75.7	74.1	5.46	4.40
1 1/4	87.1	85.4	83.6	6.05	4.88
1 5/16	96.2	94.3	92.5	6.65	5.39
1 3/8	105.2	103.4	100.7	7.29	5.91
1 7/16	114.3	111.6	109.8	8.00	6.46
1 1/2	125.2	122.5	119.8	8.71	7.04
1 9/16	136.0	133.4	130.6	9.48	7.63
1 5/8	147.0	144.2	140.6	10.28	8.26
1 11/16	159.7	156.0	153.3	11.03	8.90
1 3/4	170.6	166.9	163.3	11.87	9.57
1 13/16	183.3	179.6	176.0	12.71	10.27
1 7/8	196.0	192.3	187.9	13.61	11.00
1 15/16	205.7	205.0	200.5	14.52	11.74
2	222.3	219.6	215.9	15.48	12.50
2 1/16	236.8	233.2	229.5	16.45	13.30
2 1/8	251.3	247.7	244.0	17.48	14.52
2 3/16	265.8	262.2	257.6	18.52	14.95
2 1/4	291.2	276.7	273.1	19.61	15.83
2 3/8	312.1	322.1	303.0	21.81	17.63
2 5/16	296.7	292.1	287.6	20.71	16.73
2 7/16	326.6	322.1	316.6	23.03	18.57
2 1/2	341.1	335.7	331.1	24.20	19.54
2 9/16	355.6	350.2	344.7	25.41	20.53
2 5/8	375.3	372.9	366.4	26.65	21.53
2 11/16	391.9	385.6	380.0	27.94	22.56
2 3/4	410.1	403.7	397.3	29.29	23.63
2 7/8	448.2	440.9	434.5	32.00	25.83
3	488.1	480.8	473.5	34.84	28.12
3 1/8	529.8	521.6	513.4	37.81	30.52

Tabla 2-8 Propiedades mecánicas de los cables recubiertos de zinc

Normas establecidas por la "Wire Rope Technical Board"

Diámetro nominal en pulgs	*Resistencia mínima de ruptura en toneladas métricas. Recubrimiento Clase A*	*Peso aproximado Kg./m.*	*Area metálica aproximada en cm²*
3/8	5.9	0.36	0.419
1/2	10.4	0.62	0.768
5/8	16.3	0.97	1.174
3/4	23.6	1.41	1.729
7/8	31.7	1.90	2.328
1	41.4	2.48	3.038
1 1/8	52.4	3.14	3.844
1 1/4	65.5	3.93	4.805
1 3/8	79.6	4.78	5.844
1 1/2	94.3	5.68	6.940
1 5/8	111.5	6.71	8.192
1 3/4	129.5	7.80	9.462
1 7/8	148.7	8.97	10.901
2	168.7	10.49	12.384
2 1/8	190.5	11.50	13.997
2 1/4	213.1	12.59	15.609
2 3/8	236.7	14.30	17.351
2 1/2	261.2	15.77	19.157
2 5/8	287.5	17.29	21.092
2 3/4	311.7	18.96	23.091
2 7/8	343.8	20.65	25.219
3	373.7	22.48	27.413
3 1/4	430.8	26.78	32.505
3 1/2	491.4	31.25	37.604
3 3/4	550.5	35.71	43.022
4	662.1	40.18	48.956

Tabla 2-9 Propiedades mecánicas de aceros de fundición

Tipo ASTM	*Elongación en 2 pulgs.*	*Punto mínimo de fluencia, Kg/cm²*	*Resistencia a la tensión, Kg./cm²*
A27 Grado 65-35	24	2460	4570
A148 Grado 80-50	22	3515	5625

Tabla 2-10 Propiedades mecánicas de los aceros de forja

Tipo ASTM	Clase	Espesor	Resistencia mín. de fluencia Kg/cm²	Resistencia a la tensión, Kg/cm²	Elongación mín. en 2 pulgs., %
A235	C1	Hasta 12 pulgs.	2320	4640	23
A235	F	Hasta 12 pulgs.	2810	5625	21
A235	G	Hasta 4 pulgs.	3865	6330	20
A237		Hasta 12 pulgs.	3515	5625	24

Tabla 2-11 Propiedades mecánicas de los aceros para remaches.

Tipo ASTM	Punto mínimo de fluencia, Kg/cm²	Resistencia a la tensión, Kg/cm²	Elongación mín. en 2 pulgs., %
A141	1970	3655 a 4360	24
A195	2670	4750 a 5765	20
A502 Grado 1	1970	3655 a 4360	24
A502 Grado 2	2670	4750 a 5765	20

Tabla 2-12 Propiedades mecánicas del metal de aportación

Tipo	Valores mínimos		
	Punto de fluencia, Kg/cm²	Resistencia a la tensión, Kg/cm²	Elongación en 2 pulgs., %
Series E-60	3515 y 3870	4360 y 4710	17,22,25
Series E-70	4220	5060	17,22
SAW 1	3165	4360 a 5625	25
SAW 2	3515	4920 a 6330	22

Table 18.2 Properties of Structural Bolts*

ASTM Designation	Type Name	Bolt Diameter (in.)	tensile strength / stress area† (ksi)	proof load / stress area† (ksi)
A307-61T	Low carbon steel external and internal threaded standard fastener	All	55	None
A325-61T	High-strength steel bolts for structural steel joints	½–¾	120	85
		⅞, 1	115	78
		1⅛–1½	105	74
A490-63	High-strength alloy steel bolts for structural steel joints	½–4	150‡	120‡

* Tensile test of full-size bolts.

† Stress area $= 0.785\left(D - \frac{0.9743}{n}\right)^2$ where D = nominal bolt size, and n = threads per inch.

‡ Same as A354-BD bolts.

DATOS DE CABLE ESTRUCTURAL

Diámetro Nominal	Diámetro Real Plg.	Diámetro Real m.m.	Construcción	Area de Acero Plg.^{2}	Area de Acero m.m.^{2}	Resistencia Real (min.) Kgs.	Pes... L... K...
5/16"	0.324"	0.823	6/1	6.28×10^{-2}	40.49	6 030	
3/8"	0.382"	0.970	6/1	8.72×10^{-2}	56.24	8 370	
1/2"	0.506"	1.285	6/1	15.01×10^{-2}	96.81	14 030	
5/8"	0.632"	1.605	12/6/1	23.42×10^{-2}	151.00	21 890	1...
3/4"	0.748"	1.900	12/6/1	32.74×10^{-2}	211.17	29 600	1...
7/8"	0.882"	2.240	12/6/1	45.65×10^{-2}	294.44	41 280	2...
1"	1.002"	2.545	18/12/6/1	58.65×10^{-2}	378.29	53 040	3...
1/8"	1.134"	2.880	18/12/6/1	75.07×10^{-2}	484.3	76 000	4...
1/4"	1.282"	3.256	18/12/6/1	82.70×10^{-2}	533.4	92 000	4...
3/8"	1.390"	3.530	18/12/6/1	91.03×10^{-2}	587.2	103 000	5...
1/2"							

MODULO DE ELASTICIDAD MINIMO GARANTIZADO:

Para cables hasta 25.4 m.m. (1 inch.) 1.700.000 Kg/cm^2

Para cables mayores de 25.4 m.m. 1.600.000 Kg/cm^2

CABLE ESPECIALMENTE GALVANIZADO; PREESTIRADO A 60% DE LA CAR...
DE RUPTURA.

RANGO ELASTICO COMPRENDIDO ENTRE 5% Y 55% DE LA CARGA DE RUPTURA.

Norma Definitiva

NORMA DE CALIDAD

ACERO ESTRUCTURAL PARA PUENTES Y EDIFICIOS (A-7)
B-38-1969.
(Esta Norma cancela la DGN-B-38-1966).

I. GENERALIDADES Y DEFINICIONES

1.1. Generalidades

1.1.1. Alcance.

1.1.1.1. Esta Norma cubre perfiles, placas y barras de acero al carbono, de calidad estructural, para uso en la construcción de puentes, edificios y propósitos estructurales generales.

1.1.2. Datos para el pedido.

1.1.2.1. Las órdenes de material bajo esta Norma, deberán incluir los siguientes datos para describir el material adecuadamente:

a) Número de esta Norma.

b) Nombre del material.

c) Dimensiones de la sección transversal.

d) Longitud en metros.

e) Cantidad (kilogramos).

f) Excepciones a esta Norma.

g) Certificado de calidad o pruebas (si se requiere).

2.

1.2. Definiciones

1.2.1. Para definiciones pertinentes a esta Norma, véase la Norma Oficial DGN-B-252 en vigor.

2. CLASIFICACION Y ESPECIFICACIONES

2.1. Clasificación

2.1.1. El material suministrado bajo esta Norma no requiere clasificación, ya que la misma cubre una sola calidad.

2.2. Especificaciones

2.2.1. Requisitos generales.

2.2.1.1. El material suministrado bajo esta Norma, deberá cumplir con los requisitos especificados en la Norma Oficial DGN-B-252 en vigor.

2.2.2. Material.

2.2.2.1. Con excepción de lo que se especifica en 2.2.2.2, el acero deberá obtenerse por uno o más de los siguientes procesos: hogar abierto, básico al oxígeno u horno eléctrico.

2.2.2.2. A menos que se especifique otra cosa, el acero Bessemer ácido podrá emplearse para la fabricación de placas y perfiles con espesor de 11.10 mm y menores, y barras que no vayan a emplearse para fabricar remaches y con un diámetro o espesor de 11.10 mm o menores. Todo este material deberá usarse únicamente para partes de estructuras que no estén sujetas a cargas dinámicas. El acero Bessemer ácido no debe usarse en puentes.

2.2.3. Requisitos químicos.

2.2.3.1. El material suministrado bajo esta Norma, deberá cumplir los requisitos químicos especificados en la Tabla I.

T A B L A I.

REQUISITOS QUIMICOS

	Análisis de cuchara	Análisis de comprobación
Fósforo máximo %		
Hogar abierto, básico al oxígeno u horno eléctrico:		
Acido	0.06	0.075
Básico	0.04	0.05
Bessemer Acido	0.11	0.138
Azufre máximo %		
Hogar abierto, básico al oxígeno u horno eléctrico:	0.05	0.063
Cobre cuando se especifique, mínimo %	0.20	0.18

2.2.3.2. No se requieren análisis de comprobación en barras perfil, soleras de 12.70 mm y menores en espesor y para cualesquiera barra ordenada como de calida comercial.

Cuando las pruebas de tensión no se especifican de acuerdo con 2.2.4.4.2. deber aplicarse los requisitos de composición química que sean compatibles con las pr piedades mecánicas deseadas.

2.2.4. Requisitos mecánicos.

2.2.4.1. A menos que se especifique otra cosa, las piezas que se usen como apo para puentes, deberán sujetarse a pruebas mecánicas y cumplir con los requisito de tensión indicados en 2.2.4.4.

2.2.4.2. A menos que se especifique otra cosa, no se requerirán pruebas mecáni en placas mayores de 38.10 mm de espesor que vayan a ser usadas como placas de yo en estructuras que no sean puentes y deberán sujetarse al requisito de que e acero para la fabricación de estos materiales deberá obtenerse por los procesos horno de hogar abierto, básico al oxígeno u horno eléctrico, con un contenido c carbono de 0.20 a 0.33 % en análisis de cuchara, y la composición química estar de acuerdo con los requisitos indicados en 2.2.3.1, y deberá hacerse un descart suficiente de cada lingote para asegurar que las placas estén libres de defecto perjudiciales.

2.2.4.3. A menos que se especifique otra cosa, las barras lisas y con rosca us das para anclaje, se sujetarán a pruebas mecánicas y deberán cumplir con los re sitos de tensión indicados en 2.2.4.4; los pernos con cabeza usados para propós tos de anclaje y todas las tuercas, cumplirán con los requisitos de la Norma Of cial DGN-B-377 en vigor para el grado 1.

2.2.4.4. Propiedades a la tensión.

2.2.4.4.1. El material representado por los especímenes de prueba, exceptuando especificado en 2.2.4.2, debe cumplir los requisitos de tensión especificados e la Tabla II.

T A B L A II.

REQUISITOS DE TENSION

	Placas perfiles y barra
Resistencia a la tensión en kg/mm²	
Para perfiles en todos los espesores	42 a 53
Para placas y barras con espesor hasta de 38.10 mm inclusive.	42 a 50
Para placas y barras con espesor mayor de 38.10 mm.	42 a 53
Límite aparente de fluencia mínimo en kg/mm²	23
Alargamiento en espécimen de 203.20 mm de longitud calibrada, mínimo %	21
Alargamiento en espécimen de 50.80 mm de longitud calibrada, mínimo %	24

2.2.4.4.2. Los perfiles menores de 6.45 cm^2 de sección transversal; barras q
no sean soleras menores de 12.70 mm de espesor o diámetro, no necesitan sujet
se a pruebas de tensión por el fabricante.

2.2.4.4.3. Para materiales menores de 7.94 mm en espesor o diámetro, se pod
hacer una deducción de 1.25 % del porcentaje de alargamiento en especímenes d
longitud calibrada de 203.20 mm especificado en la Tabla II, por cada disminu
de 0.79 mm del espesor o diámetro especificado abajo de 7.94 mm.

2.2.4.4.4. Para materiales con espesor o diámetro mayor de 19.05 mm se deber
hacer una deducción de 0.50 % del porcentaje de alargamiento en especímenes d
longitud calibrada de 203.20 mm, especificado en la Tabla II por cada aumento
3.18 mm en el espesor o diámetro especificado arriba de 19.05 mm. Esta deducc
no deberá exceder del 3 %.

2.2.4.4.5. Para material con espesor o diámetro mayor de 88.90 mm, se deberá h
una deducción de 0.50 % en el porcentaje de alargamiento en especímenes de lo
tud calibrada de 50.80 mm especificado en la Tabla II, por cada aumento de 12
mm en el espesor o diámetro especificado arriba de 88.90 mm. Esta deducción n
berá exceder del 3 %.

2.2.4.5. Propiedades de doblado.

2.2.4.5.1. El espécimen de la prueba de doblado deberá sujetarse a un doblez
180° sin agrietarse la parte exterior de la porción doblada sobre un mandril,
yo diámetro debe tener una relación con el espesor del espécimen de acuerdo c
la Tabla III.

TABLA III.

REQUISITOS DE LA PRUEBA DE DOBLADO.

Espesor del material, en mm	Relación del diámetro d mandril al espesor del pécimen, para placas, p files y barras.
Hasta 19.05	0.5
Más de 19.05 a 25.40, inclusive.	1
Más de 25.40 a 38.10, inclusive.	1.5
Más de 38.10 a 50.80, inclusive.	2.5
Más de 50.80	3

2.2.5. Muestreo.

2.2.5.1. Número de pruebas.

2.2.5.1.1. Químicas.

2.2.5.1.1.1. Para acero Bessemer se hará una determinación de carbono y mang
de cada soplada y una determinación de cobre cuando se especifique acero al c

se harán también determinaciones de fósforo y azufre a intervalos no mayores de 10 sopladas, debiéndose reportar los resultados de las determinaciones efectuadas.

2.2.5.1.2. Pruebas físicas.

2.2.5.1.2.1. Se harán dos pruebas de tensión y dos de doblado de cada colada o soplada en el caso de Bessemer, a menos que el material terminado de una colada o soplada sea menor de 30 toneladas, en cuyo caso será suficiente una prueba de tensión y una de doblado; de cualquier manera, si los materiales laminados hasta de 50.80 mm en espesor, provenientes de una sola colada o soplada difieren en su espesor en más de 9.50 mm, se debe efectuar una prueba de tensión y una de doblado del material más grueso y del más delgado que se lamine sin importar el peso que represente.

2.2.5.1.2.2. Para el material mayor de 50.80 mm de espesor, de una sola colada o soplada y que difiere en 25.40 o más en espesor, se hará una prueba de tensión y una de doblado del material más grueso y del más delgado que se lamine, sin importar el peso que represente.

3. MÉTODOS DE PRUEBA

3.1. Para verificar que el material suministrado cumple con esta Norma, deben seguirse los métodos de prueba indicados en las Normas Oficiales DGN-K-179 y DGN-B-172 en vigor.

4. APENDICE

4.1. Antecedentes

ASTM - A - 7 - 66.

4.2. Normas DGN a consultar

DGN-B-252-1966.	Norma Oficial de "Requisitos generales para la entrega de placas laminadas, perfiles, tablaestacas y barras para uso estructural."
DGN-B-172-1968.	Norma Oficial de "Métodos de prueba mecánicos para productos de acero".
DGN-K-179-1968.	Norma Oficial de "Método de análisis químico para determinar la composición de aceros y fundiciones".
DGN-B-377-1968.	Norma Oficial de "Requisitos generales de calidad para tornillos".

COMITE CONSULTIVO NACIONAL DE NORMALIZACION DE LA INDUSTRIA SIDERURGICA.

ACERO ESTRUCTURAL

B 254 1973

1. GENERALIDADES.

1.1. ALCANCE

Esta Norma establece los requisitos que deben cumplir los perfiles, placas y barras, de acero al carbono, de calidad estructural.

1.2. USOS

1.2.1. Los perfiles, placas y barras a que se refiere esta Norma se usan en construcciones remachadas, atornilladas o soldadas, de puentes y edificios y para propósitos estructurales en general. Cuando el acero se use en construcciones soldadas, el procedimiento de soldadura debe ser el adecuado para el acero y el servicio requerido.

1.2.2. Se deben especificar requisitos suplementarios cuando se considere importante una alta tenacidad (resistencia al impacto). Esto se debe aplicar solamente cuando lo haya especificado el comprador en la orden de compra.

2. ESPECIFICACIONES.

2.1. ESPECIFICACIONES DEL PRODUCTO.

2.1.1. Requisitos Generales.

El material suministrado bajo esta Norma debe cumplir con los requisitos aplicables de la Norma B 252 en vigor.

Los materiales que se usen en combinación con el material cubierto por esta Norma; tales como barras para anclaje, pernos, tornillos, etc, deben cumplir con la Norma particular del producto.

2.1.2. Material.

El acero empleado en la fabricación de los productos cubiertos por esta Norma, debe obtenerse por uno o más de los siguientes procesos: horno de hogar abierto, básico al oxígeno u horno eléctrico.

2.1.3. Requisitos Mecánicos.

2.1.3.1. El material, con excepción de lo especificado en los incisos 2.1.3.2. y 2.1.3.5, debe cumplir con los requisitos de tensión indicados en la Tabla I.

TABLA I

REQUISITOS DE TENSION

Placas, perfiles[a] y barras:	
Resistencia a la tensión, en kg/mm^2	40.6 a 56.0
Límite de fluencia, mínimo, en kg/mm^2	25.2[b]
Placas y barras:	
Alargamiento en 200 mm de longitud calibrada, mínimo, en %.	20[c]
Alargamiento en 50 mm de longitud calibrada, mínimo, en %.	23
Perfiles:	
Alargamiento en 200 mm de longitud calibrada, mínimo en %.	20[c]
Alargamiento en 50 mm de longitud calibrada, mínimo en %.	21[a]

a) Para perfiles de ala ancha con peso mayor de 634 kg/m, la resistencia a la tensión mínima debe ser de 40.6 kg/mm^2 sin especificar un máximo, y el alargamient mínimo en 50 mm de longitud calibrada de 19%.

b) El límite de fluencia mínimo, en placas de más de 200 mm de espesor, debe ser d 22.4 kg/mm^2.

c) Ver inciso 2.1.3.3.

2.1.3.2. Los perfiles menores de 6.45 cm^2 de sección transversal y las barras que no sean soleras, con espesor o diámetro menor de 12.70 mm, no necesita el fabricante someterlas a prueba de tensión.

2.1.3.3. Para materiales con espesor o diámetro menor de 7.9 mm debe hacerse, por cada 0.8 mm de disminución de dicha medida, una deducción de 1.25 % del porcentaje de alargamiento que, para una longitud calibrada de 200 mm, indica la tabla I.

2.1.3.4. A menos que se especifique otra cosa, las placas que a usarse como apoyo para puentes, se deben sujetar a pruebas mecánicas y cumplir con los requisitos de tensión indicadas en los incisos 2.1.3.1, 2.1.3.2 y 2.1.3.3.

2.1.3.5. A menos que se especifique otra cosa, no se requieren pruebas mecánicas para placas mayores de 38.10 mm de espesor que vayan a usarse como placas de apoyo en estructuras distintas a puentes; este material debe contener de 0.20 a 0.33% de carbono en el análisis de cuchara y, su composición química, debe cumplir en cuanto a contenido de fósforo y azufre, con los requisitos de la Tabla III. Se debe hacer un despunte suficiente de cada lingote para asegurar una buena calidad.

2.1.3.6. Los especímenes para la prueba de doblado, deben soportar un doblez en frío a 180° sin agrietarse en la parte exterior de la porción doblada, sobre un mandril que tenga un diámetro con relación al espesor del material, de acuerdo con lo especificado en la Tabla II.

TABLA II

Requisitos para la prueba de doblado.

Espesor del material mm		Relación del diámetro del mandril al espesor del espécimen para placas, perfiles y barras(a).
	Hasta 19.05	1/2
Más de 19.05	hasta 25.40	1
Más de 25.40	hasta 38.10	1 1/2
Más de 38.10	hasta 50.80	2 1/2
Más de 50.80		3

a) Estas relaciones se aplican únicamente para el comportamiento al doblado del espécimen. Este espécimen se debe tomar siempre en dirección longitudinal, y usualmente tiene alguna preparación en sus orillas. Cuando las placas se doblan en una operación de fábrica, se puede usar un radio de doblado más liberal especialmente si el eje de doblado es en una dirección desfavorable, (longitudinal).

2.1.4. Requisitos Químicos.

2.1.4.1. El resultado del análisis de cuchara debe cumplir con los requisitos indicados en la Tabla III, con excepción de lo especificado en el inciso 2.1.3.5.

T A B L A III

REQUISITOS QUIMICOS

Producto	Perfiles (a)	Placas					Barras			
Espesores, mm	Todos	Hasta 19.05	Más de 19.05 hasta 38.10	Más de 38.10 hasta 63.50	Más de 63.50 hasta 101.6	Más de 101.6	Hasta 19.05	Más de 19.05 hasta 38.10	Más de 38.10 hasta 101.6	Más de 101.6
Carbono, máximo %	0.26	0.25	0.25	0.26	0.27	0.29	0.26	0.27	0.28	0.29
Manganeso, %	----	----	0.80 a 1.20	0.80 a 1.20	0.85 a 1.20	0.85 a 1.20	----	0.60 a 0.90	0.60 a 0.90	0.60 a 0.90
Fósforo, máximo %	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Azufre, máximo %	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Silicio %	----	----	----	0.15 a 0.30	0.15 a 0.30	0.15 a 0.30	----	----	----	----
Cobre, mínimo % (cuando se especifique).	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

a) Para perfiles con peso mayor de 634 kg/m, el contenido de manganeso debe ser de 0.85 a 1.35% y el de silicio de 0.15 a 0.30%.

2.1.4.2. En el análisis de producto (comprobación), el acero debe cumplir con los requisitos indicados en la Tabla III con las tolerancias especificadas en la Norma B 252 en vigor, con excepción de lo indicado en el inciso 2.1.4.3.

2.1.4.3. El análisis de producto no es aplicable a barras perfiles o soleras de 12.7 mm y menores en espesor.

2.1.4.4. Cuando se omitan las pruebas de tensión, de acuerdo con lo indicado en el inciso 2.1.3.2, la composición química debe cumplir con lo indicado en la Tabla III y tener las propiedades mecánicas deseadas.

2.1.5. Requisitos Suplementarios.

2.1.5.1. Los siguientes requisitos son opcionales y solo deben aplicarse cuando así se especifique en la orden de compra.

2.1.5.1.1. Los productos suministrados de acuerdo con esta Norma, no deben ser de -- acero efervescente o tapado.

2.1.5.1.2. Los productos suministrados de acuerdo con esta Norma deben ser de acero calmado al silicio, de grano fino.

3. Métodos de Prueba.

3.1. Para verificar que el material suministrado cumple con esta Norma, deben seguirse los métodos indicados en las Normas B 1 y B 172 en vigor.

4. Apéndice.

4.1. Datos para el Pedido.

4.1.1. Las órdenes de material de acuerdo con esta Norma, deben incluir los siguientes datos para describirlo adecuadamente.

a) Número de esta Norma.

b) Nombre del material.

c) Dimensiones de la sección transversal.

d) Longitud en metros.

e) Cantidad (kilogramos).

f) Excepciones a esta Norma.

g) Requisitos suplementarios.

h) Certificado de calidad o pruebas (si se requiere).

4.2. NORMAS A CONSULTAR.

B 252 1973	Requisitos generales para placas, perfiles, tablaestacas y barras, de-acero laminado en caliente, para uso estructural.
B 1 1970	Métodos de análisis químico para determinar la composición de aceros y fundiciones.
B 172 1970	Métodos de prueba mecánicos para productos de acero.

4.3. BIBLIOGRAFIA.

ASTM A 36 70

4.4. PARTICIPANTES

Altos Hornos de México, S.A.

Fundidora Monterrey, S.A.

Hojalata y Lámina, S.A.

Secretaría de Obras Públicas

Tubacero, S.A.

Comesa, S.A.

Manufacturas Métalicas Ajax, S.A.

Comisión Federal de Electricidad (IIE)

Aceros Tepeyac, S.A.

Instituto Mexicano del Petróleo

Industria del Hierro, S.A.

ACERO ESTRUCTURAL CON LIMITE DE FLUENCIA MINIMO DE 29.5 kgf/mm^2 Y CON ESPESOR MAXIMO DE 12.7 mm

B 99 1971

Structural Steel With 29.5 kgf/mm^2 Minimum Yield Point and 12.7 mm Maximum Thickness.

1. GENERALIDADES Y DEFINICIONES

1.1. Generalidades

1.1.1. Alcance.

Esta Norma cubre las placas y barras de acero al carbono con espesor o diámetro menor o igual a 12.7 mm, así como los perfiles de calidad estructural para uso en edificios y construcciones similares, para ser remachadas, atornilladas o soldadas, que se indican en la Tabla A, grupo 1 de la Norma B 252 en vigor.

Cuando las placas y barras cubiertas por esta Norma, se usen en construcciones soldadas, los procesos de soldadura empleados, deben ser los adecuados para el acero y el servicio a que se destine.

1.1.2. Datos para el pedido.

En los pedidos del material cubierto por esta Norma, se deben indicar los siguientes datos para describirlo adecuadamente:

a) Número de esta Norma.

b) Nombre del Material (Acero estructural con límite de fluencia mínimo de 29.5 kgf/mm^2).

c) Cantidad (kg).

d) Dimensiones.

e) Certificado de calidad, si se requiere.

2. CLASIFICACION Y ESPECIFICACIONES

2.1. Especificaciones

2.1.1. Requisitos Generales.

El material cubierto por esta Norma, debe cumplir con los requisitos aplicables de la Norma B 252 en vigor.

2.1.2. Material.

El acero empleado en la fabricación de las placas y las barras cubiertas por esta Norma, debe obtenerse por cualquiera de los siguientes procesos: horno de hogar abierto, básico al oxígeno u horno eléctrico.

2.1.3. Químicas.

El acero debe cumplir con los requisitos de composición química indicados en la Tabla I, tanto en el análisis de cuchara como en el de comprobación, de acuerdo a lo especificado en la Norma B 252 en vigor, en lo que corresponda.

...

Las barras perfil o soleras, no están sujetas a análisis de comprobación.

TABLA I

REQUISITOS QUIMICOS

Elemento	Análisis de cuchara	Análisis de comprobación
Carbono, máximo, en porciento...........	0.27	0.31
Manganeso, máximo, en porciento........	1.20	1.25
Fósforo, máximo, en porciento...........	0.04	0.050
Azufre, máximo, en porciento............	0.05	0.060
Cobre, cuando se especifique, mínimo, en porciento	0.20	0.18

2.1.4. Mecánicas.

2.1.4.1. Tensión.

El material cubierto por esta Norma, debe cumplir con los requisitos de ten-sión indicados en la Tabla II, excepto lo indicado en 2.1.4.1.1.

2.1.4.1.1. Los perfiles de sección transversal menor de 6.45 cm^2, así como las b-rras que no sean soleras, con espesor o diámetro menor de 12.7 mm, no están suje-tas a requisitos de tensión.

TABLA II

REQUISITOS DE TENSION

Resistencia a la tensión en kgf/mm^2 (espécimen longitudinal de sección o espesor completo).................	42 a 60
Límite de fluencia, mínimo, en kgf/mm^2 (espécimen longitudinal de sección o espesor completo).............	29.5
Alargamiento en 203.20 mm de longitud calibrada, mínimo, en porciento..	19

2.1.4.1.2. Para materiales con espesor o diámetro menor de 7.94 mm, por cada dis-minución de 0.79 mm en el espesor o diámetro especificado por abajo de 7.94 mm, d-be hacerse una deducción de 1.25% del porcentaje de alargamiento en 203.20 mm de longitud calibrada especificado en la Tabla II.

2.1.4.2. Doblado.

Los especímenes para la prueba de doblado que representen material de acuerd- con esta Norma, deben resistir un doblado en frío a 180° con un diámetro interior igual al espesor o diámetro del espécimen, sin agrietarse en la parte exterior de la porción doblada.

La relación entre el diámetro del mandril y el espesor del espécimen en la prueba de doblado sólo es aplicable para juzgar el comportamiento del espécimen e- dicho ensayo. El espécimen en esta prueba, debe tomarse siempre en dirección longi-tudinal y usualmente deben redondearse las aristas. Cuando las placas van a some-terse a doblado en una operación de fabricación, debe usarse un radio de doblez - más grande, particularmente si el eje de doblado se encuentra en dirección desfav-rable.

2.1.5.1. Químicas.

El muestreo para los análisis de cuchara y de comprobación debe efectuarse de acuerdo a lo indicado en la Norma B 252 en vigor.

2.1.5.2. Mecánicas.

Deben realizarse dos pruebas de tensión y dos de doblado en especímenes representativos del material proveniente de cada colada de acero.

2.1.5.3. Inspección.

El fabricante debe dar al inspector representante del comprador, todas las facilidades razonables para satisfacerlo de que el material se está suministrando de acuerdo con esta Norma; todas las pruebas e inspección (excepto el análisis de comprobación), se deben efectuar en el local del fabricante antes de su embarque y llevarse a cabo de manera tal que no interfieran innecesariamente con los trabajos de la planta.

2.1.5.4. Rechazo.

El material solicitado de acuerdo con esta Norma, que no cumpla con alguno de los requisitos especificados, debe rechazarse.

3. METODOS DE PRUEBA

3.1. Químicas.

Los métodos de análisis para determinar la composición química del material cubierto por esta Norma, deben ser los indicados en la Norma B 1 en vigor.

3.2. Mecánicas.

Los métodos de prueba para determinar las propiedades mecánicas del material cubierto por esta Norma, deben ser los indicados en la Norma B 172 en vigor.

4. APENDICE

4.1. Antecedentes

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4.2. Normas a consultar

B 1 1970	Métodos de Análisis Químico para determinar la Composición de Aceros y Fundiciones.
B 172 1970	Métodos de Prueba Mecánicos para Productos de Acero.
B 252 1968	Requisitos Generales para la Entrega de Planchas, Placas, Perfiles Tablaestacas y Barras de Acero Laminados para usos Estructurales.

COMITE CONSULTIVO NACIONAL DE NORMALIZACION DE LA INDUSTRIA SIDERURGICA

"ACERO ESTRUCTURAL DE BAJA ALEACION Y ALTA RESISTENCIA"
B 282 1973

1. GENERALIDADES

1.1. ALCANCE

Esta Norma establece los requisitos que deben cumplir los perfiles, placas y barras de acero estructural de baja aleación y alta resistencia. Esta Norma está limitada a material hasta de 101.60 mm en espesor.

1.2. USOS

Los perfiles, placas y barras a que se refiere esta Norma se usan en construcciones soldadas, atornilladas o remachadas como miembros estructurales donde es importante el ahorro de peso y la durabilidad. Estos aceros tienen una resistencia a la corrosión atmosférica del doble como mínimo de los aceros estructurales al carbono con cobre. La técnica de soldadura es de importancia fundamental y se presupone que el procedimiento de soldadura cumple con métodos aprobados.

2. ESPECIFICACIONES

2.1. ESPECIFICACIONES DE PRODUCTO

2.1.1. Requisitos generales.

El material suministrado bajo esta Norma debe cumplir con los requisitos especificados en la Norma B 252 en vigor.

2.1.2. Material.

El acero debe ser fabricado por uno o más de los siguientes procesos: hogar abierto, básico al oxígeno u horno eléctrico.

2.1.3. Requisitos mecánicos.

2.1.3.1. El material debe cumplir con los requisitos de resistencia a la tensión indicados en la Tabla I.

TABLA I

REQUISITOS DE TENSION

	Placas y barras			Perfiles estructurales		
	Para espesores de 19.05 mm y menores	Para espesores mayores de 19.05 mm hasta 38.1 mm	Para espesores mayores de 38.1 mm hasta 101.6 mm	Grupos 1 y 2	Grupo 3	Grupos 4 y 5
Resistencia a la tensión mínima, en kg/mm^2	49.2	47.1	44.3	49.2	47.1	44.3
Límite de fluencia mínimo en kg/mm^2	35.2	32.3	29.5	35.2	32.3	29.5
Alargamiento en 200 mm de longitud calibrada, mín. %	18[a]	18	18	18[a]	18	18
Alargamiento en 50 mm de longitud calibrada, mín. %	----	21	21	----	----	21[b]

a) Ver 2.1.3.2.

b) Para perfiles de ala ancha mayores de 634 kg/m, el alargamiento en 50 mm de longitud calibrada, debe ser de 18% como mínimo.

2.1.3.2. Para material con espesor o diámetro menor de 7.9 mm debe hacerse, por cada 0.8 mm de disminución de dicha medida, una deducción de 1.25% del porcentaje de alargamiento que, para una longitud calibrada de 200 mm, indica la Tabla I.

2.1.3.3. Los especímenes para la prueba de doblado, deben soportar un doblez en frío a 180º sin agrietarse la parte exterior de la porción doblada, alrededor de un mandril cuyo diámetro debe tener una relación con el espesor del espécimen, como se indica en la Tabla II.

TABLA II

REQUISITOS PARA LA PRUEBA DE DOBLADO

Espesor del material, mm	Relación del diámetro del mandril al espesor del espécimen
hasta 19.05	1
Mayor de 19.05 hasta 25.40	1 1/2
Mayor de 25.40 hasta 38.10	2

2.1.4. Requisitos químicos.

2.1.4.1. El análisis de cuchara debe cumplir con los requisitos indicados en la Tabla III.

TABLA III

REQUISITOS QUIMICOS (análisis de cuchara)

ELEMENTO	Composición %	
	Tipo 1	Tipo 2
Carbono, máximo	0.15	0.20
Manganeso, máximo	1.00	1.35
Fósforo, máximo	0.15	0.04
Azufre, máximo	0.05	0.05
Cobre, mínimo	0.20	0.20[a]

(a) Si los contenidos de cromo y silicio son cada uno de 0.50% mín., no es entonces aplicable el requisito de 0.20% mín. de contenido de cobre.

2.1.4.2. En el análisis de producto (comprobación), el acero debe cumplir con los requisitos indicados en la Tabla III, con las tolerancias especificadas en la Norma B 252 en vigor.

2.1.4.3. El fabricante debe hacer la selección de los elementos de aleación, que combinados con el carbono, manganeso, fósforo, azufre y cobre, dentro de los límites especificados en el inciso 2.1.4.1., cumpla con los requisitos necesarios indicados en el inciso 2.1.3.1., y asegure la resistencia a la corrosión atmosférica mencionada en el inciso 1.2; debe además incluír y reportar datos en el análisis de cuchara para identificar así el tipo de acero usado. Los elementos de aleación que comunmente se usan son: cromo, níquel, silicio, vanadio, titanio y zirconio.

2.1.4.4. Cuando se requiera, el fabricante debe proporcionar al comprador evidencias satisfactorias de resistencia de la corrosión.

3. METODOS DE PRUEBA

Para verificar que el material suministrado cumpla con esta Norma, deben seguirse los métodos indicados en las Normas B.1 y B 172 en vigor.

4. APENDICE

4.1. DATOS PARA EL PEDIDO

Las órdenes de material de acuerdo con esta Norma, deben incluír los siguientes datos para describirlo adecuadamente:

b) Nombre del material.

c) Dimensiones de la sección transversal.

d) Longitud en metros.

e) Cantidad (kilogramos).

f) Si se requiere resistencia especial a la corrosión.

g) Si se solicitan requisitos especiales de soldabilidad.

h) Excepciones a esta Norma.

i) Certificado de calidad o pruebas, si se requiere.

4.2. NORMAS A CONSULTAR

B 1 1970	"Métodos de análisis químico para determinar la composición de aceros y fundiciones"
B 172 1970	"Métodos de prueba mecánicos para productos de acero"
B 252 1973	"Requisitos generales para placas, perfiles, tablestacas y barras, de acero laminado en caliente, para uso estructural"

4.3. BIBLIOGRAFIA

ASTM A 242 70

4.4. PARTICIPANTES

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COMITE CONSULTIVO NACIONAL DE NORMALIZACION DE LA INDUSTRIA SIDERURGICA

ACERO ESTRUCTURAL DE ALTA RESISTENCIA
B 285 1973

1. GENERALIDADES

1.1. ALCANCE

Esta Norma establece los requisitos que deben cumplir los perfiles, planchas barras de acero de alta resistencia, de calidad estructural. La resistencia a la corrosión atmosférica de este acero es de aproximadamente el doble que la del acero estructural al carbono.

Esta Norma está limitada a material hasta de 101.6 mm de espesor.

1.2. USOS

Los perfiles, planchas y barras a que se refiere esta Norma se usan en construcción de puentes y edificios atornillados y/o remachados y para otros propósitos estructurales especiales, donde es importante el ahorro en peso.

2. ESPECIFICACIONES

2.1. ESPECIFICACIONES DEL PRODUCTO

2.1.1. Requisitos generales.

El material suministrado bajo esta Norma debe cumplir con los requisitos aplicables de la Norma B 252 en vigor.

La reparación de los defectos con soldadura debe ser hecha con electrodos adecuados.

2.1.2. Material

El acero debe ser fabricado por uno o más de los siguientes procesos: hogar abierto, básico al oxígeno u horno eléctrico.

2.1.3. Requisitos mecánicos.

2.1.3.1. El material representado por la probeta, debe cumplir con los requisitos de resistencia a la tensión indicados en la Tabla I.

TABLA I

REQUISITOS DE TENSION

	Planchas y Barras			Perfiles Estructurales		
	Para espesores de 19.1 mm y menores	Para espesores mayores de 19.1 mm hasta 38.1 mm	Para espesores mayores de 38.1 mm hasta 101.6 mm	Grupos 1 y 2 (a)	Grupo 3 (a)	Grupos 4 y 5 (a)
Resistencia a la tensión, mínima en kg/mm^2	49.2	47.1	44.3	49.2	47.1	44.3
Límite de fluencia mínimo en kg/mm^2	35.2	32.3	29.5	35.2	32.3	29.5
Alargamiento en 200 mm de longitud calibrada, mínimo en %	18(b)	18	18	18(b)	18(b)	18
Alargamiento en 50 mm de longitud calibrada, mínimo en %	----	21	21	----	---	21(c)

a) Ver Tabla A de Norma B 252

b) Ver 2.1.3.2.

c) Para perfiles de ala ancha mayores de 634 kg/m, el alargamiento en 50.8 mm de longitud calibrada, debe ser de 19% como mínimo.

2.1.3.2. Para material representado por la probeta, menor de 7.9 mm en espesor o diámetro, debe hacerse una deducción de 1.25% del porcentaje de alargamiento especificado en la Tabla I, para una longitud calibrada de 200 mm, por cada disminución de 0.79 mm a partir del espesor o diámetro especificado, abajo de 7.9 mm.

2.1.3.3. Las probetas para la prueba de doblado, deben soportar un doblez en frío a 180° sin agrietarse la parte exterior de la porción doblada, alrededor de un mandril cuyo diámetro debe tener una relación con el espesor de la probeta como se indica en la Tabla II.

TABLA II

REQUISITO PARA LA PRUEBA DE DOBLADO

Espesor del material, en mm	Relación del diámetro del mandril al espesor de la probeta (a)
Hasta 19.05	1
Mayor de 19.05 hasta 25.40	1 1/2
Mayor de 25.40 hasta 38.10	2
Mayor de 38.10 hasta 50.80	2 1/2
Mayor de 50.80 hasta 101.60	3

a) Estas relaciones se aplican únicamente para el comportamiento al doblado de la probeta. Esta probeta se debe tomar siempre en dirección longitudinal y usualmente tiene alguna preparación en sus orillas; cuando las planchas se doblan en una operación de fabricación, se puede usar un radio de doblado más liberal, especialmente si el eje de doblado es en una dirección desfavorable (longitudinal).

2.1.4. Requisitos químicos

2.1.4.1. El análisis de colada debe cumplir con los requisitos indicados en la Tabla III

TABLA III

REQUISITOS QUIMICOS

ELEMENTO	CONTENIDO, EN %
Carbono, máximo	0.28
Manganeso	1.10 a 1.60
Fósforo, máximo	0.04
Azufre, máximo	0.05
Silicio, máximo	0.30
Cobre mínimo	0.20

2.1.4.2. En el análisis de producto, el acero debe cumplir con los requisitos indicados en la Tabla III, con las tolerancias especificadas en la Norma B 252 en vigor.

3.- METODOS DE PRUEBA

4.1. DATOS PARA EL PEDIDO

Las órdenes de material de acuerdo con esta Norma, deben incluír los siguientes datos para describirlo adecuadamente:

a) Número de esta Norma.

b) Nombre del material.

c) Dimensiones de la sección transversal.

d) Longitud en metros.

e) Cantidad (kilogramos).

f) Requisitos adicionales o excepciones a esta Norma.

g) Certificado de calidad o pruebas (si se requiere).

4.2. NORMAS A CONSULTAR

B 252 1973 "Requisitos generales para placas, perfiles, tablestacas y barras de acero laminado en caliente para uso estructural".

B 172 1970 "Métodos de prueba mecánicos para productos de acero".

B 1 1970 "Métodos de análisis químico para determinar la composición de aceros y fundiciones".

4.3. BIBLIOGRAFIA

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4.4. PARTICIPANTES

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Comisión Federal de Electricidad

Norma Definitiva

NORMA DE CALIDAD

TUBOS CON O SIN COSTURA DE ACERO AL CARBONO, FORMADOS EN CALIENTE PARA USOS ESTRUCTURALES.
B-200-1966.

1. GENERALIDADES Y DEFINICIONES

1.1. Generalidades

1.1.1. Alcance.

1.1.1.1. Esta Norma cubre los requisitos que deben cumplir los tubos con y sin costura, de acero al carbono, formados en caliente de secciones cuadradas, rectangulares o de secciones especiales para usos estructurales en construcciones metálicas para puentes o edificios y usos estructurales en general.

1.1.1.2. Cuando se necesiten tubos con y sin costura en acero al carbono de sección circular para estas mismas aplicaciones, se recomienda el uso de tubos cubiertos por la Norma Oficial DGN-B-10 en vigor, los tubos cubiertos por la Norma Oficial DGN-B-177 en vigor, dependiendo su elección de la calidad del tubo requerida, adicionando los requisitos especificados en esta Norma en los párrafos 2.2.1 y 3.2.3.

1.1.2. Datos para el pedido.

1.1.2.1. En los pedidos de estos tubos es necesario indicar los siguientes datos, como se requiera, para describir adecuadamente el material.

a) Número de esta Norma.

b) Cantidad (metros o número de tubos).

c) Descripción del material (tubos formados en caliente).

d) Proceso de fabricación (sin costura (Tipo I) soldados a tope (Tipo II).

e) Tamaño (dimensiones exteriores y espesor de pared).

f) Longitud (de fabricación, múltiples o fijos), en mm.

g) Condición final.

h) Eliminación de rebabas.

i) Certificación.

j) Uso final o título informativo.

k) Requisitos especiales.

1.2. Definiciones

1.2.1. Para los efectos de esta Norma, se aplicarán las siguientes definiciones:

1.2.1.1. Tubos estructurales (structural tubing).

Son los tubos destinados a ser usados como elementos estructurales o para aplicaciones mecánicas en general.

2. CLASIFICACION Y ESPECIFICACIONES

2.1. Clasificación

2.1.1. Para los efectos de esta Norma, los tubos se clasifican de acuerdo al proceso de fabricación como sigue:

TIPO I. Con costura, formados en caliente.

TIPO II. Sin costura, formados en caliente.

2.2. Especificaciones

2.2.1. Material.

2.2.1.1. El acero para la fabricación de estos tubos debe ser producido por uno o más de los siguientes procesos: hogar abierto, básico al oxígeno y horno eléctrico.

2.2.2. Composición química.

2.2.2.1. El acero debe cumplir con los requisitos de composición química especificados en la Tabla I.

/// 3.

TABLA I.

REQUISITOS DE COMPOSICION QUIMICA

Elemento	Análisis de cuchara	Análisis de comprobación
Carbono, máximo %	0.26	0.30
Fósforo, máximo %	0.04	0.05
Azufre, máximo %	0.05	0.063
Cobre cuando ha sido especificado, mínimo %	0.20	0.18

2.2.3. Fabricación.

2.2.3.1. Los tubos deben ser fabricados por el proceso sin costura o soldados a tope.

2.2.4. Requisitos mecánicos.

2.2.4.1. Requisitos a la tensión.

2.2.4.1. Los tubos deben cumplir con las propiedades a la tensión especificadas en la Tabla II.

TABLA II.

PROPIEDADES A LA TENSION DE TUBOS DE SECCIONES CUADRADAS, RECTANGULARES Y DE SECCIONES ESPECIALES

Resistencia a la tensión, mín, kg/mm^2	41 (a)
Límite de fluencia, mín, kg/mm^2	25
Alargamiento en 50.80 mm de longitud calibrada, mín. % (c)	23
Alargamiento en 203.20 mm de longitud calibrada, mín. % (c)	20 (b)

(a) La resistencia a la tensión máxima debe ser de 56 kg/mm^2

(b) Para material con espesor de pared inferior de 7.92 mm el valor de alargamiento en 203.20 mm especificado debe deducirse en 1.25% por cada 0.79 mm de deducción del espesor de pared.

(c) El alargamiento debe ser determinado en una longitud calibrada de 50.80 mm ó de 203.20 mm, a opción del fabricante.

2.2.4.2. Requisitos de doblado.

2.2.4.2.1. Todos los productos manufacturados de acuerdo a esta Norma deben ser sometidos a la prueba de doblado en el número de pruebas indicado en 2.2.8.

2.2.4.2.2. Los especímenes para la prueba de doblado deben tomarse longitudinalmente del tubo y deben ser del espesor total de pared del material.

Los especímenes pueden tener las esquinas redondeadas con un radio máximo de 1.59 mm.

2.2.4.2.3. El espécimen deberá ser doblado en frío 180º sin mostrar grietas en el exterior de la porción doblada. El doblado debe ser hecho alrededor de un mandril con un diámetro exterior que tenga una relación con respecto al espesor del espécimen como se describen en la Tabla III.

T A B L A III.

REQUISITOS PARA LA PRUEBA DE DOBLADO.

Espesor del material, mm	Relación del diámetro de doblado con respecto al espesor del espécimen.
19.05 y menores	1/2
Mayores de 19.05 a 25.40 incl.	1

2.2.5. Manufactura.

2.2.5.1. Todos los tubos deben estar libres de defectos superficiales y deben tener un acabado adecuado dentro de las prácticas usuales.

2.2.5.2. Los defectos superficiales deben considerarse como perjudiciales cuando tengan una profundidad que exceda del 15% del espesor de pared establecido en las Tablas IV y V y cuando las imperfecciones del material afecten la apariencia del miembro estructural, o cuando su longitud (medida en dirección transversal) y profundidad no reduzcan el área de la sección transversal total en cualquier punto.

2.2.5.3. Defectos perjudiciales que tengan una profundidad que no exceda el 33 1/3% del espesor de pared establecido en las Tablas IV y V pueden ser reparados por soldadura siempre que se sujeten a las siguientes condiciones:

2.2.5.3.1. Los defectos deben ser completamente removidos o emparejados y limpiados hasta encontrar material sano.

2.2.5.3.2. La reparación por soldadura, deberá ser hecha usando electrodos cubiertos apropiados.

2.2.5.3.3. El metal de la soldadura proyectado debe ser removido por amolado para producir un buen acabado.

2.2.5.3.4. Los extremos de los tubos estructurales, exceptuando otra cosa que se haya especificado, deben ser cortados a escuadra y las rebabas eliminadas a un mínimo. Las rebabas pueden eliminarse en diámetro exterior, interior, o ambas; como un requisito suplementario, y cuando se desee esta operación extra, deberá ser asentada en la orden de compra.

2.2.6. Dimensiones.

2.2.6.1. Tubos estructurales cuadrados.

Las dimensiones exteriores (a través de los lados), el peso por metro y el espesor nominal de pared calculado para tubos estructurales cuadrados más usuales, están indicados en la Tabla IV.

2.2.6.2. Tubos estructurales rectangulares.

Las dimensiones exteriores (a través de los lados,), el peso por metro y el espesor de pared calculado para tubos estructurales rectangulares más usuales, están indicados en la Tabla V.

2.2.6.3. Tubos estructurales de secciones especiales.

Las dimensiones y tolerancias de tubos estructurales de sección especial, deberán ser fijadas de común acuerdo entre fabricante y comprador y asentarse en la orden de compra.

2.2.6.4. Otros tamaños.

Tubos estructurales con o sin costura formados en caliente de acuerdo con los requisitos de esta Norma y en dimensiones diferentes a las especificadas en las Tablas IV y V deben ser fabricados por convenio prévio y en este caso las tolerancias dimensionales deben ser las mismas que aquellas mostradas en esta Norma para tipos y tamaños similares.

T A B L A IV.

DIMENSIONES MAS COMUNES PARA TUBOS ESTRUCTURALES CUADRADOS

Tamaños exteriores dimensionales a través de los lados planos mm	Peso teórico	Espesor nominal de pared calculado mm
25.40 por 25.40	1.62	2.41
	2.10	3.39
50.80 por 50.80	4.00	2.79
	4.52	3.18
	5.43	3.91
	6.41	4.78

T A B L A V. (Continuación)

254.00 por 152.40	37.86	6.35
	46.49	7.92
	54.81	9.53
	70.46	12.70

2.2.6.5. Longitud.

2.2.6.5.1. Los tubos estructurales producidos en largos de fabricación entre 4.88 m a 6.70 m o entre 5.76 m a 13.40 m, en largos múltiples y en largos fijos, el largo necesario deberá establecerse en la orden de compra.

2.2.7. Tolerancias en las dimensiones.

2.2.7.1. Dimensiones exteriores.

2.2.7.1.1. Las dimensiones especificadas, medidas a través de los lados planos en posiciones localizadas por lo menos a 50 mm, de cualquiera de los extremos e incluyendo el margen necesario para la concavidad y convexidad no debe exceder las cantidades en más y en menos especificadas en la Tabla VI.

2.2.7.2. Peso.

2.2.7.2.1. El peso de los tubos estructurales especificados en las Tablas IV y V no deben ser menores del indicado en más de 3.5%.

2.2.7.3. Longitud.

2.2.7.3.1. Cuando se han especificado tubos en longitudes fijas, las tolerancias permitidas serán de acuerdo a lo especificado en la Tabla VII.

2.2.7.4. Rectitud.

2.2.7.4.1. La variación permisible para la rectitud de estos tubos debe ser de 10 mm por el número de metros, dividido entre 5.

2.2.7.5. Descuadrado de los lados.

2.2.7.5.1. Para tubos cuadrados o rectangulares, los lados adyacentes pueden desviarse de los 90° por una tolerancia ya sea en más o menos de 2° máximo

2.2.7.6. Torcido

2.2.7.6.1. La variación para el torcido o la variación sobre el alineamiento axial de los tubos de sección cuadrada, rectangular o especial, debe ser de acuerdo a lo especificado en la Tabla VIII.

2.2.7.6.2. El torcido es medido manteniendo uno de los extremos planos del tubo en una superficie plana y anotando la altura de la otra esquina en el extremo opuesto en el mismo lado plano del tubo, colocado sobre la superficie plana.

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2.2.7.7. Radio de las esquinas.

2.2.7.7.1. El radio de las esquinas no debe exceder de 3 veces el espesor de pared especificado.

T A B L A VI.

TOLERANCIAS SOBRE LAS DIMENSIONES EXTERIORES DE LOS TUBOS DE SECCION CUADRADA, RECTANGULAR, O ESPECIAL.

Dimensión exterior máxima a través de los lados planos, mm	Tolerancia (a) en más o en menos, mm
63.50 y menores	0.51
Mayores de 63.50 a 88.90 incl.	0.64
Mayores de 88.90 a 141.30 incl.	0.76
Mayores de 141.30	1 %

(a).- Tolerancias para la dimensión exterior respectiva incluye las tolerancias para convexidad y concavidad.

T A B L A VII.

TOLERANCIAS PARA LONGITUDES FIJAS DE LOS TUBOS EN mm

	6.70 y menores		Mayores de 6.70 a 13.40 m incl.	
	en más	en menos	en más	en menos
Tolerancia sobre la longitud	12.70	6.35	19.05	6.35

T A B L A VIII.

TOLERANCIA SOBRE EL TORCIDO DE LOS TUBOS DE SECCION CUADRADA, RECTANGULAR O ESPECIAL.

Dimensión exterior mayor especificada mm	Máxima torsión permitida por cada metro, mm
38.10 y menores	1.39
Mayores de 38.10 a 63.50 incl.	1.72
Mayores de 63.50 a 101.60 incl.	2.08
Mayores de 101.60 a 152.40 incl.	2.42
Mayores de 152.40 a 203.20 incl.	2.76
Mayores de 203.20	3.11

2.2.8. Muestreo.

2.2.8.1. Exceptuando otra cosa que se indique, el muestreo será hecho de acuerdo a lo indicado en los siguientes párrafos.

2.2.8.2. Número de pruebas.

2.2.8.2.1. Químicas.

2.2.8.2.1.1. Análisis de cuchara.

Un análisis de cuchara deberá ser hecho de cada colada de acero producido por el fabricante. Este análisis debe ser hecho de un lingote durante el vaciado del acero. La composición química del acero así determinada debe estar de acuerdo a los requisitos especificados para este análisis en la Tabla I.

2.2.8.2.1.2. Análisis de comprobación.

Un análisis de comprobación puede ser hecho por el comprador en tubos terminados de acuerdo con esta Norma, o un análisis puede ser hecho de la materia prima en existencia, cuando se van a producir tubos soldados. Cuando el análisis de comprobación es hecho, dos muestras deben seleccionarse de cada lote de 500 tubos o fracción. En el caso de que uno de los análisis efectuado en una de las muestras no esté conforme a los requisitos especificados en la Tabla I para análisis de comprobación, un nuevo análisis debe ser hecho en dos muestras adicionales seleccionadas del mismo lote, cada uno de los cuales debe estar de acuerdo con los requisitos especificados.

2.2.8.2.2. Mecánicas.

2.2.8.2.2.1. Dos pruebas de tensión y dos pruebas de doblado deben ser hechas en tubos representativos de cada colada, sin embargo, si los tubos fabricados de una misma colada son de diferentes espesores de pared, una prueba de tensión y una prueba de doblado deberán hacerse en muestras representativas del espesor más delgado y del espesor más grueso.

2.2.8.2.3. Re-pruebas.

2.2.8.2.3.1. Si el resultado de las pruebas de tensión y de doblado no resultan conforme a lo especificado, se permitirá una nueva prueba en el doble de muestras seleccionadas del mismo lote. En caso de que estas nuevas pruebas fallen de acuerdo con los requisitos establecidos de tensión y de doblado, el fabricante puede elegir en dar un tratamiento térmico y someter los tubos a nuevas pruebas, o en eliminar la condición responsable de la falla hasta encontrar que el material cumple con los requisitos especificados. De otra manera el material de la colada será rechazado.

2.2.9. Marcado.

2.2.9.1. En adición a las marcas especificadas en la Norma Oficial DGN-B-139 en vigor se debe incluir el nombre del fabricante, grado, letra y número de esta Norma.

2.2.10. Recepción.

2.2.10.1. Inspección.

Mientras se fabrica una orden de compra según esta Norma, el comprador podrá enviar un inspector a la planta del productor quien le facilitará libre acceso a las secciones de fabricación, inspección y control que intervengan en la producción y despacho del material. Si no se establece lo contrario previamente, la toma de muestras y prueba para la aceptación del material debe ser hecha en la planta del fabricante antes de su embarque, sin interferir en las operaciones de trabajo normales de la fábrica.

2.2.10.2. Aceptación.

Los tubos se aceptarán cuando hayan cumplido con todos los requisitos de esta Norma y cuando la aceptación del material por parte del comprador se haga con base a certificados, éstos deben cumplir con lo establecido en 2.2.10.3.

2.2.10.3. Cuando el comprador solicite certificados, el productor deberá entregar uno que incluya el nombre y número de esta Norma, el grado de acero, los resultados de los análisis químicos de comprobación y de las pruebas mecánicas, estableciéndose que el material entregado, cumple con lo especificado en esta Norma.

2.2.10.4. Rechazos.

En la eventualidad de que los tubos una vez entregados y sometidos a las operaciones de aplicación ya sea en talleres especializados o el lugar de su aplicación, revelaren defectos perjudiciales imputables a material defectuoso o al proceso de fabricación, los tubos serán separados y se deberá avisar al fabricante para calificar dichos defectos en conjunto. Por acuerdo previo se decidirá el destino de estos tubos.

3. METODOS DE PRUEBA.

3.1. Para las pruebas especificadas en esta Norma, se usarán los métodos de prueba descritos en las Normas Oficiales DGN-B-172 y DGN-K-179 en vigor.

4. APENDICE.

4.1. Antecedentes.

ASTM-A-501-64

4.2. Normas DGN a consultar.

DGN-B-177-1966.	Norma Oficial de Calidad para "Tubos con y sin Costura, de Acero al Carbono, para conducción.
DGN-B-139-1966.	Norma Oficial de "Requisitos Generales para Tubos de Acero al Carbono, de Aleaciones Ferríticas y de Aceros Austeníticos Aleados.

DGN-B-10-1966.	Norma Oficial de Calidad para "Tubos con y sin Costura de Acero al Carbono para Usos Comunes.
DGN-B-172-1967.	Norma Oficial de "Métodos de Prueba Mecánicos para Productos de Acero".
DGN-K-179-1967.	Norma Oficial de "Métodos de Análisis Químico para Determinar la Composición de Aceros y -- Fundiciones".

COMITE CONSULTIVO NACIONAL DE NORMALIZACION DE LA INDUSTRIA SIDERURGICA

"REQUISITOS GENERALES PARA PLANCHAS, PERFILES, TABLAESTACAS Y BARRAS, DE ACERO LAMINADO EN CALIENTE, PARA USO ESTRUCTURAL"

B 252 1974

I. GENERALIDADES

1.1. DEFINICIONES

1.1.1. Plancha

Para los fines de esta Norma; es el producto plano de acero laminado en caliente de las siguientes características:

Ancho* en mm	Espesor en mm
De 450 hasta 3657	De 5 hasta 203

* El ancho es como sale del molino (con orillas de molino).

Los planchones para fabricar lámina delgada, así como las láminas para fabricar tubos, frecuentemente caen dentro de las dimensiones de las planchas, sin embargo no deben clasificarse como tales.

1.1.2. Perfiles estructurales

Para los fines de esta Norma, son las piezas de acero laminado, cuya forma de su sección transversal puede ser la de una I, H, canal, ángulo etc., de acuerdo con una necesidad estructural, en la cual la dimensión mayor debe tener como mínimo 76 mm.

1.1.3. Tablaestacas

Para los fines de esta Norma, son las piezas de acero laminado, cuya forma les permite interconectarse entre sí para formar una pared continua, cuando cada pieza es hincada junto a la siguiente.

1.1.4. Barras

Para los fines de esta Norma, son las piezas de acero laminado, cuya forma de su sección transversal puede ser, circular, cuadrada ó hexagonal en todos los tamaños, rectangulares (soleras) con espesor de 5.16 mm y mayores y ancho de 152 mm como máximo; rectangulares (soleras) con espesor de 5.84 mm y ancho de 152 mm hasta 203 mm.

1.1.5. Perfiles-barra

Para los fines de esta Norma, son las piezas de acero laminado, cuya forma de su sección transversal puede ser de una I, H, Z, canal, ángulo etc. en la cual la dimensión mayor debe ser menor de 76 mm.

1.2. ALCANCE

Esta Norma establece una serie de requisitos comunes que, a menos que se especifique otra cosa en la orden de compra o en la Norma particular del producto, deben aplicarse a las planchas, perfiles, tablaestacas y barras de acero laminado en caliente, para uso estructural. En el apéndice de esta Norma, se indica la designación y el título de las Normas a las cuales sirve de complemento esta Norma.

2. ESPECIFICACIONES

2.1. ESPECIFICACIONES DEL PRODUCTO

2.1.1. Análisis de cuchara

El fabricante debe realizar un análisis químico para determinar el contenido de carbono, manganeso, fósforo y azufre y de cualquier otro elemento o elementos especificados o restringidos por la Norma particular del producto. Dicho análisis debe realizarse en muestras tomadas de acuerdo con lo indicado en 3.2.1. El resultado de este análisis debe informarse al comprador y cumplir con lo especificado en la Norma particular del producto.

2.1.2. Análisis de producto (comprobación)

El comprador puede realizar un análisis químico en una muestra representativa del producto terminado. Dicha muestra debe tomarse de acuerdo con lo indicado en 3.2.2. El resultado de este análisis debe estar de acuerdo con lo especificado en la Norma particular del producto, dentro de las tolerancias indicadas en la Tabla B, C, D ó E que le corresponda.

Cuando se especifique un intervalo en la composición, las determinaciones de cualquier elemento en una colada, no deben variar en más ó en menos de los límites especificados. Los aceros efervescentes ó tapados se caracterizan por la falta de homogeneidad en su composición, especialmente para los elementos carbono, fósforo y azufre; por lo que las limitaciones para estos elementos no deben considerarse a menos que se indique claramente una mala aplicación del producto.

2.1.2.1. Tolerancias en el análisis de comprobación para placas, perfiles estructurales y tablaestacas.

Las planchas, perfiles estructurales y tablaestacas, de acero al carbono, deben estar sujetos a las tolerancias indicadas en la Tabla B.

Las planchas, perfiles estructurales y tablaestacas, de aceros de alta resistencia y de alta resistencia y de baja aleación, deben estar sujetas a las tolerancias indicadas en la Tabla B, en cuanto a: carbono, manganeso, fósforo, azufre, silicio y cobre (cobre únicamente cuando se especifique en cantidades de 0.20% y mayores) y a las tolerancias de la Tabla C para los demás elementos (incluyendo al cobre cuando se especifique un intervalo del mismo).

Las planchas, perfiles estructurales y tablaestacas, de acero aleado, deben estar sujetos a las tolerancias indicadas en la Tabla C.

2.1.2.2. Tolerancias en el análisis de comprobación para barras y perfiles-barra.

Las barras y perfiles-barra, de acero al carbono, deben estar sujetos a las tolerancias indicadas en la Tabla D.

Las barras y perfiles-barra, de aceros de alta resistencia y de alta resistencia y baja aleación, deben estar sujetos a las tolerancias indicadas en la Tabla D, en cuanto a: carbono, manganeso, fósforo, azufre, silicio y cobre (cobre únicamente cuando se especifique en cantidades de 0.20% y mayores) y a las tolerancias de la Tabla E para los elementos de aleación (incluyendo al cobre cuando se especifique un intervalo del mismo).

2.1.3. Tolerancias en las dimensiones y peso.

2.1.3.1. Planchas

Las tolerancias en las dimensiones de las planchas, deben ser las indicadas en las Tablas I a XV.

2.1.3.2. Perfiles estructurales

La tolerancia para el área de la sección transversal o para el peso, de un perfil estructural, debe ser como máximo de 2.5% del área o peso teórico o especificado.

Las tolerancias en las dimensiones de los perfiles estructurales, deben ser las indicadas en las Tablas XVI a XXV.

2.1.3.3. Tablaestacas

La tolerancia en peso para una tablaestaca, debe ser como máximo de 2.5% del peso teórico o especificado. La tolerancia en longitud para una tablaestaca debe ser de 125 mm en más y de 0 mm en menos, del largo especificado.

2.1.3.4. Barras y perfiles-barra.

Las tolerancias en las dimensiones de las barras y perfiles-barra, deben ser las indicadas en las Tablas XXVI a XXXV.

2.1.4. Acabado

2.1.4.1. General

El material debe estar libre de defectos perjudiciales y tener un acabado compatible con una buena práctica de fabricación.

2.1.4.2. Planchas

Las planchas pueden acondicionarse por el fabricante, eliminando los defectos de la superficie o depresiones en cualquiera de las superficies de las planchas, mediante esmerilado, de manera que el área esmerilada quede limpia, sin cambios bruscos en su contorno y sin que se disminuya el espesor de la plancha en:

a) Más del 7% del espesor nominal, cuando las planchas se ordenen en peso/m^2, sin que la disminución del espesor exceda, en ningún caso, de 3.18 mm.

b) Más del espesor mínimo permitido, cuando las planchas se ordenen por espesor en mm.

Las planchas pueden tener imperfecciones sobre ambas superficies y éstas pueden eliminarse por cincelado, esmerilado o "arco-aire" y un posterior depósito de soldadura, sujeto todo esto a las siguientes limitaciones:

a) El área cincelada, esmerilada o tratada con "arco-aire" de cada superficie de una plancha, no debe exceder del 2% del área de esa superficie.

b) La disminución del espesor del material resultado de la eliminación de los defectos, antes del depósito de soldadura, en cualquier lugar de la plancha, no debe exceder del 30% del espesor nominal de la plancha.

2.1.4.2.1. Las orillas de las planchas pueden acondicionarse por el fabricante para eliminar imperfecciones superficiales, mediante cincelado, esmerilado o "arco-aire" y un posterior depósito de soldadura (ver inciso 2.1.5). Antes del depósito de soldadura la profundidad de la depresión, medida a partir de la orilla de la plancha hacia adentro debe limitarse al espesor de la plancha con una profundidad máxima de 25 mm.

2.1.4.3. Perfiles estructurales, perfiles-barra y tablaestacas.

Los perfiles estructurales, perfiles-barra y tablaestacas, pueden acondicionarse por el fabricante, eliminando los defectos perjudiciales de la superficie o depresiones, mediante un esmerilado o cincelado y esmerilado, previendo que el área esmerilada quede limpia, sin cambios bruscos en su contorno y que las depresiones abajo de la superficie de laminación del perfil no sean mayores de:

a) 0.79 mm para materiales con espesor menor de 9.53 mm.

b) 1.59 mm para materiales con espesor de 9.53 mm hasta 50.80 mm.

c) 3.18 mm para materiales con espesor mayor de 50.80 mm.

2.1.4.3.1. Los defectos superficiales con profundidad mayor a los límites antes citados (a,b y c) pueden eliminarse por cincelado o esmerilado, y un posterior depósito de soldadura (ver inciso 2.1.5), sujeto todo esto a las siguientes limitaciones:

a) El área total de la superficie cincelada o esmerilada de cualquier pieza antes del depósito de soldadura, no debe exceder del 2% del -

b) La disminución del espesor del material, resultado de la eliminación de los defectos en cualquier lugar, antes de proceder a depositar la soldadura, no debe exceder del 30% del espesor de pared nominal en el lugar del defecto, ni la profundidad de la depresión, antes de soldar, debe ser mayor de 32 mm en cualquier caso, excepto lo indicado en C.

c) La raíz de los ángulos, de las vigas, de las canales y las zetas; así como las almas y las raíces de las tes, pueden acondicionarse por esmerilado, cincelado o "arco-aire" y un posterior depósito de soldadura. Antes de depositar la soldadura debe verificarse que la profundidad de la depresión, medida desde la parte interior de la raíz, debe limitarse por los espesores del material en la base de la depresión, con una profundidad máxima de 13 mm.

d) Las conexiones de las tablaestacas pueden acondicionarse, soldando (ver inciso 2.1.5), y esmerilando, para reparar o reconstruir cualquier parte de la conexión, siempre y cuando, el área reparada o reconstruida no excede del 2% del área total.

2.1.4.4. Barras

2.1.4.4.1. Las barras pueden acondicionarse por el fabricante, eliminando los defectos superficiales, mediante esmerilado o cincelado o cualquier otro medio, previendo que el área esmerilada o cincelada quede limpia y que el área de la sección afectada no se reduzca en más de las tolerancias indicadas en 2.1.3.5.

2.1.4.4.2. Las imperfecciones mayores en profundidad que las limitaciones indicadas en 2.1.4.4. pueden eliminarse por cincelado o esmerilado y un posterior depósito de soldadura (ver inciso 2.1.5) sujeto todo esto a las siguientes limitaciones.

a) El área total de la superficie esmerilada o cincelada de cualquier pieza antes de soldar, no debe exceder del 2% del área total de la superficie de la pieza.

b) La disminución de la dimensión de la sección de una barra redonda, cuadrada o hexagonal o la reducción en espesor de una solera, resultado de la eliminación de una imperfección, antes del depósito de soldadura, no debe exceder del 5% de las dimensiones nominales o espesor en el lugar donde se presento la imperfección.

c) En las orillas de las soleras la profundidad de la depresión de acondicionamiento, antes del depósito de soldadura, debe medirse a partir de las orillas hacia adentro, y debe limitarse a una profundidad máxima igual al espesor de la solera o a 13 mm, lo que sea menor.

2.1.5. Reparación por soldadura

2.1.5.1. Aceros al carbono y aceros de alta resistencia y de baja aleación.

2.1.5.1.1. Todas las soldaduras para aceros al carbono y para aceros de alta resistencia y de baja aleación deben ejecutarse por soldadores calificados, usando electrodos de bajo carbono, de acuerdo con las series adecuadas (ver inciso 5.1 del apéndice). Los electrodos deben protegerse de la humedad durante su almacenamiento y uso.

2.1.5.1.2. El fabricante debe establecer y seguir procedimientos de soldadura aprobados, y adecuados al material a soldar.

2.1.5.2. Acero aleado

2.1.5.2.1. Cuando se especifique en la orden de compra, para realizar reparaciones por soldadura, debe obtenerse antes la aprobación del comprador.

2.1.5.2.2. El fabricante debe establecer y seguir los procedimientos de soldadura aprobados y apropiados para el material a soldar.

Cuando el comprador lo especifique en la orden de compra, los procedimientos deben ser aprobados por el comprador y los soldadores deben ser calificados para realizar dichos procedimientos.

2.1.5.2.3. Después de la eliminación completa del defecto y antes de soldar, la cavidad debe examinarse mediante el método de inspección con partículas magnéticas o líquidos penetrantes, a fin de asegurarse que la imperfección ha sido eliminada totalmente. Cuando se use la inspección con partículas magnéticas la cavidad debe examinarse en sentido paralelo y normal a la longitud de la cavidad.

2.1.5.2.4. Los electrodos deben protegerse de la humedad durante su almacenamiento y uso.

2.1.5.2.5. Los electrodos y el metal base deben estar libres de hidrógeno producido por contaminantes tales como aceite, grasa u otros materiales orgánicos. El material base debe mantenerse seco durante la operación de soldadura.

2.1.5.2.6. Para materiales tratados térmicamente, todas las soldaduras deben realizarse usando el proceso de soldadura de arco con electrodos protegidos o en atmósfera de gas inerte ver inciso 5.1., del apéndice. Los electrodos deben seleccionarse de manera que el metal depositado sea compatible con las propiedades mínimas del metal base.

El contenido de humedad no debe exceder del nivel tolerable para el metal base.

Para el proceso de gas inerte, la composición del metal depositado debe ser compatible con las propiedades mínimas especificadas para el metal base. Los gases usados para la protección deben ser de calidad de soldadura.

Cuando las reparaciones por cualquiera de los dos procesos mencionados, vayan a ser tratadas térmicamente, debe tenerse especial cuidado en la selección de los electrodos a fin de evitar aquellas composiciones que den fragilidad como resultado del tratamiento térmico.

2.1.5.2.7. La zona afectada por el calor, en los aceros aleados templados y revenidos, puede ser afectada adversamente por calor excesivo o precalentamiento excesivo o ambos. Similarmente un precalentamiento y aplicación de calor insuficiente en la soldadura para aceros aleados templados y revenidos, pueden dar como resultado defectos indeseables; por tanto debe usarse una combinación adecuada de aplicación de calor y precalentamiento (incluyendo temperaturas de interpaso).

2.1.5.2.8. Para material que va a ser templado y revenido después de la reparación por soldadura, los electrodos de soldadura deben seleccionarse de manera que la soldadura depositada, cumpla con las propiedades mecánicas del metal base, después del tratamiento térmico.

2.1.5.2.9. Las reparaciones sobre material que posteriormente vaya a ser tratado térmicamente, deben examinarse después del tratamiento térmico. Las reparaciones sobre material que no va a ser posteriormente, tratado térmicamente en la fábrica, debe ser examinado después de 48 horas.

En cualquier caso el área reparada debe examinarse por cualquiera de los métodos indicados en 2.1.5.2.3.

2.1.5.2.10. La localización de las reparaciones por soldadura deben marcarse en la pieza terminada.

5.1.5.3. Calidad de la reparación por soldadura.

Las soldaduras y las zonas adyacentes afectadas por el calor deben estar sanas y libres de grietas, el metal de la soldadura debe estar totalmente fundido y todas las superficies y orillas sin socavaciones o sobremontas, cualquier grieta visible, porosidad, falta de fusión o socavación en cualquier cordón de soldadura, debe eliminarse antes de depositar el siguiente cordón. El metal depositado de soldadura debe sobresalir como mínimo 1.6 mm arriba de la superficie laminada y el material sobresaliente debe eliminarse por cincelado y/o esmerilado hasta nivelarlo con la superficie laminada y lograr así un buen acabado.

2.1.5.4. Inspección de las reparaciones.

El fabricante debe mantener un programa de inspección de acuerdo con lo siguiente:

1. Las imperfecciones deben removerse completamente.

2. No deben excederse las limitaciones establecidas en esta Norma.

3. Deben seguirse los procedimientos de soldadura establecidos.

4. Cualquier depósito de soldadura debe ser de la calidad establecida anteriormente.

2.2. ESPECIFICACIONES DEL MARCADO

2.2.1. Planchas

Cada una de las planchas debe marcarse por estampado, troquelado o pintado, con el número de la colada, el nombre del fabricante o marca registrada, tamaño y espesor; a menos que se especifique otra cosa, tales marcas, en el caso de paquetes perfectamente asegurados, de planchas con espesor de 9.52 mm (en caso que se especifique material para la construcción de puentes debe considerarse 7.93 mm en lugar de 9.52 mm) de espesor y menores, en todos los tamaños y de planchas con anchos de 914.40 mm y menores en todos los espesores, pueden marcarse por estampado o pintado de la plancha superior de cada paquete o bien anotando todos los datos en una tarjeta o etiqueta atada a cada paquete.

2.2.2. Perfiles estructurales y barras perfil.

Cada uno de los perfiles estructurales y barras perfil, debe marcarse con el número de colada, tamaño de la sección, longitud y marcas de identificación de la laminación. El nombre del fabricante o marca registrada debe marcarse con letras realzadas a intervalos a lo largo de toda la longitud, con excepción de aquellos perfiles estructurales y barras perfil, pequeños, cuya dimensión más grande de su sección transversal no sobrepase de 127 mm, que pueden embarcarse en atados, en cuyo caso pueden identificarse mediante una tarjeta o etiqueta sujeta a cada atado.

2.2.3. Tablaestacas

Cada tablaestaca de acero al carbono debe marcarse con el número de colada, nombre del fabricante o marca registrada, tamaño de la sección, longitud y marcas de identificación de la laminación.

2.2.4. Barras

Las barras en atados perfectamente aseguradas, deben identificarse mediante una tarjeta con los siguientes datos: número de la orden de compra, grado o especificación, tamaño, longitud, peso del atado y número de colada. Las barras no necesitan estamparse con dado.

2.3. ESPECIFICACIONES DEL EMBALAJE

Deben ser motivo de acuerdo previo entre fabricante y comprador.

3. MUESTREO

3.1. ESPECIMENES DE PRUEBA

1. Los especímenes de prueba deben prepararse del material en su condición de entrega, excepto los especímenes para materiales tratados térmicamente que pueden proceder: del material ya tratado térmicamente y listo para su uso, de piezas preparadas con el espesor total o a la sección completa con tratamiento térmico similar.

2. Los especímenes deben tomarse longitudinalmente y a excepción de lo especificado en 3.3. deben ser del espesor total o de la sección completa del material tal como se entrega.

9.-

3.1.3. Los especímenes deben tomarse de las almas de las vigas, canales y zetas; de las alas de los ángulos y ángulos de bulbo así como de las almas de las secciones T laminadas.

3.1.4. Los especímenes para pruebas de tensión y doblado de barras que vayan a usarse como pasadores y rodillos, menores de 76 mm de diámetro, deben tomarse de modo que el eje quede a la mitad entre el centro y la superficie. Los especímenes para la prueba de tensión y doblado para pasadores y rodillos de 76 mm y mayores en diámetro, deben tomarse de manera que el eje quede a 25 mm de la superficie.

Los especímenes de prueba para las planchas deben tomarse de las esquinas de las mismas.

3.2. NUMERO DE PRUEBAS

3.2.1. Análisis de cuchara

Se debe realizar un análisis de cada colada de acero, en muestras tomadas durante el vaciado de la misma.

3.2.2. Análisis de producto (comprobación)

Se debe realizar un análisis en una muestra tomada del material terminado procedente de cada colada.

3.2.3. Deben realizarse dos pruebas de tensión y dos de doblado de cada colada y de cada grado de resistencia con las siguientes excepciones:

a) Cuando el material terminado procedente de una colada o de un mismo grado de resistencia, sea menor de 50 toneladas, en cuyo caso se considera suficiente una prueba de tensión y una de doblado.

b) Cuando el material terminado, con espesor de 50.80 mm y menor, procedente de una colada o de un mismo grado de resistencia, difiera 9 mm o más en espesor, en cuyo caso se deben hacer una prueba de tensión y una de doblado, tanto del material más grueso como del más delgado, independientemente del peso que representen.

c) Cuando el material terminado, con espesor mayor de 50.80 mm, procedente de una colada o de un mismo grado de resistencia, difiera 25.4 mm o más en espesor, en cuyo caso se deben hacer una prueba de tensión y una de doblado, tanto del material más grueso como del más delgado, independientemente del peso que representen.

3.3. PREPARACION DE LOS ESPECIMENES

3.3.1. Los especímenes para las pruebas de tensión de perfiles, soleras y planchas, con excepción de las planchas de acero aleado que tengan un espesor mayor de 38.10 mm, pueden maquinarse de acuerdo a la forma y dimensiones indicadas en la fig. 1 o con ambos cantos paralelos (fig. 4, Nota 2 de la Norma B 172 en vigor).

3.3.2. Los especímenes para pruebas de tensión de material mayor de 38.10 mm de espesor o diámetro, con excepción de las planchas y barras de acero aleado que se vayan a usar como pasadores y rodillos pueden maquinarse a un espesor o diámetro no menor de 19.05 mm para una longitud de la sección reducida no menor de 226.60 mm.

3.3.3. Los especímenes para pruebas de tensión para materiales mayor de 19.05 mm en espesor o diámetro, pueden maquinarse de acuerdo a la forma o dimensiones indicadas en la fig. 2. Los especímenes para pruebas de tensión de planchas de acero aleado mayores de 38.10 mm de espesor y para barras que se vayan a usar como pasadores o rodillos, deben maquinarse conforme a la forma y dimensiones indicadas en la fig. 2.

3.3.4. Con excepción de lo indicado en 3.3.5. y 3.3.6., los especímenes para pruebas de doblado de perfiles, soleras y planchas, deben tener un ancho mínimo de 31.7 mm, ambas orillas paralelas y pueden ser preparados por maquinado, cortados con cizalla o cortados con gas.

3.3.5. Los especímenes para pruebas de doblado de planchas de acero aleado con espesor mayor de 19.05 mm y para cualquier otro material con espesor o diámetro mayor de 38.10 mm, excepto las barras que se vayan a usar como pasadores o rodillos, pueden maquinarse a un espesor o diámetro no menor de 19.05 mm o bién a una sección transversal rectangular de 25.40 x 12.70 mm. Cuando la prueba se efectúa en un espécimen de espesor reducido, la superficie de laminación debe quedar en la parte exterior de la porción doblada.

3.3.6. Los especímenes para prueba de doblado para barras que se vayan a usar como pasadores o rodillos deben tener una sección transversal rectangular de 25.4 x 12.7 mm.

3.3.7. Los lados de los especímenes para pruebas de doblado, pueden tener las esquinas redondeadas a un radio no mayor de 1.6 mm para especímenes con espesor de 50.80 mm y menor y mayor de 3.18 mm para especímenes con espesor mayor de 50.80 mm.

3.4. REPETICION DE PRUEBAS

3.4.1. Si cualquier espécimen de prueba muestra defectos de maquinado o revelado imperfecciones, debe descartarse y sustituirse por otro.

3.4.2. Si en cualquier espécimen probado a la tensión, el porcentaje de alargamiento es menor que el especificado y/o la fractura se localiza a más de 19 mm del centro de la longitud calibrada de un espécimen de 50 mm o a más de 50 mm de un espécimen de 200 mm, se debe repetir la prueba.

3.4.3. Si los resultados en un espécimen probado a la tensión se encuentran: dentro de 1.4 kg/mm^2 del valor de la resistencia a la tensión especificada, dentro de 0.70 kg/mm^2 del límite de fluencia especificado o dentro de dos unidades del porciento de alargamiento especificado, se permite realizar otra prueba en un espécimen tomado al azar del mismo lote o colada. Si los resultados de esta nueva prueba cumplen con lo especificado, la colada o lote debe aceptarse.

3.4.4. Si un espécimen sometido a la prueba de doblado falla, debido a condiciones de doblez más severas que las especificadas en la Norma particular del producto, se permite repetir la prueba.

3.4.5. Las planchas de acero aleado deben cumplir con las pruebas adicionales especificadas en la Norma particular del producto.

3.4.6. Si un espécimen cortado con cizalla o con gas, falla debido a las condiciones de corte, se permite realizar otra prueba, sobre un espécimen maquinado.

3.5. CRITERIO DE ACEPTACION

3.5.1. A menos que se especifique otra cosa, cualquier rechazo basado en el análisis de producto (comprobación), realizado de acuerdo a la Norma particular del producto, debe reportarse al fabricante dentro de los 10 días hábiles contados a partir del recibo de las muestras por el comprador.

3.5.2. Las muestras que representan material rechazado, deben conservarse dos semanas contadas a partir de la fecha del reporte de la prueba, el fabricante puede pedir una nueva revisión dentro de ese tiempo.

3.5.3. Los materiales que muestren defectos perjudiciales, posteriores a su aceptación en la fábrica, deben rechazarse notificando al fabricante.

3.6. INSPECCION

El inspector representante del comprador debe tener libre acceso, mientras se esté fabricando el material objeto del contrato, a todas las partes de la fábrica relacionadas con la manufactura del material ordenado. El fabricante debe dar al inspector todas las facilidades razonables para satisfacerlo de que el material es elaborado de acuerdo con esta Norma. A menos que se especifique otra cosa, todas las pruebas e inspección (excepto el análisis de comprobación) deben realizarse en la fábrica, antes del embarque, de manera tal que no interfieran con las operaciones de la planta.

4. METODOS DE PRUEBA

4.1. COMPOSICION QUIMICA

Para verificar la composición química tanto en el análisis de cuchara como en el de producto, se deben seguir los métodos de análisis indicados en la Norma B 1 en vigor.

4.2. REQUISITOS DE TENSION Y DE DOBLADO

Para verificar los requisitos de tensión y de doblado, se deben seguir los métodos de prueba indicados en la Norma B 172 en vigor.

5. APENDICE

5.1. OBSERVACIONES

Los requisitos especificados en esta Norma son aplicables a las siguientes Normas:

B 254 "Acero Estructural"

B 263 "Acero estructural para locomotoras y carros"

B 262 "Acero estructural para barcos"

B 281 "Placas de acero al carbono de calidad estructural, de resistencia a la tensión baja e intermedia"

B 282 "Acero estructural de baja aleación y alta resistencia"

B 285 "Acero estructural de alta resistencia"

B 284 "Acero estructural de alta resistencia y baja aleación al manganeso vanadio"

5.2. NORMAS A CONSULTAR

B 1 1970 "Métodos de análisis químico para determinar la composición de aceros y fundiciones"

B172 1969 "Métodos de prueba mecánicos para productos de acero"

5.3. BIBLIOGRAFIA

ASTM A 6 1971

5.4. PARTICIPANTES

Centro de Investigación de Materiales de la UNAM

Estructuras Fabriles, S.A.

Comisión Federal de Electricidad

Altos Hornos de México, S.A.

Instituto Mexicano del Petróleo

Secretaría de Obras Públicas

Fundidora Monterrey, S.A.

Hojalata y Lámina, S.A.

Departamento del Distrito Federal.

TABLA A. PERFILES ESTRUCTURALES AGRUPADOS POR PROPIEDADES DE TENSION

Estructural	Grupo 1	Grupo 2	Grupo 3	Grupo 4	Grupo 5
s W	[illegible] W 53 Y 113 W 46 X 114 hasta 152 W 46 X 90 W 41 X 66 hasta 127 W 36 X 56 hasta 135 W 30 X 36 hasta 147 W 25 X 29 hasta 114 W 20 X 25 hasta 122 W 15 X 22 hasta 64 W 13 X 41 hasta 47 W 10 X 33	W 91 Y 343 hasta 493 W 84 X 300 hasta 386 W 76 X 251 hasta 533 W 69 X 213 hasta 450 W 61 X 173 hasta 406 W 53 X 140 hasta 361 W 46 X 163 hasta 290 W 41 X 147 hasta 244 W 36 X 155 hasta 245 W 30 X 165 hasta 269 W 25 X 124 hasta 284 W 20 X 147 hasta 170	W 91 X 584 hasta 762 W 84 X 505 hasta 610 W 36 X 361 hasta 536 W 30 X 305 hasta 483	W 36 X 556 hasta 1397	W 36 X 1537 hasta
s M	Hasta 52 kg/m	Más de 52 kg/m			
os S	Hasta 52 kg/m	Más de 52 kg/m			
es HP		Hasta 152 kg/m	Más de 152 kg/m		
s estándar (c)	Hasta 31 kg/m	Más de 31 kg/m			
s misceláneos (MC)	Hasta 42 kg/m	Más de 42 kg/m			
s (estructural y barra).	Hasta 1.3 cm	Más de 1.3 cm hasta 1.9 cm	Más de 1.9 cm		

Las tes estructurales que procedan de perfiles W, M y S deben considerarse en el mismo grupo de perfiles estructurales de los cuales se cortan.

TABLA B. TOLERANCIA EN EL ANALISIS DE PRODUCTO PARA PLANCHAS, PERFILES DE TAMAÑO ESTRUCTURAL Y TABLESTACAS, DE ACERO AL CARBONO Y DE ALTA RESISTENCIA Y BAJA ALEACION (a)

Elemento	Límite superior o máximo del rango especificado, %	Tolerancias en %	
		en menos, límite mínimo	en más, límite máximo
Carbono	Hasta 0.15	0.02	0.03
	Más de 0.15 hasta 0.40	0.03	0.04
Manganeso	Hasta 0.60	0.03	0.03
	Más de 0.60 hasta 1.15	0.04	0.04
	Más de 1.15 hasta 1.65	0.05	0.05
Fósforo			0.010
Azufre			0.010
Silicio	Hasta 0.30	0.02	0.03
	Más de 0.30 hasta 1.00	0.05	0.05
Cobre	Abajo del mínimo únicamente	0.02	

(a) La tolerancia en el análisis de producto para elementos de aleación de aceros de alta resistencia y baja aleación, ver Tabla C.

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TABLA C. TOLERANCIAS EN ANALISIS DE PRODUCTO (planchas de acero aleado)

Elemento	Límite o máximo del elemento especificado, en %	Tolerancias en más del límite máximo o en menos del límite mínimo, en %
Carbono	Hasta 0.30	0.02
Manganeso	Hasta 0.90 Más de 0.90 hasta 2.10	0.04 0.05
Fósforo	Más sobre el máximo únicamente	0.01
Azufre	Hasta 0.060 y más, máximo solamente.	0.01
Silicio	Hasta 0.40 Más de 0.40 hasta 2.20	0.02 0.06
Níquel	Hasta 1.00 Más de 1.00 hasta 2.00	0.03 0.05
Cromo	Hasta 0.90 Más de 0.90 a 2.10	0.04 0.06
Molibdeno	Hasta 0.20 Más de 0.20 hasta 0.40 Más de 0.40 hasta 1.15	0.01 0.03 0.04
Cobre	Hasta 1.00 Más de 1.00 hasta 2.00	0.03 0.05
Titanio	Hasta 0.10	0.01 (a)
Vanadio	Hasta 0.10 Más de 0.10 hasta 0.25 Este valor se especifica únicamente para análisis de comprobación.	0.01 (a) 0.02 0.01
Boro	No se especifican	
Columbio	Hasta 0.10	0.01 (a)
Zirconio	Hasta 0.15	0.03
Nitrógeno	Hasta 0.030	0.005

(a) Si el intervalo mínimo es 0.01 %, la tolerancia en menos es 0.005 %.

TABLA D. TOLERANCIAS EN EL ANALISIS DE PRODUCTO PARA BARRAS Y PERFILES BARRA DE ACERO AL CARBONO Y DE ALTA RESISTENCIA Y BAJA ALEACION (a)

E l e m e n t o	Límite o intervalo máximo, en %	Tolerancia en más, límite máximo o en menos, límite mínimo, en %
Carbono	Hasta 0.25 Más de 0.25 hasta 0.55	0.02 0.03
Manganeso	Hasta 0.90 Más de 0.90 hasta 1.65	0.03 0.06
Fósforo	Sobre el máximo únicamente.	0.008
Azufre	Sobre el máximo únicamente.	0.008
Silicio	Hasta 0.35 Más de 0.35 hasta 0.60	0.02 0.05
Cobre	Abajo del mínimo únicamente	0.02

(a) Las tolerancias en análisis de producto para elementos de aleación de aceros de alta resistencia y baja aleación, ver Tabla E.

TABLA E. TOLERANCIAS EN EL ANALISIS DE PRODUCTO PARA BARRAS Y PERFILES BARRA DE ACERO ALEADO

Elemento	Límite o intervalo máximo, en %	Tolerancia en más del límite máximo o en menos del límite mínimo, en %.
Níquel	Hasta 1.00 Más de 1.00 hasta 2.00	0.03 0.05
Cromo	Hasta 0.90 Más de 0.90 hasta 2.10	0.03 0.05
Molibdeno	Hasta 0.20 Más de 0.20 hasta 0.40	0.01 0.02
Cobre	Hasta 1.00 Más de 1.00 hasta 2.00	0.03 0.05
Titanio	Hasta 0.10	0.01 (a)
Vanadio	Hasta 0.10 Más de 0.10 hasta 0.25	0.01 (a) 0.02
Columbio	Hasta 0.10	0.01 (a)
Zirconio	Hasta 0.15	0.03
Nitrógeno	Hasta 0.030	0.005

(a) Si el intervalo mínimo es 0.01 %, la tolerancia en menos es 0.005 % .

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TABLA 1

[illegible] Y [illegible] PARA PLANCHAS RECTANGULARES, EN ANCHOS DE LAMINACION Y CORTADAS CON CIZALLA, DE [illegible] Y MENOR[illegible] SOR, CUANDO SE ORDENEN POR ESPESOR

[illegible], en mm (a)	Tolerancia en más, en el promedio del peso del lote[b], expresada en % de los pesos nomina[illegible] para los anchos en mm siguientes:									
	Menores de 1219	Mayores de 1219 a 1524 excl	De 1524 a 1829 excl	De 1829 a 2134 excl.	De 2134 a 2438 excl	De 2438 a 2743 excl	De 2743 a 3084 excl.	De 3084 a 3353 excl.	De 3353 a 3658 excl.	De 3658 a 4267 excl	D[illegible]
6.4 excl.	6.0	7.0	8.0	8.5	10.5	12.0	14.0	16.0	18.5	-----	
6.4 a 7.9 excl	6.0	6.0	7.0	8.0	8.5	10.5	12.0	14.0	16.5	19.5	
7.9 a 9.5 excl	5.0	6.0	6.0	7.0	8.0	8.5	10.5	12.0	15.0	17.0	
9.5 a 11.1 excl	4.5	5.0	6.0	6.0	7.0	8.0	8.5	11.0	13.0	15.0	
1.1 a 12.7 excl	4.0	4.5	5.0	6.0	6.0	7.0	8.0	9.5	11.0	13.0	
2.7 a 15.9 excl	4.0	4.0	4.5	5.0	6.0	6.0	7.0	8.0	9.5	11.0	
5.9 a 19.1 excl	4.0	4.0	4.0	4.5	5.0	6.0	6.0	7.0	8.0	9.0	
9.1 a 25.4 excl	3.5	4.0	4.0	4.0	4.5	5.0	6.0	6.0	7.0	8.0	
5.4 a 50.8 excl	3.5	3.5	4.0	4.0	4.0	4.5	5.0	6.0	6.0	7.0	
0.8 a 76.2 excl	3.5	3.5	3.5	4.0	4.0	4.5	5.0	6.0	6.0	6.5	
76.2 a 101.6 excl	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.0	4.5	
01.6 a 152.4 excl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5	
52.4 a 203.2 excl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
03.2 a 254.0 excl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
54.0 a 304.8 excl	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
4.8 a 381.0 incl	2.5	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	

a tolerancia en menos en el espesor, es de 0.25 mm.

l término "lote" se aplica a todas las planchas de cada grupo, del mismo ancho y espesor, representadas en cada embarque.

1. La tolerancia en sobrepeso para lotes de planchas circulares y de plantilla, es de 1.25 veces las cantidades de esta T[illegible]

2. La tolerancia en sobrepeso para planchas aisladas, es de 1.33 veces las cantidades de esta Tabla.

3. La [redacted]ncia en sobrepeso para las planchas circular[illegible] de plantilla, aisladas, es de 1.66 veces las c[illegible]dades de e[illegible] Tabla.

T A B L A II

TOLERANCIAS EN EL ESPESOR PARA PLANCHAS RECTANGULARES, EN ANCHOS DE LAMINACION, MAYORES DE 50.80 mm DE ESPESOR (aplicable únicamente a acero aleado)

Espesor, en mm	Tolerancia en más, en mm, sobre el espesor nominal para los anchos en mm siguientes:					
	Hasta 914.40 excl	De 914.40 a 1524 - excl	De 1524 a 2133- excl	De 2133 a 3048 excl	De 3048 a 3352- excl	De 3353 o más.
Mayores de 50.80 hasta 76.20 excl	1.59	2.38	2.78	3.18	3.18	3.57
De 76.20 hasta 101.60 excl	1.98	2.38	2.78	3.18	3.18	3.57
De 101.60 y mayores	2.38	3.18	3.57	3.57	3.97	4.37

NOTAS:

1. La tolerancia en menos sobre el espesor nominal no debe ser mayor de 0.25 mm.
2. Estas tolerancias se aplican únicamente cuando el espesor se mide a 9.5 mm de las orillas longitudinales de las planchas.
3. Cuando la tolerancia en espesor se limite por la tolerancia en sobrepeso, apliquese la Tabla I.

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TABLA III

[illegible] PLANCHAS RECTANGULARES, EN ANCHOS DE LAMINACION Y CORTADAS CON CIZALLA, DE HASTA 2988 Kg/m², CUANDO SE [illegible] POR PESO (no aplicables a acero aleado)

Espesores Kg/m² De	a excl	Tolerancias en el promedio del peso del lote, (a) expresadas en % de los pesos nominales, para los anchos siguientes: De 1219 y mayores		Mayores de 1219 a 1524 excl		De 1524 a 1829 excl		De 1829 a 2136 excl		De 2136 a 2438 excl		De 2438 a 2743 excl		De 2743 a 3048 excl		De 3048 a 3353 excl		De 3353 a 3658 excl		De 3658 a 4140 excl		De 41[illegible] mayo[illegible]
-	49	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	9.0	3.0	---	---	---	---	---	---	---
[illegible]	51	4.5	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.5	3.0	7.0	3.0	8.0	3.0	9.0	3.0	---	---	---
	73	[illegible]	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	8.0	3.0	11.0	3.0	---
[illegible]	[illegible]	[illegible]	[illegible]	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.0	3.0	9.0	3.0	10.0
[illegible]	[illegible]	[illegible]	[illegible]	3.5	2.5	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	8.0	3.0	9.0
[illegible]	122	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	7.0	3.0	8.0
[illegible]	146	3.0	2.5	3.5	2.5	3.5	2.5	2.5	3.0	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	6.5	3.0	7.0
[illegible]	195	3.0	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.5	3.5	2.5	4.0	3.0	4.5	3.0	6.0	3.0	6.5
[illegible]	390	2.5	1.5	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	4.0	3.0	5.5	3.0	6.0
[illegible]3	553	2.5	1.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.5
[illegible]	797	2.5	1.0	2.5	1.5	2.5	1.5	2.5	1.5	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	3.0	2.0	3.5
[illegible]	1195	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0	3.5
[illegible]5	1594	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0
[illegible]	1997	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0
[illegible]2	2390	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5
[illegible]0	2988	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5

[illegible] término lote se aplica a todaslas planchas de cada grupo, del mismo ancho y espesor, representadas en cada embarque.

1. La tolerancia en sobrepeso para lotes de planchas circulares y de plantilla, debe ser 1.25 veces las cantidades de esta
2. La tolerancia en sobrepeso para planchas aisladas debe ser como máximo 1.33 veces las cantidades de esta Tabla.
3. La tolerancia en sobrepeso para planchas circulares y de plantilla, aisladas, debe ser 1.66 veces las cantidades de esta Tabla.

ANCIAS EN ANCHO Y LONGITUD PARA PLANCHAS DE 38.10 mm Y MENORES EN ESPESOR, CORTADAS CON CIZALLA; EN LONGITUD SOLAMENTE SE API
CAN A PLANCHAS DE 63.50 mm Y MENORES EN ESPESOR, EN ANCHOS DE LAMINACION

Dimensiones en m			Tolerancias en más[a], en mm, sobre el ancho y la longitud, para espesores en mm y pesos equivalentes, en kg/m^2 siguientes:							
			ESPESORES							
LONGITUD	ANCHO		Hasta 9.53 excl		De 9.53 a 15.90 excl		De 15.90 a 25.40 excl		De 25.40 a 50.80 incl	
			PESOS							
			Hasta 75 excl		De 75 hasta 125 excl		De 125 hasta 199 excl		De 199 hasta 398 incl	
a exclusive	De	a exclusive	Ancho	Longitud	Ancho	Longitud	Ancho	Longitud	Ancho	Longitud
3.05	----	1.52	9.5	12.7	11.1	15.9	12.7	19.1	15.9	25.4
	1.52	2.13	11.1	15.9	12.7	17.5	15.9	22.2	19.1	25.4
	2.13	2.74	12.7	19.1	15.9	22.2	19.1	25.4	25.4	28.6
	2.74	----	15.9	22.2	19.1	25.4	22.2	28.6	28.6	31.8
6.10	----	1.52	9.5	19.1	12.7	22.2	15.9	25.4	19.1	28.6
	1.52	2.13	12.7	19.1	15.9	22.2	19.1	25.4	22.2	31.8
	2.13	2.74	14.3	22.2	17.5	23.8	20.6	28.6	25.4	34.9
	2.74	----	15.9	25.4	19.1	28.6	22.2	31.8	28.6	34.9
9.14	----	1.52	9.5	25.4	12.7	28.6	15.9	31.8	19.1	38.1
	1.52	2.13	12.7	25.4	15.9	28.6	19.1	31.8	22.2	38.1
	2.13	2.74	14.3	25.4	17.5	31.8	22.2	34.9	25.4	38.1
	2.74	----	17.5	28.6	22.2	31.8	25.4	34.9	31.8	44.5
12.19	----	1.52	11.1	28.6	12.7	31.8	15.9	34.9	19.1	41.3
	1.52	2.13	12.7	31.8	15.9	34.9	19.1	38.1	25.4	41.3
	2.13	2.74	14.3	31.8	19.1	34.9	22.2	38.1	25.4	47.6
	2.74	----	19.1	34.9	22.2	38.1	25.4	41.3	31.8	47.6
15.24	----	1.52	11.1	31.8	12.7	38.1	15.9	41.3	19.1	47.6
	1.52	2.13	12.7	34.9	15.9	38.1	19.1	41.3	22.2	47.6
	2.13	2.74	15.9	34.9	19.1	38.1	22.2	41.3	25.4	47.6
	2.74	----	19.1	38.1	22.2	41.3	25.4	44.5	31.8	47.6
18.29	----	1.52	12.7	44.5	15.9	47.6	19.1	47.6	22.2	57.2
	1.52	2.13	15.9	44.5	19.1	47.6	22.2	47.6	25.4	57.2
	2.13	2.74	15.9	44.5	19.1	47.6	22.2	47.6	28.6	57.2
	2.74	----	22.2	44.5	25.4	50.8	28.9	57.2	31.8	63.5

TABLA IV (CONTINUACION)

Dimensiones en m				Tolerancias en más [a], en mm, sobre el ancho y la longitud, para espeso[illegible] en mm y pesos equivalentes, en kg/m² siguientes:							
				ESPESORES							
				Hasta 9.53 excl		De 9.53 a 15.90- excl		De 15.90 a 25.40- excl		De 25.40 a [illegible] incl	
				PESOS							
LONGITUD		ANCHO		Hasta 75 excl		De 75 hasta 125- excl		De 125 hasta 199 excl		De 199 hasta incl	
	a exclusive	De	a exclusive	Ancho	Longitud	Ancho	Longitud	Ancho	Longitud	Ancho	Lon[illegible]
29	----	----	1.52	14.3	50.8	19.1	54.0	22.2	57.2	25.4	6[illegible]
		1.52	2.13	19.1	50.8	22.2	54.0	25.4	57.2	28.6	6[illegible]
		2.13	2.74	19.1	50.8	22.2	54.0	25.4	57.2	31.8	6[illegible]
		2.74	----	25.4	50.8	28.6	60.3	31.8	63.5	34.9	7[illegible]

.a tolerancia en menos sobre el ancho y la longitud especificada debe ser 6.4 mm.

.a tolerancia en longitud se aplica también a planchas con ancho de laminación hasta de 304.8 mm y espesores mayores de 5[illegible] hasta 63.5 mm, con excepción de las de acero aleado donde el espesor máximo debe ser de 44.5 mm.

TABLA V

TOLERANCIAS EN ANCHO PARA PLANCHAS CON ANCHOS DE LAMINACION EN ROLLOS Y PARA PLANCHAS CORTADAS EN TRAMOS PRODUCIDAS EN MOLINO DE TIRA (no aplicables a acero aleado)

Ancho, en mm De	 a exclusive	Tolerancia, en más, en mm (a), (b)
-----	355.6	11.1
355.6	431.8	12.7
431.8	482.6	14.3
482.6	533.4	15.9
533.4	609.6	17.5
609.6	660.4	20.6
660.4	711.2	23.8
711.2	889.0	28.6
889.0	1270	31.8
1270	1524	38.1
1524	1651	41.3
1651	1778	44.5
1778	2032	47.6
2032	----	50.8

a) No hay tolerancia en menos para el ancho.

b) Esta tolerancia no se aplica a las planchas en rollo con orillas de molino, sin recortar.

TABLA VI

TOLERANCIA EN EL ANCHO PARA PLANCHAS EN ANCHO DE LAMINACION, HASTA DE 381 mm DE ESPESOR

Ancho, en mm		Tolerancia en más, en mm, sobre el ancho (a), para espesores en mm y pesos equivalentes en kg/m² siguientes:					
		ESPESORES					
		Hasta 9.5 excl	De 9.5 a 15.9 excl	De 15.9 a 25.4 excl	De 25.4 a 50.8 excl	Mayor de 50.8 a 254.0 incl	Mayor de 254.0 a 381.0 incl
		PESOS					
De	a exclusive	Hasta 75 excl	De 75 a 125 excl	De 125 a 199 excl	De 199 a 398 incl	Mayor de 398 a 1992 incl	Mayor de 1992 a 2988 incl
203.2	508.0	3.18	3.18	4.76	6.35	9.53	12.70
508.0	914.4	4.76	6.35	7.94	9.53	11.11	14.29
914.4	-----	7.94	9.53	11.11	12.70	14.29	15.88

a) La tolerancia en menos para los anchos debe ser 3.2 mm.

T A B L A VII

TOLERANCIA EN EL DIAMETRO PARA PLANCHAS CIRCULARES, CORTADAS CON CIZALLA, HASTA DE 25.4 mm DE ESPESOR

Diámetros, en mm		Tolerancia en más (a), en mm, sobre el diámetro para los espesores en mm siguientes:		
De	a exclusive	A 9.5 excl	De 9.5 a 15.9 - excl	De 15.9 hasta - 25.4
-----	812.8	6.35	9.53	12.70
812.8	2133.6	7.94	11.11	14.29
2133.6	2743.2	9.53	12.70	15.88
2743.2	3302.0	11.11	14.29	17.46
3302.0	------	12.70	15.88	19.05

a) No hay tolerancia en menos.

T A B L A VIII

TOLERANCIA EN EL DIAMETRO PARA PLANCHAS CIRCULARES CORTADAS CON SOPLETE (no aplicables a acero aleado)

Diámetro, en mm		Tolerancias en más (a), en mm, sobre el diámetro, para los espesores en mm siguientes:					
De	a exclusive	A 25.4 excl	De 25.4 a 50.8 excl	De 50.8 a 101.6 excl	De 101.6 a 152.4 excl	De 152.4 a 203.2 excl	De 203.2 hasta - 381.0
-----	812.8	9.53	9.53	12.70	12.70	15.88	19.05
812.8	2133.6	9.53	12.70	12.70	15.88	19.05	22.23
2133.6	2743.2	12.70	14.29	15.88	19.05	22.23	25.40
2743.2	3302.0	12.70	14.29	17.46	22.23	25.40	28.58
3302.0	------	15.88	19.05	22.23	25.40	28.58	31.75

a) No hay tolerancia en menos para el diámetro.

T A B L A IX

TOLERANCIA EN ANCHO Y LONGITUD PARA PLANCHAS RECTANGULARES, DE ACERO ALEADO, CORTADAS CON SOPLETE

Espesor, en mm		Tolerancia en más (a), en mm, para todos los anchos o longitudes especificados.
De	a exclusive	
----	50.8	19.05
50.8	101.6	25.40
101.6	-----	28.58

a) Estas tolerancias pueden tomarse todas en menos o dividirse en más o en menos, según se requiera.

NOTA: Las planchas con orillas de molino pueden cortarse con soplete, únicamente a lo largo.

T A B L A X

TOLERANCIA EN ANCHO Y LONGITUD, PARA PLANCHAS RECTANGULARES, CORTADAS CON SOPLETE (no aplicables a acero aleado)

Espesor, en mm		Tolerancia en más[a], en mm, para todos los anchos o longitudes especificados
De	a exclusive	
-----	50.8	12.7
50.8	101.6	15.9
101.6	152.4	19.1
152.4	203.2	22.2
203.2	381.0	25.4

a) Estas tolerancias pueden tomarse todas en menos o dividirse en más o en menos, según se requiera.

NOTA: Las planchas con orillas de molino pueden cortarse con soplete, únicamente a lo largo.

T A B L A XI

TOLERANCIAS EN EL DIAMETRO PARA PLANCHAS CIRCULARES, DE ACERO ALEADO, CORTADAS CON SOPLETE

Diámetro, en mm		Tolerancias en más[a], en mm, para los diámetros especificados, para los espesores, en mm (*) siguientes:					
De	a exclusive	A 25.4 excl	De 25.4 a 50.8 excl	De 50.8 a 101.6 excl	De 101.6 a 152.4 excl	De 152.4 a 203.2 excl	De 203.2 hasta 381.0
-----	812.8	12.7	12.7	19.1	19.1	25.4	25.4
812.8	2133.6	12.7	15.9	22.2	25.4	28.6	31.8
2133.6	2743.2	15.9	19.1	25.4	28.6	31.8	34.9
2743.2	3302.0	22.2	25.4	28.6	31.8	44.5	38.1

a) No hay tolerancia en menos para el diámetro.

T A B L A XII

TOLERANCIAS EN FLECHA (CAMBER)* PARA PLANCHAS EN ANCHOS DE LAMINACION PARA ACEROS AL CARBONO, ALEADOS Y DE ALTA RESISTENCIA Y BAJA ALEACION Y PARA PLANCHAS RECTANGULARES CORTADAS CON CIZALLA Y CON SOPLETE DE ACEROS ALEADOS Y DE ALTA RESISTENCIA Y BAJA ALEACION

Espesores, en mm		Peso, en kg/m^2		Ancho, en mm	Tolerancia en flechas para espesores y anchos dados, en mm.
Mayor de	hasta	De	hasta		
----	50.8	---	398	Todos	2.1 x longitud en metros.
50.8	381.0	398	2988	Hasta 762.0	3.1 x longitud en metros.
50.8	381.0	398	2988	Mayor de 762.0 hasta 1524.0.	4.2 x longitud en metros.

* Flecha (camber)*, cuando se trate de planchas, es la curvatura horizontal de la orilla, medida sobre la longitud total de la plancha en una posición plana.

T A B L A XIII

..CIA EN FLECHA (CAMBER), PARA PLANCHAS CORTADAS CON CIZALLA Y PLANCHAS RECTANGULARES CORTADAS CON SOPLETE, DE ACERO AL ...
EN TODOS LOS ESPESORES

Flecha máxima, en mm	2.1 X longitud, en m

T A B L A XIV

..CIAS EN PLANEZA PARA PLANCHAS RECTANGULARES, DE ACERO AL CARBONO, EN ANCHOS DE LAMINACION, CIRCULARES Y CORTADAS CON PL...

...or, en mm		Peso, en kg/m²		Tolerancias en mm, medidas a partir de una superficie plana, para los anchos, en mm siguie...									
	a exclusive	De	a exclusive	A 914- excl	De 914 a 1219 - excl	De 1219 a 1524 excl	De 1524 a 1829 excl	De 1829 a 2134 excl	De 2134 a 2438 excl	De 2438 a 2743 excl	De 2743 a 3048- excl	De 3045 a 3658 excl	De 3658 a 4267 excl
	6.4	----	50	14.3	19.1	23.8	31.8	34.9	38.1	41.3	44.5	47.6	----
	9.5	50	75	12.7	15.9	19.1	23.8	28.6	31.8	34.9	38.1	41.3	----
,	12.7	75	100	12.7	14.3	15.9	15.9	19.1	22.2	25.4	28.6	31.8	47.6
	19.1	100	149	11.1	12.7	14.3	15.9	15.9	19.1	25.4	25.4	28.6	38.1
:	25.4	149	199	11.1	12.7	14.3	15.9	15.9	15.9	19.1	22.2	25.4	34.9
4	50.8	199	398	9.5	12.7	12.7	14.3	14.3	15.9	15.9	15.9	17.5	28.6
0	101.6	398	797	7.9	9.5	11.1	12.7	12.7	12.7	12.7	14.3	15.9	22.2
5	152.4	797	1195	9.5	11.1	12.7	12.7	14.3	14.3	15.9	19.1	22.2	22.2
4	203.2	1195	1594	11.1	12.7	12.7	15.9	17.5	19.1	22.2	22.2	25.4	25.4
2	254.0	1594	1992	12.7	12.7	15.9	17.5	19.1	20.6	22.2	23.8	25.4	25.4
0	304.8	1992	2390	12.7	15.9	19.1	20.6	22.2	23.8	25.4	25.4	25.4	25.4
3	381.0	2390	2988	15.9	19.1	20.6	22.2	23.8	25.4	25.4	25.4	25.4	25.4

...erancia en planeza en sentido longitudinal. Se considera longitud a la dimensión mayor, la tolerancia a lo largo de tod... ...ngitud no debe exceder de la cantidad especificada para el ancho, en planchas hasta de 3.6 m de longitud o en cualquier... 3.6 m en planchas de mayor longitud.

1. Cuando la dimensión más larga es inferior a 914 mm, la tolerancia no debe exceder de 6.4 mm, cuando la dimensión ma... tá comprendida entre 914 mm hasta 1829 mm, la tolerancia no debe exceder del 75 % de la cantidad tabulada para el a... especificado, pero en ningún caso debe ser menor de 6.4 mm.

2. Estas tolerancias se aplican a planchas que tengan una resistencia mínima a la tensión de 42.2 kg/mm² o una composi... química o dureza compatibles. Los límites anotados en la Tabla deben incrementarse en un 50 % para planchas con un... resistencia a la tensión o análisis químico o dureza compatibles.

3. E[redacted]abla y las notas correspondientes, cubren la ...lerancias para una planeza de planchas circular... de plan... b[redacted]ose en la dimensión máxima de dichas planchas

T A B L A XV

[illegible] PLANCHAS DE ACERO DE ALTA RESISTENCIA Y BAJA ALEACION, RECTANGULARES CORTADAS CON CIZALLA, EN [illegible] CORTADAS CON PLANTILLA, LAMINADAS EN CALIENTE O TRATADAS TERMICAMENTE (no aplicables a aceros al carbono)

[illegible] a exclusive	Peso, en kg/m² De	a exclusive	Tolerancia, en mm, a partir de una superficie plana, para los anchos, en mm siguientes (a): A 914 excl	De 914 a 1219 excl	De 1219 a 1524 excl	De 1524 a 1828 excl	De 1828 a 2134 excl	De 2134 a 2438 excl	De 2438 a 2743 excl	De 2743 a 3048 excl	De 3048 a 3658 excl	De 3658 a 4267 excl	[illegible]
6.4	----	50	20.6	28.6	34.9	47.6	50.8	57.2	60.3	66.7	69.9	----	---
9.5	50	75	19.1	23.8	28.6	34.9	44.5	47.6	50.8	57.2	60.3	----	---
12.7	75	100	19.1	22.2	23.8	23.8	28.6	33.3	38.1	41.3	47.6	69.9	[illegible]
19.1	100	149	15.9	19.1	20.6	22.2	25.4	28.6	31.9	34.9	41.3	57.2	[illegible]
25.4	149	199	15.9	19.1	22.2	22.2	23.8	25.4	28.6	33.3	38.1	50.8	[illegible]
50.8	199	398	14.3	15.9	19.1	20.6	22.2	23.8	25.4	25.4	25.4	41.3	[illegible]
101.6	398	797	12.7	14.3	17.5	19.1	19.1	19.1	19.1	22.2	25.4	31.8	[illegible]
152.4	797	1195	14.3	17.5	19.1	19.1	22.2	22.2	23.8	28.6	31.8	31.8	[illegible]
203.2	1195	1594	15.9	19.1	19.1	23.8	25.4	28.6	31.8	33.3	38.1	38.1	38.
254.0	1594	2041	19.1	20.6	23.8	25.4	23.6	31.8	33.3	34.9	38.1	38.1	38.
304.8	2041	2390	19.1	23.8	28.6	31.8	33.3	34.9	38.1	38.1	38.1	38.1	38.
381.0	2390	2988	22.2	25.4	30.2	33.3	34.9	38.1	38.1	38.1	38.1	38.1	38.

erancia en planeza en sentido longitudinal. Se considera longitud a la dimensión mayor, la tolerancia a lo largo de toda l gitud no debe exceder de la cantidad especificada para el ancho, en planchas hasta de 3.6 m de longitud o en cualquier tramo m en planchas de mayor longitud.

Cuando la dimensión mayor es menor de 914 mm, la tolerancia no debe exceder de 9.5 mm. Cuando la dimensión mayor está comprendida entre 914 hasta 1829 mm, la tolerancia no debe exceder del 75 % de la cantidad tabulada para el ancho especificado

Esta tabla y las notas cubren las tolerancias en planeza para planchas circulares y de plantilla, tomando como base las dimensiones máximas de dichas planchas.

T A B L A XVI

[illegible] SECCION TRANSVERSAL PARA VIGAS ESTANDAR, VIGAS "H" EN SECCION DE LAMINACION ([illegible]
cables a aceros aleados)

Vigas estándard

Vigas "H"

Canales

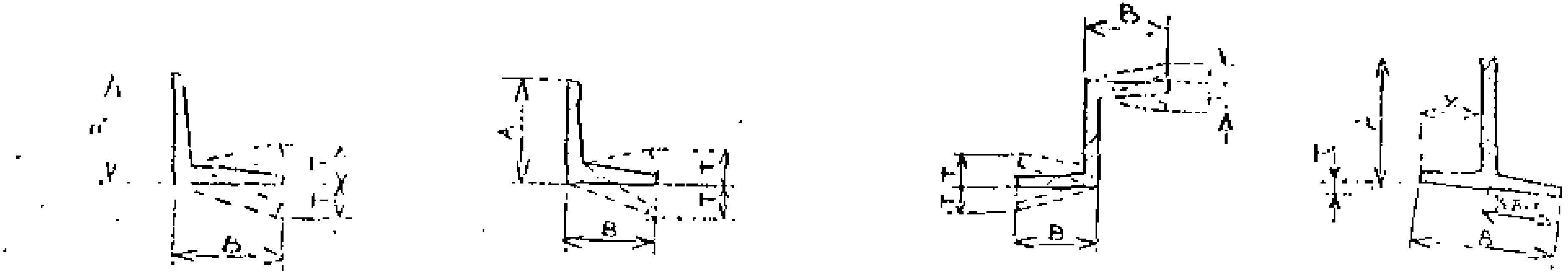
a interior de la escuadra debe colocarse paralela
e del alma para medir el "Fuera de escuadra".

T + T' se aplica cuando los patines de las canales están in
hacia adentro o hacia afuera.

S E C C I O N	TAMAÑO NOMINAL, en mm	"A" peralte (a), en mm		"B" ancho del patín, en mm		T + [illegible]
		Arriba del teórico	Abajo del teórico	Arriba del teórico	Abajo del teórico	
estándar	76.2 hasta 177.8	2.4	1.6	3.2	3.2	
	Mayor de 177.8 hasta 355.6	3.2	2.4	4.0	4.0	
	Mayor de 355.6 hasta 609.6	4.8	3.2	4.8	4.8	
"H" de laminador estándar	101.6	2.4	1.6	3.2	3.2	
	127.0	2.4	1.6	4.0	4.0	
	152.4 hasta 203.2	3.2	2.4	4.8	4.8	
ales	76.2 hasta 177.8	2.4	1.6	3.2	3.2	
	Mayor de 177.8 hasta 355.6	3.2	2.4	3.2	4.0	
	Mayores de 355.6	4.8	3.2	3.2	4.3	

TABLA XVII

...RANCIAS EN LA SECCION TRANSVERSAL PARA ANGULOS DE BULBO, TES LAMINADAS Y ZETAS (no aplicables a acero aleado)



Angulo   Angulo de bulbo   Zeta   Te

...lado de la escuadra, debe colocarse paralelo al eje del alma para medir el "fuera de escuadra".

SECCION	TAMAÑO, en mm Mayor de	hasta	"A" peralte, en mm Arriba del teórico	Abajo del teórico	"B" ancho del patín o longitud del ala, en mm Arriba del teórico	Abajo del teórico	"T" fuera de escuadra en mm por mm de "B"	"E" destramien del alma máximo, mm
...ulos (a)	76	102	-	-	3.2	2.4	0.023(b)	-
	102	152	-	-	3.2	3.2	0.023(b)	-
	152		-	-	4.8	3.2	0.023(b)	-
...ulos de bulbo (Peralte)	76	102	3.2	1.6	3.2	2.4	0.023(b)	-
	102	152	3.2	1.6	3.2	3.2	0.023(b)	-
	152		3.2	1.6	4.8	3.2	0.023(b)	-
... laminadas (Ala o patín)	---	127	2.4	1.6	3.2	3.2	0.031	2.4
	127	178	2.4	1.6	3.2	3.2	0.031	3.2
...s	76	102	3.2	1.6	3.2	2.4	0.023(b)	-
	102	152	3.2	1.6	3.2	3.2	0.023(b)	-

Para ángulos de alas desiguales, el ala de mayor tamaño determinará su clasificación.

0.023 = 1 ½ grados

T A B L A XVIII

TOLERANCIAS EN LONGITUD, PARA PERFILES ESTANDAR (no aplicables a acero aleado)

	Tolerancias en mm, para las longitudes en m siguientes:									
	Hasta 9.14		Mayor de 9.14 hasta 12.19		Mayor de 12.19 hasta 15.24		Mayor de 15.24 hasta 19.81		Mayores de - 19.81	
	En más	En menos	En más	En menos	En más	En menos	En más	En menos	En más	En menos
Todos los perfiles estándard.	12.7	6.4	19.1	6.4	25.4	6.4	28.6	6.4	31.8	6.4

T A B L A XIX

TOLERANCIAS EN LOS EXTREMOS FUERA DE ESCUADRA, PARA PERFILES ESTANDAR (no aplicables a acero aleado)

P E R F I L E S	T O L E R A N C I A S
Vigas estándar	
Canales	
Vigas "H" en sección de laminación	0.016 mm por milímetro de peralte.
Angulos (a)	0.023 mm por milímetro de longitud de lado o 1.5 grados.
Angulos de bulbo	0.023 mm por milímetro de peralte o 1.5 - grados.
Tes laminadas (a)	0.016 mm por milímetro del patín o alma.
Zetas	0.023 mm por milímetro de la suma de las longitudes de las alas.

(a) Las tolerancias para extremos "fuera de escuadra" se determinan sobre los elementos de mayor longitud del perfil.

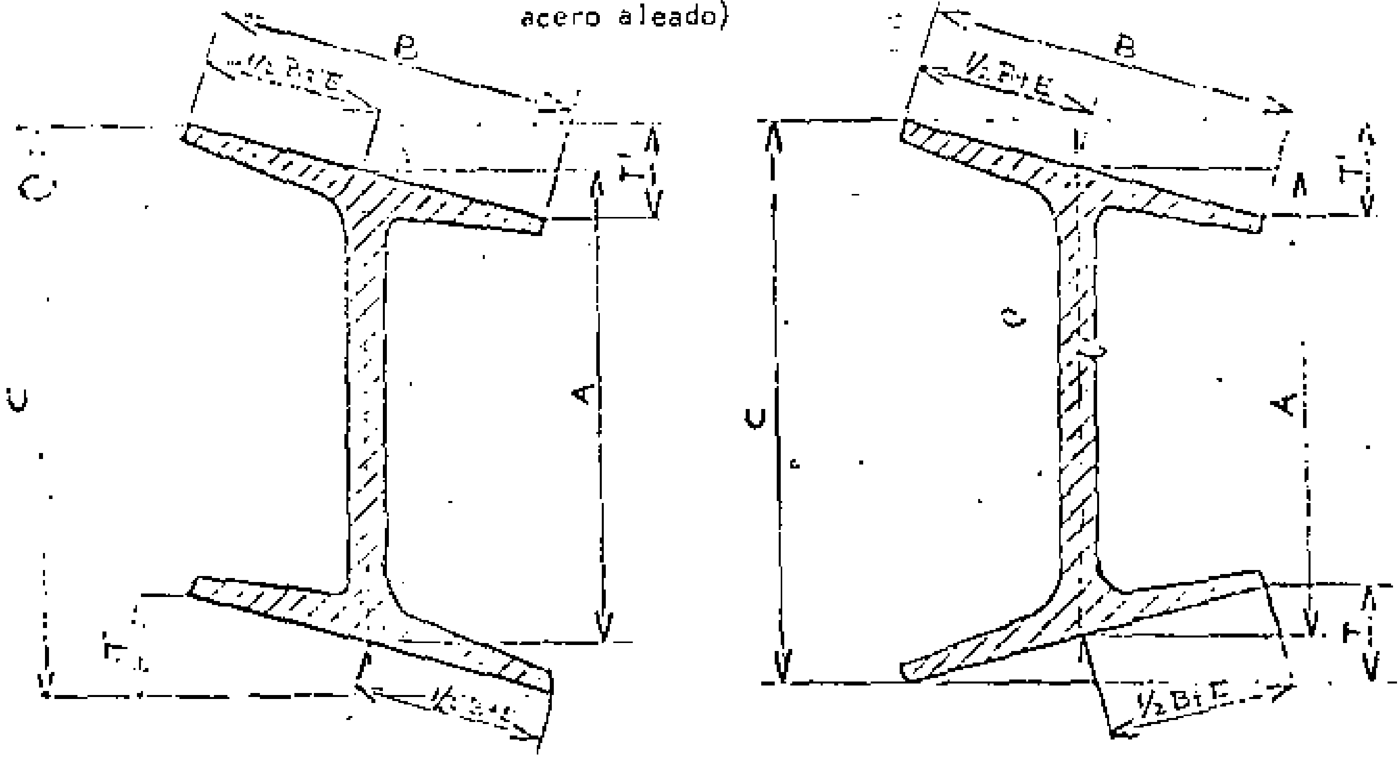
T A B L A XX

TOLERANCIAS EN RECTITUD, PARA PERFILES ESTANDAR (no aplicables a acero aleado)

	T O L E R A N C I A S, en mm
Flecha (camber)	2.1 x longitud total en metros.
Curvatura	Debido a las variaciones máximas en la flexibilidad de las vigas y canales estándard, las tolerancias por curvatura deben - sujetarse a un convenio entre fabricante y comprador, para la sección individual de que se trate.

T A B L A XXI

TOLERANCIA EN LA SECCION TRANSVERSAL PARA PERFILES DE PATIN ANCHO (no aplicables a acero aleado)



TAMAÑO DE LA SECCION, en mm	"A" peralte, en mm		"B" ancho del patín, en mm		T + T' patines fuera de escuadra, máxima, en mm	"E" descentramiento del alma máximo en mm	"C" peralte máximo en cualquier sección transversal sobre el peralte teórico, en mm
	Arriba del teórico	Abajo del teórico	Arriba del teórico	Abajo del teórico			
Hasta 304.8	3.2	3.2	6.4	4.8	6.4	4.8	6.4
Mayores de 304.8	3.2	3.2	6.4	4.8	8.0	4.8	6.4

A se mide sobre el eje del alma

B se mide paralela al patín

C se mide paralela al alma

Para secciones mayores de 426 lb/pie la tolerancia máxima es de 8 mm.

T A B L A XXII

TOLERANCIA EN LONGITUD, PARA PERFILES a, b, DE PATIN ANCHO (no aplicables a acero aleado)

PERFILES DE PATIN ANCHO	Tolerancias en mm para las longitudes en m siguientes:			
	Hasta 9.15		Mayores de 9.15	
	En más	En menos	En más	En menos
Vigas de 610 mm y menores en peralte.	9.5	9.5	9.5 mm, más 1.0 mm por cada metro adicional o fracción.	9.5 mm
Vigas mayores de 610 mm de peralte y todas las columnas.	12.7	12.7	12.7 mm, más 1.0 mm por cada metro adicional o fracción.	12.7 mm

(a) Cuando los perfiles de patín ancho se usen como pilotes de carga, la tolerancia en longitud es de 127 mm en más, y 0 mm en menos.

(b) La tolerancia en "fuera de escuadra" en los extremos de perfiles de patín ancho es de 0.016 mm por mm de peralte o ancho de patín si este es mayor que el peralte.

T A B L A XXIII

TOLERANCIA EN LONGITUD Y EXTREMOS FUERA DE ESCUADRA PARA SECCIONES ESTRUCTURALES MAQUINADAS (no aplicables a acero aleado)

PERALTE, en mm	LONGITUD a, b, en mm	Ambos extremos maquinados (b)			Un extremo maquinado (b)		
		Tolerancia en longitud, en mm		Fuera de escuadra de los extremos, máxima, en mm	Tolerancias en longitud, en mm		Fuera de escuadra del extremo maquinado, en mm
		En más	En menos		En más	En menos	
152 a 915	1.83 a 21.34	0.8	0.8	0.8	6.4	6.4	0.8

(a) La longitud se mide a lo largo del eje del alma. Las mediciones se hacen estando el acero y la cinta métrica a la misma temperatura.

(b) Los extremos "fuera de escuadra" se miden a partir del eje del alma o a partir del eje del patín. La variación obtenida en la medición de "fuera de escuadra" en cualquiera de los planos no debe exceder de la cantidad tabulada.

(c) Las tolerancias en longitud y en fuera de escuadra, son aditivas.

32.-

T A B L A XXIV

TOLERANCIAS EN RECTITUD PARA PERFILES DE PATIN ANCHO (no aplicables a acero aleado)

Perfiles de patín ancho	Tolerancias
Flecha (camber) y curvatura.	1 mm por cada metro [a]
Para ciertas secciones [b] con un ancho de patín aproximadamente igual al peralte (columna), las tolerancias son las siguientes:	
Longitudes hasta de 14 m	1 mm por cada metro pero no más de 10 mm.
Longitudes mayores de 14 m	10 mm + (1 mm por cada metro de longitud que exceda de los 14 m).

(a) La tolerancia en curvatura para secciones con un ancho de patín menor de 150 mm, es de 2 mm por cada metro de longitud.

(b) Tolerancias aplicables solamente a las siguientes secciones:

De 203 mm de peralte, con 46 kg/m y más pesadas

De 254 mm de peralte, con 73 kg/m y más pesadas

De 305 mm de peralte, con 97 kg/m y más pesadas

De 356 mm de peralte, con 116 kg/m y más pesadas

Cuando se especifique otra sección para usarse como columna, las tolerancias deben fijarse por común acuerdo entre comprador y vendedor.

T A B L A XXV

TOLERANCIAS EN LAS DIMENSIONES PARA TES Y ANGULOS CORTADOS DE OTROS PERFILES [a] (no aplicables a acero aleado)

Peralte, en mm	Tolerancias en más y en menos, en mm [b]
Hasta 152 excl (vigas y canales)	3.2
De 152 a 406 excl (vigas y canales)	4.8
De 406 a 508 excl (vigas y canales)	6.4
De 508 a 610 excl (vigas y canales)	7.9
610 y mayores (vigas)	9.5

(a) La tolerancia en longitud para tes y ángulos producidos por corte de otro perfil, es la misma que la aplicable a la sección de la cual proceden estos perfiles.

(b) Estas tolerancias para peralte de tes o ángulos, incluyen las tolerancias en peralte propias de las vigas o canales de las cuales proceden. Deben aplicarse tanto las tolerancias en peralte como en rectitud, propias de las vigas o canales de donde se cortan estos perfiles, con excepción de que la tolerancia en rectitud es de 2 mm por cada metro de longitud.

T A B L A XXVI

TOLERANCIAS EN LAS DIMENSIONES DE LA SECCION TRANSVERSAL DE LOS ANGULOS BARRAS ESTANDAR
(no aplicables a acero aleado)

LONGITUD DEL ALA, en mm	Tolerancia en mm, en más y en menos, para los espesores en mm siguientes:			Tolerancias en mm, en más y en menos, para la longitud del ala.
	Hasta 4.8	Mayores de 4.8 hasta 9.5	Mayores de 9.5	
Hasta 25.4	0.20	0.25	----	0.79
Mayores de 25.4 hasta 50.8	0.25	0.25	0.30	1.19
Mayores de 50.8 a 76.2 excl	0.30	0.38	0.38	1.59

NOTAS:

1. Para ángulos de lados desiguales las tolerancias deben aplicarse tomándose como base el ala más larga.

2. La tolerancia en "fuera de escuadra" en cualquier dirección es de 1 ½ grados.

T A B L A XXVII

TOLERANCIAS EN LAS DIMENSIONES DE LA SECCION TRANSVERSAL DE LOS CANALES - BARRA ESTANDAR
(no aplicables a acero aleado)

TAMAÑO DE LA CANAL, en mm	Tolerancia en mm, en más y en menos:				Tolerancia en mm para "fuera de escuadra" de los patines, por cada cm de ancho del patín (a) en mm
	Para el peralte de la sección	Para el ancho de los patines	Para los espesores del alma, en mm siguientes:		
			De 4.8 y menores	Mayores de 4.8	
Hasta 38.1	0.79	0.79	0.25	0.38	0.31
Mayores de 38.1 a 76.2 excl	1.59	1.59	0.38	0.51	0.31

(a) Para canales con peralte 15.90 mm y menores, la tolerancia en "fuera de escuadra" es de 0.47 mm/cm de peralte.

NOTA: Las mediciones de peraltes y anchos de patín se efectúan por la parte exterior de los canales.

34.-

T A B L A XXVIII

OLERANCIA EN LAS DIMENSIONES DE LA SECCION TRANSVERSAL DE BARRAS TE STANDAR (no aplicables a acero aleado)

amaño de la - e (a), en mm	Ancho o peralte(b), en mm		Espesor del patín, en mm		Espesor del alma, en mm		Alma fuera de escuadra(c) en mm
	En más	En menos	En más	En menos	En más	En menos	
asta 31.8	1.19	1.19	0.25	0.25	0.13	0.51	0.79
ayores de 31.8 hasta 50.8	1.59	1.59	0.30	0.30	0.25	0.51	1.59
ayor de 50.8 76.2 excl	2.38	2.38	0.38	0.38	0.38	0.51	2.38

a) El lado más largo de una "te" desigual determina el tamaño para aplicar las tolerancias.

b) Las mediciones tanto en ancho como en peralte se efectúan por la parte exterior.

c) Las variaciones del alma "fuera de escuadra" a partir de la posición real del eje del alma se miden en ese punto.

T A B L A XXIX

OLERANCIAS EN LAS DIMENSIONES DE LA SECCION TRANSVERSAL PARA SOLERAS DE CANTOS VIVOS Y REDONDEADOS (no aplicables a acero aleado)

NCHO, en mm		Tolerancias en mm, en más y en menos en el espesor para los espesores en mm siguientes:							Tolerancia en mm, en el ancho	
Mayor de	hasta	De 5.2 a 5.8 excl	De 5.8 a 6.4 excl	De 6.4 hasta 12.7	Mayor de 12.7 hasta 25.4	Mayor de 25.4 hasta 50.8	Mayor de 50.8 hasta 76.2	Mayor de 76.2	En más	En menos
	25.4	0.18	0.18	0.20	0.25	----	----	----	0.40	0.40
25.4	50.8	0.18	0.18	0.30	0.38	0.79	----	----	0.79	0.79
50.8	101.6	0.20	0.20	0.38	0.51	0.79	1.19	1.19	1.59	0.79
101.6	152.4	0.23	0.23	0.38	0.51	0.79	1.59	1.59	2.38	1.59
152.4	203.2	(a)	0.38	0.41	0.64	0.79	1.59	(b)	(b)3.18	2.38(b)

a) Las soleras de 152.4 hasta 203.2 mm en ancho y con espesor menor de 5.8 mm, no deben considerarse como barras de acero al carbono, laminadas en caliente.

b) Para soleras mayores de 152.4 hasta 203.2 mm en ancho y con espesor mayor de 76.20 mm debe consultarse al fabricante para las tolerancias en espesor y ancho.

T A B L A XXX

TOLERANCIAS EN LAS DIMENSIONES DE LA SECCION TRANSVERSAL DE BARRAS REDONDAS, CUADRADAS Y CUADRADAS CON LAS ESQUINAS REDONDEADAS (no aplicables a acero aleado)

Tamaño, en mm		Tolerancia en el tamaño, en mm		Fuera de redondo o fuera de cuadrado (a), en mm
Mayor de	hasta	En más	En menos	
	7.9	0.13	0.13	0.20
7.9	11.1	0.15	0.15	0.23
11.1	15.9	0.18	0.18	0.25
15.9	22.2	0.20	0.20	0.30
22.2	25.4	0.23	0.23	0.33
25.4	28.6	0.25	0.25	0.38
28.6	31.8	0.28	0.28	0.41
31.8	34.9	0.30	0.30	0.46
34.9	38.1	0.36	0.36	0.53
38.1	50.8	0.40	0.40	0.58
50.8	63.5	0.79	0	0.58
63.5	88.9	1.19	0	0.89
88.9	114.3	1.59	0	1.17
114.3	139.7	1.98	0	1.47
139.7	165.1	3.18	0	1.78
165.1	209.6	3.97	0	2.16
209.6	241.3	4.76	0	2.54
241.3	254.0	6.35	0	3.05

(a) Fuera de redondo es la diferencia entre los diámetros máximo y mínimo de la barra medidos en la misma sección transversal. Fuera de cuadrado es la diferencia entre las dos dimensiones en la misma sección transversal de una barra cuadrada, entre caras opuestas.

T A B L A XXXI

TOLERANCIA EN LAS DIMENSIONES DE LA SECCION TRANSVERSAL DE BARRAS HEXAGONALES (no aplicables a acero aleado)

Tamaños entre lados opuestos, en mm		Tolerancia en el tamaño, en mm		Diferencia máxima tres mediciones (a) en mm
Mayor de	hasta	En más	En menos	
	12.7	0.18	0.18	0.28
12.7	25.4	0.25	0.25	0.38
25.4	38.1	0.53	0.33	0.64
38.1	50.8	0.79	0.40	0.79
50.8	63.5	1.19	0.40	0.19
63.5	88.9	1.59	0.40	1.59

(a) Se refiere a la diferencia mayor entre dos medidas cualquiera, de las tres posibles.

T A B L A XXXII

TOLERANCIAS EN LAS DIMENSIONES DE LA SECCION TRANSVERSAL DE BARRAS MEDIA CAÑA, OVALOS Y OTRAS BARRAS - PERFIL ESPECIALES (no aplicables a acero aleado)

Las tolerancias en barras media caña, óvalos y otros perfiles barra especiales, que

T A B L A XXXIII

TOLERANCIA EN LA RECTITUD PARA BARRAS Y BARRAS - PERFIL (no aplicables a acero aleado)

	Tolerancia máxima en rectitud
Barras y perfiles - barra (a)	4 mm por cada metro de longitud

(a) Las tolerancias en rectitud, no se aplican a las barras laminadas en caliente, si después de fabricadas se someten a calentamiento.

T A B L A XXXIV

TOLERANCIAS EN LONGITUD PARA BARRAS DE ACERO AL CARBONO, CORTADAS EN CALIENTE (no aplicables a acero aleado) (a)

Tamaño de redondos, cuadrados y hexagonos, en mm		Tamaño de soleras, en mm				Tolerancia en mm, en más respecto a la longitud especificada en metros (no hay tolerancia en menos)				
		ESPESOR		ANCHO						
Mayor de	hasta	Mayor de	hasta	Mayor de	hasta	De 1.52 a 3.05 excl	De 3.05 a 6.10 excl	De 6.10 a 9.14 excl	De 9.14 a 12.19 excl	De 12.19 a 18.29 excl
-----	25.4	----	25.4	-----	76.2	12.70	19.05	31.75	44.45	57.15
25.4	50.8	25.4	----	-----	76.2	15.88	25.40	38.10	50.80	63.50
25.4	50.8	----	25.4	76.2	152.4	15.88	25.40	38.10	50.80	63.50
50.8	127.0	25.4	----	76.2	152.4	25.40	38.10	44.45	57.15	69.85
127.0	254.0	----	----	-----	-----	50.80	63.50	69.85	76.20	82.55
		5.8	25.4	152.4	203.2	19.05	31.75	44.45	88.90	101.60
		25.4	76.2	152.4	203.2	31.75	44.45	50.80	88.90	101.60
Otras dimensiones		----	----	-----	-----	15.88	25.40	38.10	50.80	63.50
				CORTE EN CALIENTE						
50.8	127.0 (b)	25.4	----	76.2	-----	(a)	38.10	44.45	57.15	69.85
127.0	254.0	----	----	----	-----	(a)	63.50	69.85	76.20	82.55

(a) Para soleras con ancho mayor de 152.4 hasta 203.2 mm y espesor mayor de 76.2 mm, consultar al fabricante para las tolerancias en longitud.

(b) Los tamaños y longitudes menores, generalmente no se cortan en caliente.

T A B L A XXXV

TOLERANCIAS EN LONGITUD PARA BARRAS CORTADAS DESPUES DE ENDEREZARSE (no aplicables a acero aleado) (a), (b)

Tamaño de secciones redondas, cuadradas, hexagonales; anchos de soleras y dimensión máxima de otras secciones, en mm		Tolerancia en mm, para longitudes en m siguientes:			
		Hasta 3.66 m		Mayor de 3.66 m	
		En más	En menos	En más	En menos
Mayor de	hasta				
-----	76.2	4.76	1.59	6.35	1.59
76.2	152.4	6.35	1.59	9.53	1.59
152.4	203.2	9.53	1.59	12.70	1.59
203.2	254.0	12.70	1.59	15.88	1.59

(a) Para soleras con ancho mayor de 152.4 hasta 203.2 mm inclusive, y espesor mayor de 76.2 mm, consultar al fabricante para las tolerancias en longitud.

(b) Algunas veces se requiere que todas las tolerancias sean en más o todas en menos, de la longitud especificada, en cuyo caso se aplica la suma de las dos to-

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PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

COMPLEMENTO II

ING. RAUL GRANADOS

JULIO, 1979

CONTROL DE LA DISTORSION.

La aplicación de las reglas siguientes ayudará a reducir o controlar las distorsiones provocadas por la soldadura.

REGLA I Reducir la fuerza efectiva de contracción.

REGLA II Hacer trabajar a las fuerzas de contracción para reducir la distorsión.

REGLA III Balancear las fuerzas de contracción con otras fuerzas.

I.- Para reducir la fuerza efectiva de contracción, debe tenerse en cuenta lo siguiente:

a) Evitar el uso de soldadura en exceso. A menor cantidad de soldadura, menos calor y menor distorsión.

b) Seleccionar la preparación más apropiada para las uniones a tope. El empleo de placas de respaldo mejora la penetración sin necesidad de calor adicional.

c) Usar pocos pases. Esto reducirá la distorsión lateral.

d) Localizar las soldaduras tan cerca como sea posible del eje neutro. Esto reducirá la combadura longitudinal.

e) Usar cordones intermitentes. Esto reducirá la cantidad de calor.

f) Usar la ténica de soldar " retrocediendo ". Consiste en colocar los cordones de " adelante hacia atrás ".

II.- La segunda regla se logra con algunas de las siguientes recomendaciones.

a) Colocar las piezas por soldar giradas en dirección contraria a la distorsión. Cuando se presenta la fuerza de contracción, la parte desviada quedará en posición correcta.

b) Desalinear las partes por soldar en dirección contraria a la distorsión. Al aplicar la soldadura, la fuerza de contracción jalará a las partes a la posición correcta.

c) Aplicar pre-deformación contraria a las placas por medios mecánicos.

III.- El balanceo de las fuerzas de contracción se puede lograr con alguna de las siguientes recomendaciones.

a) Seguir una secuencia de pases tal que la fuerza de contracción de cada uno se equilibre con otra en forma simétrica.

b) Martillear los cordones con una herramienta puntiaguda. Esta operación produce una dilatación en los cordones cuando están calientes, ayudando ésto a contrarestar la contracción.

c) Usar soportes mecánicos o atiesadores. Esta es una de las formas más eficientes de satisfacer la regla III.

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PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

CONEXIONES

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JUNIO, 1979.

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CONEXIONES

La mayor parte de las especificaciones relativas a estructuras de acero reconocen como medios de unión entre unos elementos a los remaches, los tornillos y la soldadura.

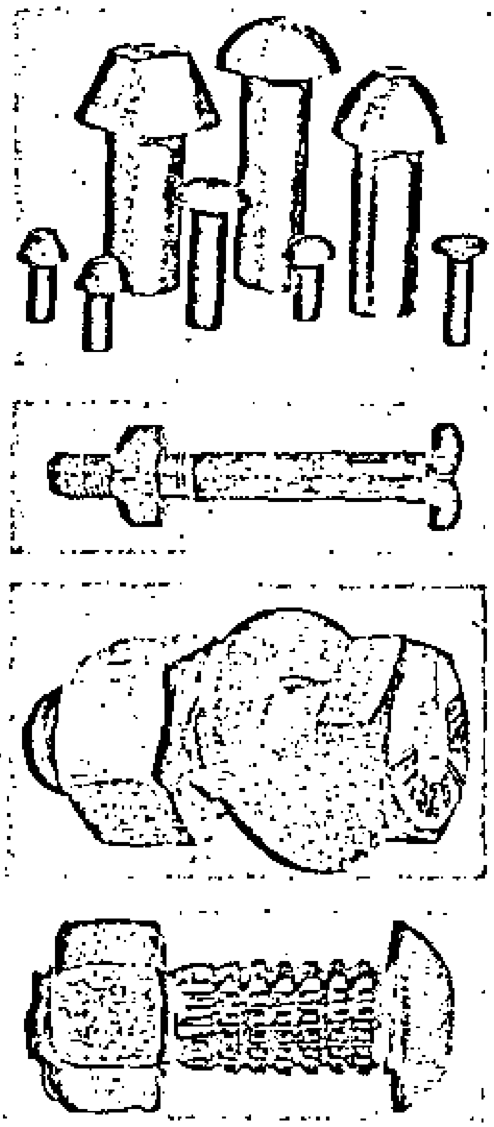
Desde hace años, los primeros han caido en desuso y se puede decir que actualmente han desaparecido ya en la práctica. Esto se ha debido al uso creciente de la soldadura y a la aparición de los tornillos de alta resistencia que sustituyen con ventaja a los remaches.

TORNILLOS

Se utilizan dos tipos de tornillos, los llamados comunes y los de alta resistencia.

Se designan, con el nombre que les dan las normas del ASTM para especificar sus características químicas y mecánicas, los primeros como tornillos A307 y los de alta resistencia como tornillos A325 ó A490

TALL
pg. 594.



Rivets

A 307 square head bolt

A 325 high-strength bolt

Interference body bolt

Fig. 18.1 Mechanical fasteners. (Courtesy of Bethlehem Steel Corp.)

TORNILLOS COMUNES (A 307)

Son históricamente, el primer medio de unión utilizado en estructuras de acero; en la actualidad tienen una aplicación estructural muy limitada ya que su resistencia es reducida y no se recomiendan cuando pueden esperarse cambios de signo en los esfuerzos de las piezas que conectan o cuando sean de esperarse cargas dinámicas.

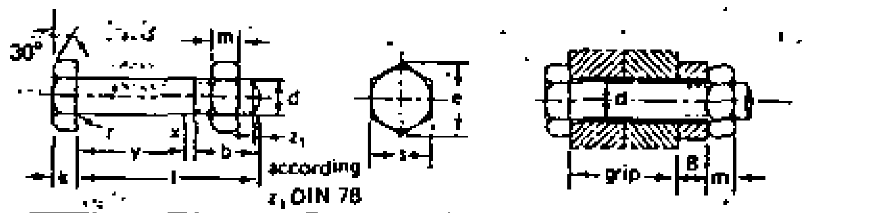
En este sentido, las especificaciones del AISC fijan una serie de casos concretos en que los tornillos A307 no deben usarse.

No se usarán en estructuras esbeltas:

a) Que tengan una altura de más de 60 m.

b) Que tengan una altura entre 30 y 60 m. cuando la base es menor del 40% de la altura.

c) Que tengan una altura cualquiera si la base mide menos del 25% de la altura.



d	M10	M12	M16	M20	M22	M24	M27	M30	M33	M36
b	17.5	19.5	23	26	28	29.5	32.5	35	38	40
x max	2.5	2.5	3	4	4	4.5	4.5	5	5	6
e (approx.)	19.6	21.9	27.7	34.6	36.9	41.6	47.3	53.1	57.7	63.5
k	7	8	10.5	13	14	15	17	19	21	23
m	8	9.5	13	16	17	18	20	22	25	28
r	0.5	1	1	1	1	1	1	1	1	1
s	17	19	24	30	32	36	41	46	50	55
d_1	11	13	17	21	23	25	28	31	34	37

Figure [illegible] Unfinished Hexagonal Bolts A307, DIN 7990 (Dimensions in mm). (From *Stahlbau*, Deutsches Stahlbau Verband, Cologne, 1957, p. 15).

No se usará en estructuras que deban soportar trabes grua.

No se usarán donde halla máquinas o alguna carga viva que produzca impacto o reversión de esfuerzos.

Sin embargo, en estructuras ligeras en que los problemas mencionados no aparecen, así como en conexiones de elementos secundarios tales como largueros de techo, constituyen una buena solución pues son económicos y su manejo y colocación es muy simple.

TORNILLOS DE ALTA RESISTENCIA

A 325

A 490

Basan su capacidad en el hecho de que pueden ser sometidos a una gran fuerza de tensión controlada que aprieta firmemente los elementos de la conexión.

Las ventajas de este apriete firme se conocen desde hace tiempo pero su aplicación práctica en estructuras proviene de 1951 en que se publicaron las primeras normas para regir su utilización. Desde entonces los tornillos de alta resistencia se han venido utilizando en forma creciente en EE.UU y en la última década, también en México.

A partir de 1951, las normas relativas a estos tornillos se han modificado varias veces para poder incluir los resultados de las investigaciones que, en forma casí continua, se han venido realizando en torno a ellos.

Los primeros tornillos de alta resistencia que se desarrollaron y aún los más comunmente usados son los A-325; posteriormente y con objeto de contar con capacidades aún mayores, se desarrollaron los A-49-; ambos se obtienen de -

aceros al carbón tratados térmicamente.

Los tornillos A325 se marcan, para distinguirlos, con la leyenda; A-325 y tres líneas radiales en su cabeza; la - tuerca tiene tres marcas espaciadas 120°.

Los tornillos A490 se marcan con su nombre en la cabeza y con la leyenda 2H ó DH en la tuerca.

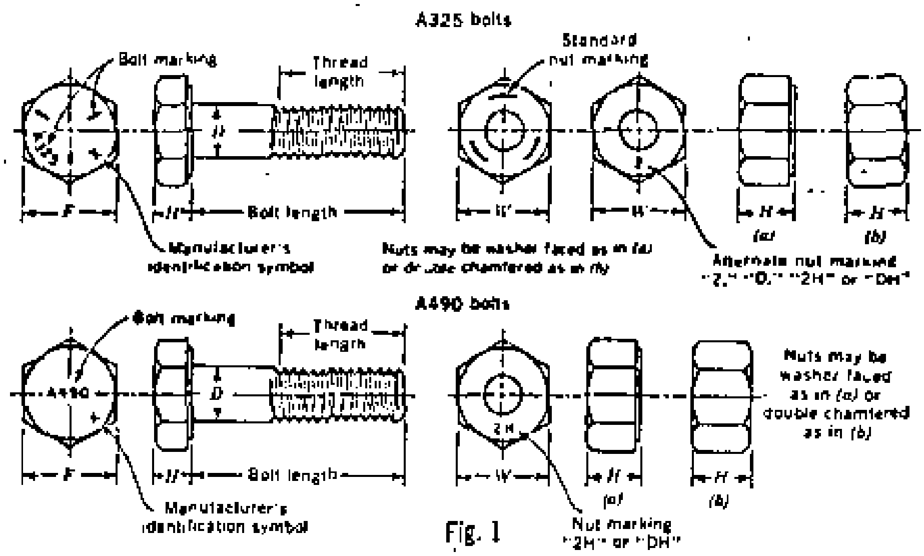


Fig. 1

Table 5

Nominal bolt size, *D*	Bolt Dimensions, in Inches			Nut Dimensions, in Inches	
	Heavy Hex Structural Bolts			Heavy Hex Nuts	
	Width across flats *F*	Height, *H*	Thread length	Width across flats *W*	Height, *H*
1/2	7/8	5/16	1	7/8	31/64
5/8	1 1/16	25/64	1 1/4	1 1/16	39/64
3/4	1 1/4	15/32	1 3/8	1 1/4	47/64
7/8	1 7/16	35/64	1 1/2	1 7/16	55/64
1	1 5/8	39/64	1 3/4	1 5/8	63/64
1 1/8	1 13/16	11/16	2	1 13/16	1 7/64
1 1/4	2	25/32	2	2	1 7/32
1 3/8	2 3/16	27/32	2 1/4	2 3/16	1 11/32
1 1/2	2 3/8	15/16	2 1/4	2 3/8	1 15/32

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Las últimas normas reconocer 3 tipos distintos de tornillos A325; los tornillos tipo 1 son los originales y cuando se solicitan simplemente tornillos A325 son los que se suministran. Son los más utilizados.

Los tornillos tipo 2 (A325) se fabrican con acero martensítico de bajo carbono, para distinguirlos se marcan con líneas radiales a 60° en vez de 120° como los tipo 1.

Los tornillos A325 tipo 3 se caracterizan por tener una alta resistencia a la corrosión, suelen usarse con aceros de características similares a ellos. Se marcan con la leyenda A325 subrayada, la tuerca se marca con el número 3.

En México los únicos usados en forma extensa han sido los tipo 1.

Inicialmente los tornillos de alta resistencia consistían en un tornillo, una tuerca, y dos rondanas; actualmente las dimensiones de la cabeza y de la tuerca se han diseñado de tal forma que se puede, en muchos casos, prescindir totalmente de las rondanas y usar en los demás, una sola.

CARACTERISTICAS QUIMICAS Y MECANICAS.

La composición química de los tornillos de alta resistencia, junto con el tratamiento térmico a que son sometidos, les proporciona sus características de resistencia; el contenido de carbono y de manganeso es la variable más significativa en los tornillos A325. En los A490 el contenido de carbono se fija y el elemento de aleación se deja abierto - para poder proporcionar por distintos caminos las propiedades mecánicas requeridas.

Aunque, cuando es posible, los tornillos deben someterse a una prueba de tensión para probar su resistencia; a menudo son demasiado cortos para que la prueba directa de tensión se pueda realizar, se recurre entonces a controlar la resistencia, indirectamente, a través de una prueba de dureza.

Se realizan con ese fin las pruebas Brinell ó Rockwell.

TABLE 1 Chemical Requirements for Types 1 and 2 Bolts, Nuts, and Washers

Element	Composition, percent				
	Type 1 Bolts	Type 2 Bolts[A]	Nuts	Washers: Quenched and Tempered	Washers: Carburized
Carbon:					
Heat analysis	0.30 min	0.15 to 0.23	...	...	[B]
Product analysis	0.27 min	0.13 to 0.25	...	...	...
Manganese, min:					
Heat analysis	0.50	0.70	...	...	1.00 max
Product analysis	0.47	0.67	...	...	1.00 max
Phosphorus, max:					
Heat analysis	0.040	0.040	0.120	0.040	0.040
Product analysis	0.048	0.048	0.126	0.050	0.050
Sulfur, max:					
Heat analysis	0.050	0.050	0.23	0.050	0.050
Product analysis	0.058	0.058	...	0.060	0.060
Boron, min:					
Heat analysis	...	0.0005	...	...	...
Product analysis	...	0.0005	...	...	...

[A] Type 2 bolts shall be fully killed, fine grain steel

[B] The stock used for manufacture of carburized washers shall not contain over 0.25 percent carbon.

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TABLE 2 Chemical Requirements for Type 3 Bolts, Nuts, and Washers

Element	Composition, percent						
	Type 3 Bolts[A]					Type 3 Nuts[B]	Type 3 Washers[B]
	A	B	C	D	E		
Carbon:							
Heat analysis	0.33-0.40	0.38-0.48	0.15-0.25	0.15-0.25	0.20-0.25	...	...
Product analysis	0.31-0.42	0.36-0.50	0.14-0.26	0.14-0.26	0.18-0.27	...	...
Manganese:							
Heat analysis	0.90-1.20	0.70-0.90	0.80-1.35	0.40-1.20	0.60-1.00	...	...
Product analysis	0.86-1.24	0.67-0.93	0.76-1.39	0.36-1.24	0.56-1.04	...	...
Phosphorus:							
Heat analysis	0.040 max	0.06-0.12	0.035 max	0.040 max	0.040 max	0.07-0.15	0.040 max
Product analysis	0.045 max	0.06-0.125	0.040 max	0.045 max	0.045 max	0.07-0.155	0.045 max
Sulfur:							
Heat analysis	0.050 max	0.050 max	0.040 max	0.050 max	0.040 max	0.050 max	0.050 max
Product analysis	0.055 max	0.055 max	0.045 max	0.055 max	0.045 max	0.055 max	0.055 max
Silicon:							
Heat analysis	0.15-0.30	0.30-0.50	0.15-0.30	0.25-0.50	0.15-0.30	0.20-0.90	0.15-0.30
Product analysis	0.13-0.32	0.25-0.55	0.13-0.32	0.20-0.55	0.13-0.32	0.15-0.95	0.13-0.32
Copper:							
Heat analysis	0.25-0.45	0.20-0.40	0.20-0.50	0.30-0.50	0.30-0.60	0.25-0.55	0.25-0.45
Product analysis	0.22-0.48	0.17-0.43	0.17-0.53	0.27-0.53	0.27-0.63	0.22-0.58	0.22-0.48
Nickel:							
Heat analysis	0.25-0.45	0.50-0.80	0.25-0.50	0.50-0.80	0.30-0.60	1.00 max	0.25-0.45
Product analysis	0.22-0.48	0.47-0.83	0.22-0.53	0.47-0.83	0.27-0.63	1.03 max	0.22-0.48
Chromium:							
Heat analysis	0.45-0.65	0.50-0.75	0.30-0.50	0.50-1.00	0.60-0.90	0.30-1.25	0.45-0.65
Product analysis	0.42-0.68	0.47-0.83	0.27-0.53	0.45-1.05	0.55-0.95	0.25-1.30	0.42-0.68
Vanadium:							
Heat analysis	...	...	0.020 min	...	...	...	...
Product analysis	...	...	0.010 min	...	...	...	...
Molybdenum:							
Heat analysis	...	0.06 max	...	0.10 max	...	...	...
Product analysis	...	0.07 max	...	0.11 max	...	...	...
Titanium:							
Heat analysis	...	...	...	0.05 max	...	...	...
Product analysis	...	...	...	...	...	...	...

[A] A, B, C, D, and E are classes of material used for Type 3 bolts. Selection of a class shall be at the option of the bolt manufacturer.
[B] Nuts or washers may also be made of any of the above listed bolt material classes. Selection of the class shall be at the option of the manufacturer.

TABLE 3 Hardness Requirements for Bolts

Bolt Size, in.	Hardness Number			
	Brinell		Rockwell C	
	Min	Max	Min	Max
½ to 1, incl	241	331	23	35
1⅛ to 1½, incl	223	293	19	31

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TABLE 1 Chemical Requirements		
Element	Ladle Analysis, percent	Check Analysis, percent
Carbon		
For sizes through 1⅜ in.	0.30 to 0.48	0.28 to 0.50
For size 1½ in.	0.35 to 0.53	0.33 to 0.55
Phosphorus, max	0.040	0.045
Sulfur, max	0.040	0.045

TABLE 2 Hardness Requirements for Bolts'				
Bolt Size, in.	Hardness Number.			
	Brinell		Rockwell C	
	min	max	min	max
½ to 1½ in., incl	302	341	32	36

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COMPORTAMIENTO DE JUNTAS CON TORNILLOS DE ALTA RESISTENCIA

El comportamiento de una junta con tornillos de alta resistencia se puede visualizar mediante la observación de los resultados de una prueba carga-deformación en un especímen típico.

Se define una zona de comportamiento lineal (zona I) que termina en el instante en que se produce un deslizamiento de los tornillos con carga practicamente constante (zona II) y que esta controlado por el diámetro del agujero, al hacer contacto con sus bordes, el tornillo toma nuevamente carga y se reinicia un comportamiento nuevamente lineal (zona III0; esta zona termina al iniciarse el comportamiento inelástico (zona IV) que termina con la falla de la junta.

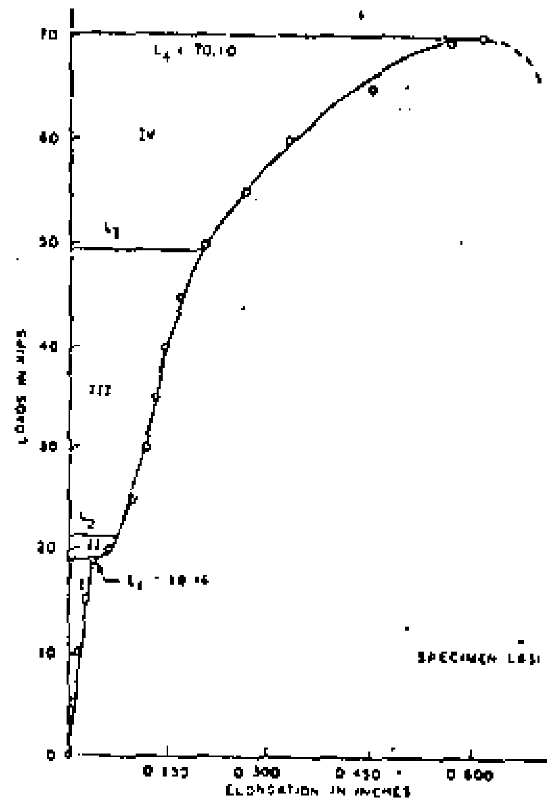

FIG. 6.—TYPICAL LOAD-JOINT ELONGATION RELATIONSHIP FOR SPECIMENS

Slockery
ASCE

Teniendo en cuenta el comportamiento mencionado se distinguen dos tipos de juntas con tornillos de alta resistencia: las - juntas de fricción y las juntas de aplastamiento.

Las primeras se caracterizan por que la trasmisión de las - fuerzas que actúan en la conexión se logra únicamente por la fricción que se desarrolla entre los elementos que la - constituyen.

En estas juntas el deslizamiento entre las piezas que se - unen no es aceptable; se considera que el deslizamiento e- quivaldría a la falla, si bien, los coeficientes de seguri- dad contra el deslizamiento se aceptan pequeños pués las consecuencias de su ocurrencia no son graves.

La magnitud de la fricción depende de la fuerza de tensión en el tornillo y de las características de la superficie de los elementos que se concitan.

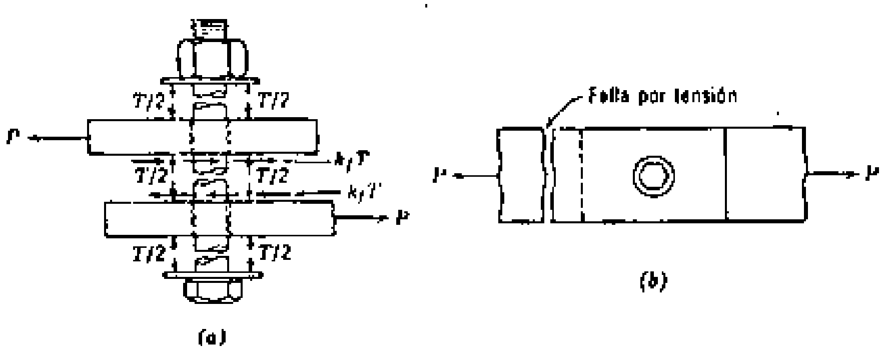

Fig. 5-15 Tornillo de alta resistencia. (*a*) Transmisión de carga por fricción, y (*b*) Falla fuera de la sección neta.

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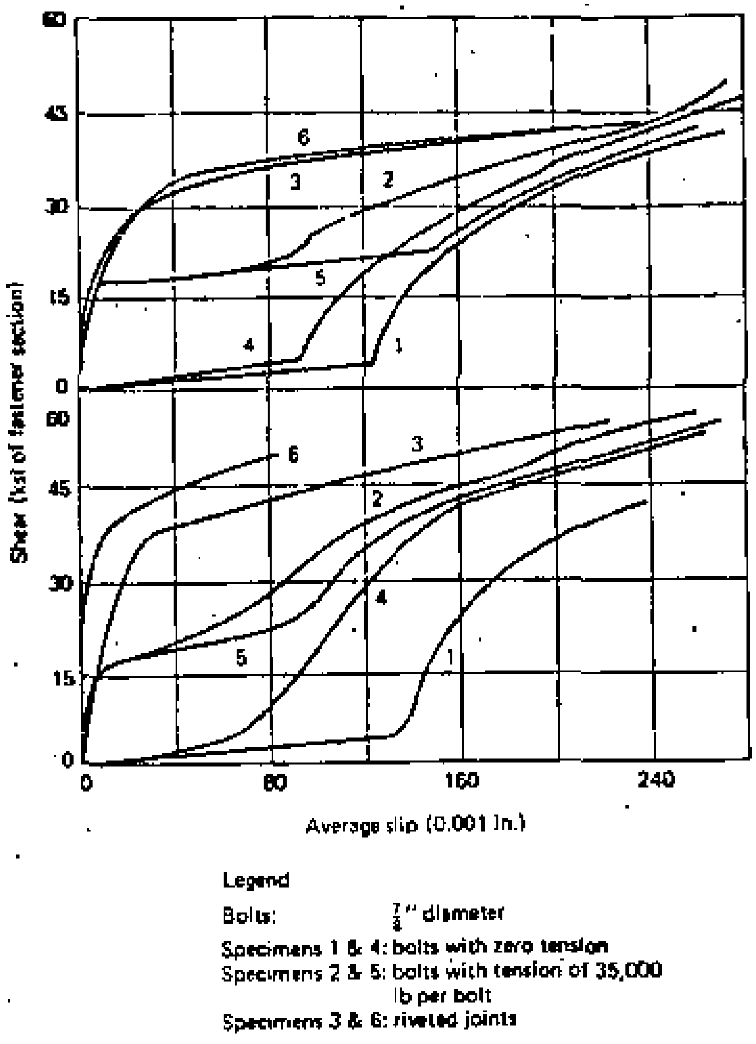

Figure 3.5 Relationship between Load and Slip. (From 3.18).

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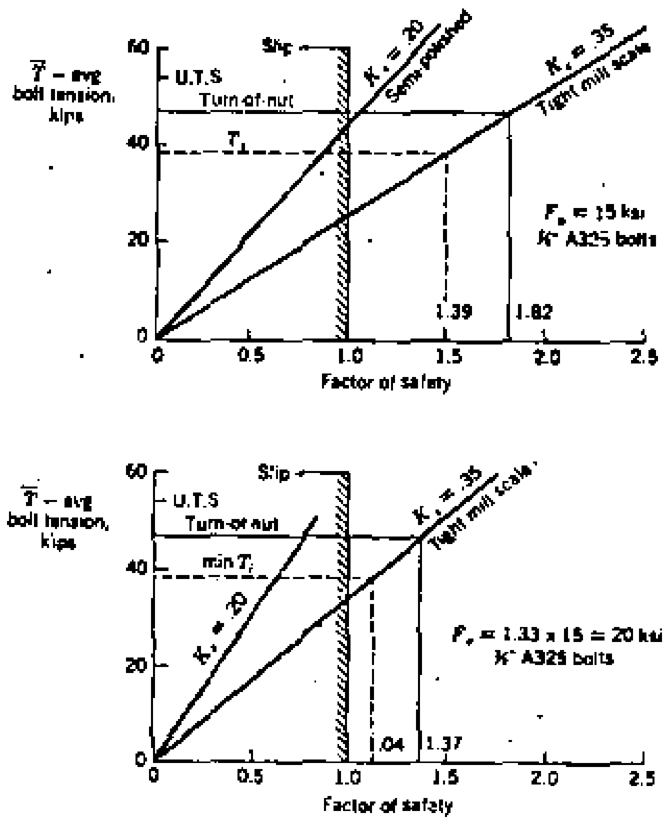

Fig. 18.16 Factor of safety against slip.

Para mantener la fricción es necesario que las superficies esten libres de todo elemento que la disminuya, se prohibe por ello, que haya aceite, pintura, oxido suelto, etc. Dada la importancia de este hecho, las últimas normas reconocen nueve condiciones distintas en que se pueden encontrar las superficies de la junta y asocian a cada una de ellas un esfuerzo permisible diferente, reconociendo las diferencias existentes en el coeficiente de fricción.

Aunque es claro que en juntas de fricción los tornillos no trabajan a esfuerzo cortante tradicionalmente se ha venido estableciendo un esfuerzo cortante permisible ficticio. para la determinación del número de tornillos que se requieren en una junta, esto ha permitido tratar el diseño de juntas con tornillos de fricción con los mismos criterios con que durante mucho tiempo, se han proporcionado las juntas remachadas.

Las conexiones de fricción se especifican como necesarias en todos aquellos casos en que se esperan inversiones de esfuerzos y en los que en condiciones de trabajo, el deslizamiento se considera indeseable.

Hay ocasiones en que la inversión de esfuerzos no ocurre y en que, al colocar los tornillos, la carga muerta los presiona contra los lados del agujero, entonces el trabajo de la junta puede ser por aplastamiento y por cortante y se presentan entonces las conexiones llamadas de aplastamiento.

Si bien, también en estas juntas, la tensión en el tornillo, que es la misma que en juntas de fricción, produce una fricción que probablemente podría tomar las cargas de trabajo, esta en realidad no se requiere. En estas juntas se puede sacar ventaja de la resistencia de los tornillos,

TABLE E1

ALLOWABLE SHEAR STRESSES, KSI,[a] BASED UPON SURFACE CONDITION OF BOLTED PARTS IN FRICTION-TYPE CONNECTIONS

Class	Surface Condition of Bolted Parts	Standard Holes		Oversized Holes and Short-slotted Holes		Long-slotted Holes	
		A325	A490	A325	A490	A325	A490
A	Clean mill scale	17.5	22.0	15.0	19.0	12.5	16.0
B	Blast-cleaned carbon and low alloy steel	27.5	34.5	23.5	29.5	19.5	24.0
C	Blast-cleaned quenched and tempered steel	19.0	23.5	16.0	20.0	13.5	16.5
D	Hot-dip galvanized and roughened[b]	21.5	27.0	18.5	23.0	15.0	19.0
E	Blast-cleaned, organic zinc rich paint	21.0	26.0	18.0	22.0	14.5	18.0
F	Blast-cleaned, inorganic zinc rich paint	29.5	37.0	25.0	31.5	20.5	26.0
G	Blast-cleaned, metallized with zinc	29.5	37.0	25.0	31.5	20.5	26.0
H	Blast-cleaned, metallized with aluminum	30.0	37.5	25.5	32.0	21.0	26.5
I	Vinyl wash	16.5	20.5	14.0	17.5	11.5	14.5

[a] Values from this table are applicable *only* when they do not exceed the lowest appropriate allowable working stresses for *bearing-type* connections, taking into account the position of threads relative to shear planes and, if required, the 20% reduction due to joint length. (See Table 1.5.2.1.)

[b] If loads causing actual stresses in excess of one-half the tabulated allowable stresses are sustained over a long period of time (e.g., gravity), slip into bearing may occur. If such slip would be severely detrimental, these increased working stresses are not recommended.

1.5.2.2 Design for rivets, bolts, and threaded parts subject to fatigue loading shall be in accordance with Appendix B, Sect. B3.

TABLE 1.5.2.1

ALLOWABLE STRESS ON FASTENERS, KSI

Description of Fasteners	Allowable Tension[g] (F_t)	Allowable Shear[g] (F_v)			
		Friction-type Connections[e,i]			Bearing-type Connections[i]
		Standard size Holes	Oversized and Short-slotted Holes	Long-slotted Holes	
A502, Grade 1, hot-driven rivets	23.0[a]				17.5[f]
A502, Grades 2 and 3, hot-driven rivets	29.0[a]				22.0[f]
A307 bolts	20.0[a]				10.0[b,f]
Threaded parts meeting the requirements of Sects. 1.4.1 and 1.4.4, and A449 bolts meeting the requirements of Sect. 1.4.4, when threads are not excluded from shear planes	$0.33F_u$[a,c,h]				$0.17F_u$[h]
Threaded parts meeting the requirements of Sects. 1.4.1 and 1.4.4, and A449 bolts meeting the requirements of Sect. 1.4.4, when threads are excluded from shear planes	$0.33F_u$[a,h]				$0.22F_u$[h]
A325 bolts, when threads are not excluded from shear planes	44.0[d]	17.5	15.0	12.5	21.0[f]
A325 bolts, when threads are excluded from shear planes	44.0[d]	17.5	15.0	12.5	30.0[f]
A490 bolts, when threads are not excluded from shear planes	54.0[d]	22.0	19.0	16.0	28.0[f]
A490 bolts, when threads are excluded from shear planes	54.0[d]	22.0	19.0	16.0	40.0[f]

[a] Static loading only.

[b] Threads permitted in shear planes.

[c] The tensile capacity of the threaded portion of an upset rod, based upon the cross-sectional area at its major thread diameter, A_b, shall be larger than the nominal body area of the rod before upsetting times $0.60F_y$.

[d] For A325 and A490 bolts subject to tensile fatigue loading, see Appendix B, Sect. B3.

[e] When specified by the designer, the allowable shear stress, F_v, for friction-type connections having special faying surface conditions may be increased to the applicable value given in Appendix E.

[f] When bearing-type connections used to splice tension members have a fastener pattern whose length, measured parallel to the line of force, exceeds 50 inches, tabulated values shall be reduced by 20 percent.

[g] See Sect. 1.5.6.

[h] See Appendix A, Table 2, for values for specific ASTM steel specifications.

[i] For limitations on use of oversized and slotted holes, see Sect. 1.23.4.

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sobre todo si se logra que la rosca se encuentre fuera de los planos de corte. Con el fin de lograr ésto en lo posible, los tornillos de alta resistencia tienen una rosca bastante corta.

En estructuras para puentes los tornillos en juntas de aplastamiento se limitan a piezas que sólo trabajan a compresión a miembros secundarios, se exige además que en todos los casos la rosca se excluya de los planos de corte.

TABLE 1.23.5

MINIMUM BOLT TENSION, KIPS*

Bolt Size, Inches	A325 Bolts	A490 Bolts
1/2	12	15
5/8	19	24
3/4	28	35
7/8	39	49
1	51	64
1 1/8	56	80
1 1/4	71	102
1 3/8	85	121
1 1/2	103	148

* Equal to 0.70 of specified minimum tensile strengths of bolts, rounded off to nearest kip.

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INSTALACION

Sea en juntas de fricción o en juntas de aplastamiento, los tornillos de alta resistencia deben colocarse de modo que queden sometidos a una fuerza mínima de tensión especificada.

Esta fuerza es de aproximadamente el 70% de la resistencia a tensión del tornillo, se denomina carga de prueba y es normalmente algo menor al límite de proporcionalidad del tornillo.

La tensión especificada se puede dar haciendo uso de un indicador directo de tensión o usando cualquiera de otros dos métodos que también se especifican en las normas y que se basan en el hecho de que la tensión en el tornillo se puede relacionar con dos cantidades observables, el alargamiento del tornillo y el giro de la tuerca.

El primero de estos métodos consigue la tensión usando llaves calibradas, el segundo dando un giro especificado a la tuerca.

METODO DEL GIRO DE LA TUERCA

Este procedimiento requiere un control de la coloración de los tornillos más simple que el anterior y es por ello, más utilizado.

Consiste en términos generales, en apretar, en una primera etapa, todos los tornillos con una llave normal de tuercas hasta el esfuerzo máximo de un hombre y enseguida, con una llave mayor, dar a la tuerca 1/2 vuelta adicional, excepcionalmente, el giro debe ser mayor.

Ha sido posible determinar experimentalmente la relación que existe entre la rotación de la tuerca y el alargamiento y la tensión en el tornillo, con ese fin se han realizado una cantidad importante de pruebas, en ellas se ha observado que la resistencia a tensión en un tornillo es menor cuando esta tensión se da girando la tuerca que se da en forma directa, esta es la razón de que la carga de prueba se fije sólo en un 70% de la resistencia a tensión directa.

METODO DE LLAVES CALIBRADAS

Implica el ajuste frecuente de la llave con un dispositivo capaz de medir la tensión en tornillos típicos de la conexión, ya que el ajuste pierde precisión con facilidad porque las condiciones de distintas juntas son muy diferentes entre si; se especifica que la calibración se realice una vez por cada día de trabajo y por cada diámetro o lote de tornillo que se utilice, aún en el caso de que se aprieten juntas similares.

Se exige también, cuando se usa este método, que se coloque una rondana bajo la parte del tronillo que se accione con la llave, con objeto de minimizar las irregularidades en la tensión producida que, inevitablemente, existen al utilizar este procedimiento.

Se observa que una vez dado el primer tercio de vuelta hay una reserva importante de deformación posible adicional hasta la falla, esto hace que el método no sea muy sensible a errores relativos al apriete que debe tener el tornillo en la primera etapa, al iniciarse la media vuelta pedida. Debido a ésto, cuando se utiliza este método, no se requiere la colocación de ninguna rondana, excepto cuando se usan tornillos A490 en auros con esfuerzo de fluencia inferior a 2800 Kg/cm^2, caso en que se necesita una rondana, cualquiera que sea el método de apriete.

Con objeto de garantizar el buen comportamiento de conexiones apretadas con este método se ha estudiado el efecto de una serie de variables que intervienen en su ejecución. Si ha estudiado, por ejemplo, el efecto de girar la tuerca en pequeños incrementos en vez de en forma continua, el efecto de la longitud del agarre y la posición relativa de tuerca y rosca. Se ha investigado, así mismo, la posibilidad del reuso de tornillos colocados con este método.

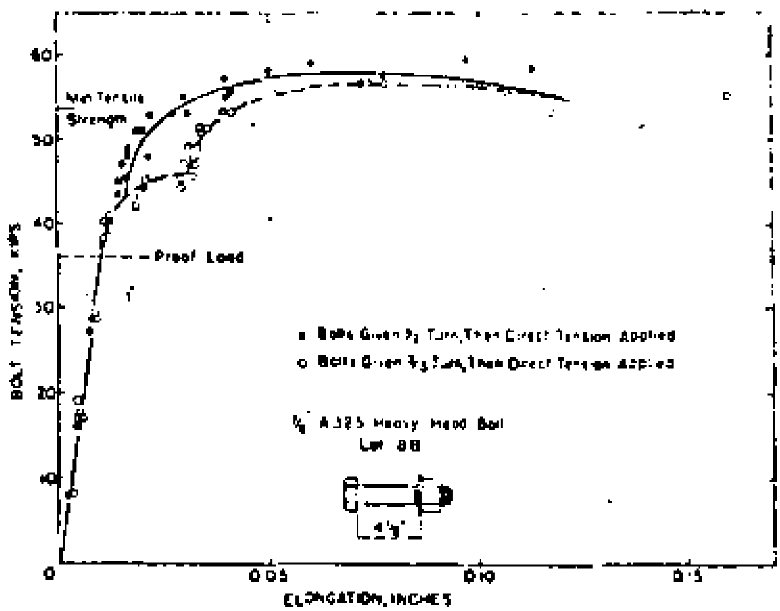

FIG. 6.—RESERVE TENSILE STRENGTH OF TORQUED BOLTS

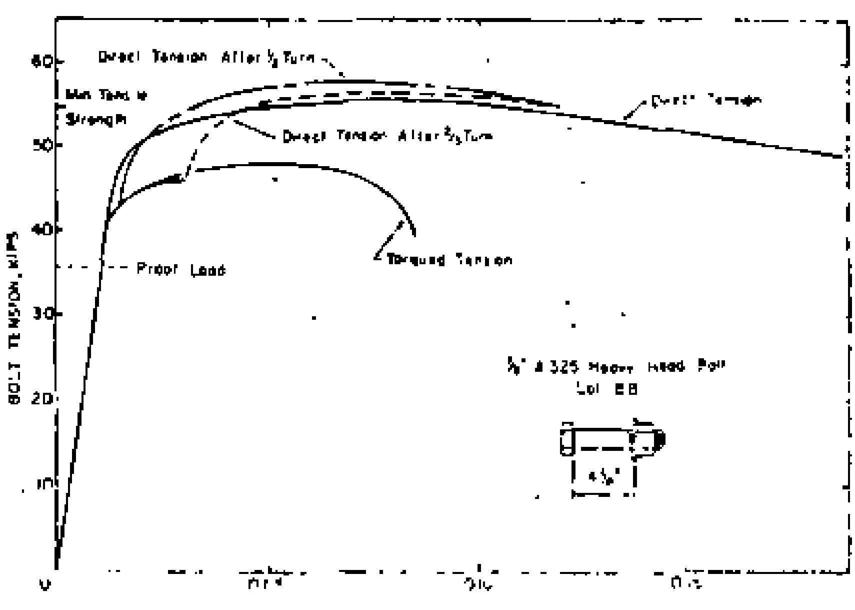

FIG. 7.—COMPARISON OF BOLT TENSION-ELONGATION RELATIONSHIPS

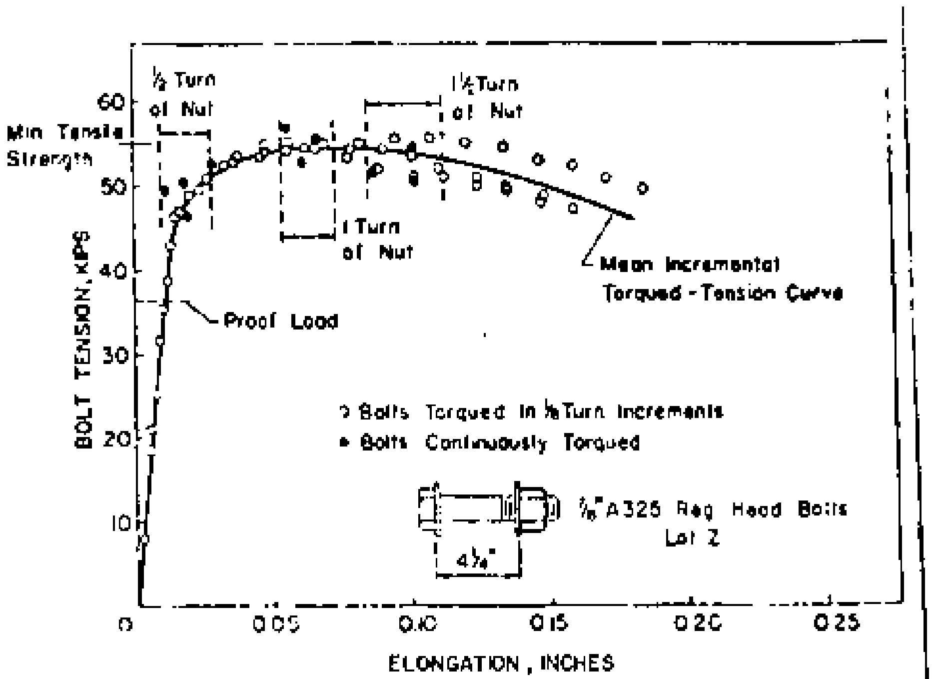

FIG. —COMPARISON OF CONTINUOUSLY AND INCREMENTALLY TORQUED BOLTS

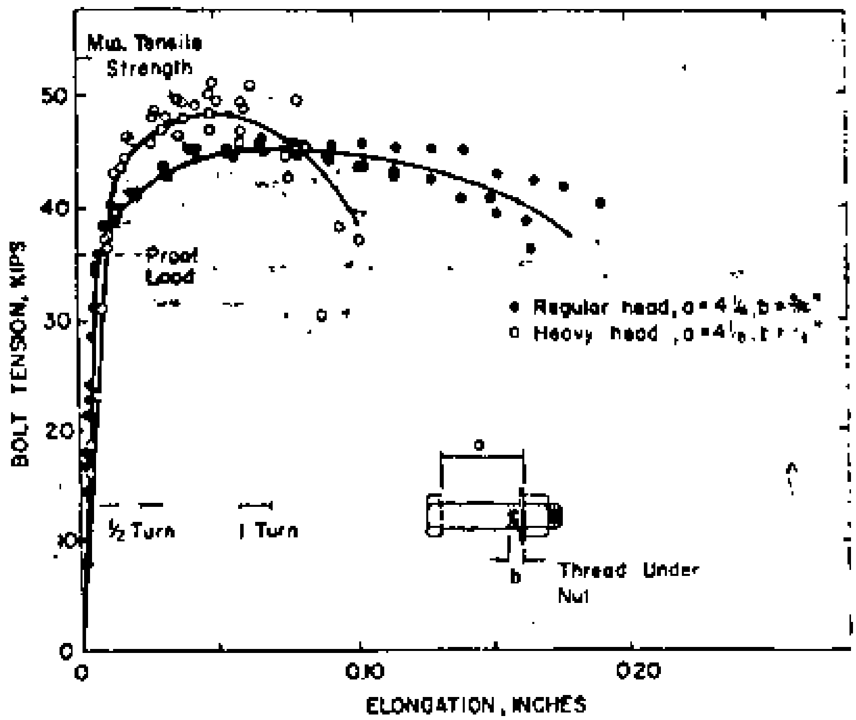

FIG. 13.—EFFECT OF THREAD LENGTH UNDER THE NUT

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Table 4 Nut Rotation[a] from Snug Tight Condition

Disposition of Outer Faces of Bolted Parts		
Both faces normal to bolt axis, or one face normal to axis and other face sloped not more than 1:20 (bevel washer not used)		Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used)
Bolt length[b] not exceeding 8 diameters or 8 inches	Bolt length[b] exceeding 8 diameters or 8 inches	For all length of bolts
½ turn	⅔ turn	¾ turn

[a] Nut rotation is rotation relative to bolt regardless of the element (nut or bolt) being turned. Tolerance on rotation: 30° over or under.
For coarse thread heavy hex structural bolts of all sizes and length and heavy hex semi-finished nuts.

[b] Bolt length is measured from underside of head to extreme end of point.

Una recomendación práctica para lograr un buen apriete general de la junta consiste en iniciarlo en los tornillos localizados en la parte más rígida de la unión y avanzar hacia los extremos libres. Durante el apriete la parte que no se gira, cabeza o tuerca se sonstendrá con una llave.

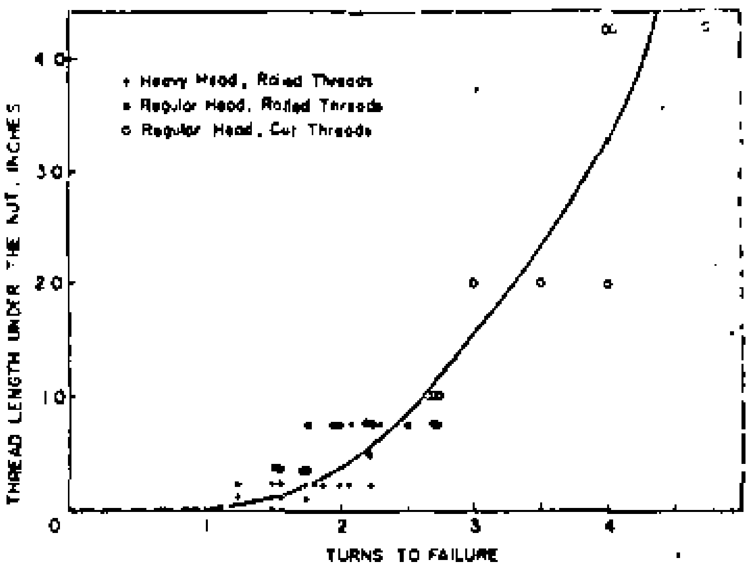
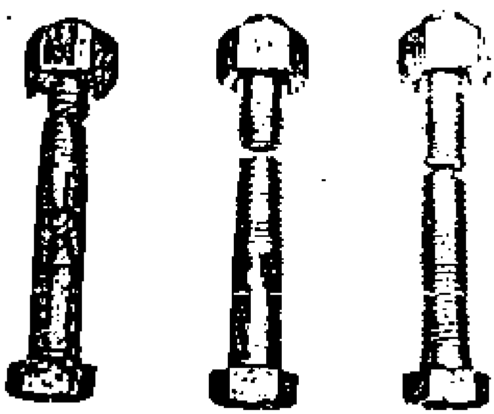


FIG. 11.—EFFECT OF THREAD LENGTH ON ROTATION CAPACITY



1.16.3 Long Grips

Rivets and A307 bolts which carry calculated stress, and the grip of which exceeds 5 diameters, shall have their number increased 1 percent for each additional $\frac{1}{16}$-inch in the grip.

1.16.4 Minimum Spacing

1.16.4.1 The distance between centers of standard, oversized, or slotted fastener holes shall be not less than $2\frac{2}{3}d$,* where d is the nominal diameter of the fastener, inches, nor less than that required by Sect. 1.16.4.2, if applicable.

1.16.4.2 Along a line of transmitted force, the distance between centers of holes shall be not less than the following:

1. Standard Holes:

$$2P/F_u t + d/2 \qquad (1.16\text{-}1)$$

where

P = force transmitted by one fastener to the critical connected part, kips
F_u = specified minimum tensile strength of the critical connected part, kips per square inch
t = thickness of the critical connected part, inches

2. Oversized and Slotted Holes:
The distance required for standard holes in subparagraph 1, above, plus the applicable increment C_1 in Table 1.16.4.2, but the clear distance between holes shall not be less than one bolt diameter.

1.16.5 Minimum Edge Distance

1.16.5.1 The distance from the center of a standard hole to an edge of a connected part shall be not less than the applicable value in Table 1.16.5.1 nor the value from Sect. 1.16.5.2 or 1.16.5.3, as applicable.

1.16.5.2. Along a line of transmitted force, in the direction of the force, the distance from the center of a standard hole to the edge of the connected part shall be not less than

$$2P/F_u t \qquad (1.16\text{-}2)$$

where P, F_u, and t are as defined in Sect. 1.16.4.2.

1.16.5.3 At end connections bolted to the web of a beam and designed for beam shear reaction only (without use of an analysis which accounts for the effects induced by fastener eccentricity), the distance from the center of the nearest standard hole to the end of the beam web shall be not less than

$$2P_R/F_u t \qquad (1.16\text{-}3)$$

where P_R is the beam reaction, in kips, divided by the number of bolts, and F_u and t are as defined in Sect. 1.16.4.2. Alternatively, the requirement of Formula (1.16-3) may be waived provided the bearing stress induced by the fastener is limited to not more than $0.90F_u$.

TABLE 1.16.4.2
VALUES OF SPACING INCREMENT C_1 IN SECT. 1.16.4.2, INCHES

Nominal Diameter of Fastener (Inches)	Oversized Holes	Slotted Holes		
		Perpendicular to Line of Force	Parallel to Line of Force	
			Short Slots	Long Slots[a]
≤7/8	1/16	0	3/16	$1\frac{1}{2}d - \frac{1}{16}$
1	3/16	0	1/4	1 7/16
≥1 1/8	1/4	0	5/16	$1\frac{1}{2}d - \frac{1}{16}$

[a] When length of slot is less than maximum allowable (see Table 1.23.4), C_1 may be reduced by the difference between the maximum and actual slot lengths.

TABLE 1.16.5.1
MINIMUM EDGE DISTANCE, INCHES
(CENTER OF STANDARD HOLE[a] TO EDGE OF CONNECTED PART)

Nominal Rivet or Bolt Diameter (Inches)	At Sheared Edges	At Rolled Edges of Plates, Shapes or Bars or Gas Cut Edges[b]
1/2	7/8	3/4
5/8	1 1/8	7/8
3/4	1 1/4	1
7/8	1 1/2[c]	1 1/8
1	1 3/4[c]	1 1/4
1 1/8	2	1 1/2
1 1/4	2 1/4	1 5/8
Over 1 1/4	1 3/4 × Diameter	1 1/4 × Diameter

[a] For oversized or slotted holes, see Sect. 1.16.5.4.
[b] All edge distances in this column may be reduced 1/8-in. when the hole is at a point where stress does not exceed 25% of the maximum allowed stress in the element.
[c] These may be 1 1/4-in. at the ends of beam connection angles.

TABLE 1.16.5.4
VALUES OF EDGE DISTANCE INCREMENT C_2 IN SECT. 1.16.5.4, INCHES

Nominal Diameter of Fastener (Inches)	Oversized Holes	Slotted Holes		
		Perpendicular to Edge		Parallel to Edge
		Short Slots	Long Slots[a]	
≤7/8	1/16	1/8	$\frac{3}{4}d$	0
1	1/8	1/8		
≥1 1/8	1/8	3/16		

[a] When length of slot is less than maximum allowable (see Table 1.23.4), C_2 may be reduced by one-half the difference between the maximum and actual slot lengths.

REFERENCIAS

1. Specification for the Design, Fabrication and Erection of Structural Steel for Buildings AISC, 1978

2. Specification for structural joints using ASTM A325 or A490 bolts, AISC, 1969

3. Standard Specifications for high-strength bolts American Society for Testing and Materials, 1971

4. Structural Steel Desing, Tall, 1974

5. Diseño de Estructuras de Acero, Bresler, 1978

6. Steel Design for Structural Engineers, Bogdan O. Kujhanovic, Nicholas Willems, 1977

7. Calibration of A325 Bolts, John L. Rumpf; John W. Fisher, ASCE, 1963

8. Bolted Connections with vaned holes diameters. Z. Shoukry, ASCE, 1970

TABLE 5.—SUMMARY OF RESULTS

Specimen group (1)	Hole over-size, in inches (2)	Plate thick-ness, in inches (3)	Average slip coefficient (4)	Average ultimate shear stress, in kips per square inch (5)
(a) Lap Joints				
L61[a]	1/16	3/8	0.352	78.4
L62	2/16	3/8	0.330	79.1
L63	3/16	3/8	0.327	79.1
L64	4/16	3/8	Data Unattainable	
L71[b]	1/16	7/16	0.347	83.3
L72	2/16	7/16	0.320	82.2
L73	3/16	7/16	0.326	82.4
L74	4/16	7/16	Data Unattainable	
(b) Butt Joints				
B61	1/16	3/8	0.346	67.0
B62	1/16	3/8	0.309	65.1
B63	3/16	3/8	0.316	64.3
B64	4/16	3/8	Data Unattainable	
B71	1/16	1/2	0.313	69.0
B72	2/16	1/2	0.300	66.6
B73	3/16	1/2	0.267	69.0
B74	4/16	1/2	0.215	66.6

[a] L61-L64 and B61-B64: 6/8-in. bolts.
[b] L71-L74 and B71-B74: 7/8-in. bolts.

PRUEBAS CON AGUJEROS AGRANDADOS.-

Shoukry
ASCE

OTROS TOPICOS RELATIVOS A TORNILLOS DE ALTA RESISTENCIA

AGUJEROS.- Durante bastante tiempo sólo se aceptaron agujeros exactamente 1/16" mayores que el diámetro del tornillo, sin embargo, la necesidad de facilitar las condiciones de montaje de las estructuras atornilladas indujo a que se realizaran una extensa serie de pruebas para demostrar la posibilidad de utilizar agujeros con diámetros algo mayores sin detrimento de la resistencia.

El resultado de esas investigaciones ha conducido a que se acepten agujeros mayores aunque en este caso se requiere colocar una rondana en el lado exterior de la junta.

En juntas de aplastamiento sólo se permiten agujeros ovalados, el lado alargado normal a la dirección de los esfuerzos.

Table 1 . Washer Dimensions[a]

Bolt Size D	Circular Washers				Square or Rectangular Beveled Washers for American Standard Beams and Channels		
	Nominal Outside Diameter	Nominal Diameter of Hole	Thickness Min.	Thickness Max.	Minimum Side Dimension	Mean Thickness	Slope or Taper in Thickness
1/2	1 1/16	17/32	0.097	0.177	1 3/4	5/16	1:6
5/8	1 5/16	21/32	0.122	0.177	1 3/4	5/16	1:6
3/4	1 15/32	13/16	0.122	0.177	1 3/4	5/16	1:6
7/8	1 3/4	15/16	0.136	0.177	1 3/4	5/16	1:6
1	2	1 1/16	0.136	0.177	1 3/4	5/16	1:6
1 1/8	2 1/4	1 1/4	0.136	0.177	2 1/4	5/16	1:6
1 1/4	2 1/2	1 3/8	0.136	0.177	2 1/4	5/16	1:6
1 3/8	2 3/4	1 1/2	0.136	0.177	2 1/4	5/16	1:6
1 1/2	3	1 5/8	0.136	0.177	2 1/4	5/16	1:6
1 3/4	3 3/8	1 7/8	0.178[b]	0.28[b]			
2	3 3/4	2 1/8	0.178[b]	0.28[b]			
Over 2 to 4 Incl.	2D—1/2	D + 1/8	0.24[c]	0.34[c]			

[a] Dimensions in inches. (Tolerances as noted in Table 1-A.)
[b] 7/32 in. nominal.
[c] 9/32 in. nominal.

2(c), may be used. Such alternate fasteners may differ in other dimensions from those of the specified bolts and nuts. Their installation procedure may differ from those specified in paragraphs 5(c) and 5(d) and their inspection may differ from that specified in Section 6. When a different installation procedure or inspection is used, it shall be detailed in a supplemental specification applying to the alternate fastener and this specification must be approved by the engineer responsible for the design of the structure.

(e) Circular washers and square or rectangular beveled washers shall conform to the dimensions in Table 1 within tolerances given in Table 1-A. Beveled washers shall taper in thickness. Washers shall have no raised markings on their bearing surfaces.

Where necessary, washers may be clipped on one side to a point not closer than 7/8 of the bolt diameter from the center of the washer.

Table 1-A Washer Dimension Tolerances (inches)

Dimension	Washer Size	
	To 1 3/4 in. Nominal Bolt Size, Incl.	Over 1 3/4 in. Nominal Bolt Size
Nominal diameter of hole	−0; +1/32	−0; +1/16
Nominal outside dimensions	−1/32; +1/4	−1/16; +1/4
Flatness; max. deviation from straight edge placed on "cut" side shall not exceed	0.01	0.015
Burr shall not project above immediately adjacent washer surface more than	0.01	0.015

TABLE 1.23.4

MAXIMUM SIZES[a] OF FASTENER HOLES, INCHES

Nominal Fastener Diameter (d)	Standard Hole Diameter	Oversized[b] Hole Diameter	Short-Slotted[b] Hole Dimensions	Long-Slotted[b] Hole Dimensions
≤ 7/8	d + 1/16	d + 3/16	(d + 1/16) × (d + 1/4)	(d + 1/16) × 2½d
1	1 1/16	1 1/4	1 1/16 × 1 5/16	1 1/16 × 2 1/2
≥ 1 1/8	d + 1/16	d + 5/16	(d + 1/16) × (d + 3/8)	(d + 1/16) × 2½d

[a] Sizes are nominal.

[b] Not permitted for riveted connections.

ESPECIFICACIONES
AISC

mostrado un comportamiento adecuado aún teniendo en cuenta posibles efectos de fatiga.

No ha ocurrido lo mismo con los tornillos A490 cuyo galvanizado no se permite.

En juntas de fricción, se permite también el galvanizado de la estructura siempre que se trate la zona de la conexión con cepillo de alambre o chorro de arena para galbanizar la fricción adecuada. Debe cuidarse, por supuesto, no dañar el galvanizado.

DETERMINACION DE LA LONGITUD DE LOS TORNILLOS

Debe añadirse al agarre (espesor de todo el material conectado) ciertas distancias especificadas con objeto de garantizar la correcta colocación teniendo en cuenta las tolerancias de fabricación.

Por cada rondana plana se debe considerar una longitud adicional de 5/32" y por cada rondana tipo cuña 5/16". La longitud así obtenida se cierra al cuarto de pulgada superior más próximo.

Por lo que se refiere a la ejecución de los agujeros las normas recomiendan que cuando el espesor del material no es mayor que el diámetro del tornillo más 1/8 se puedan punzonar, en caso contrario deben ser taladrados o subpunzonados y rimados.

GALVANIZADO

Otro avance importante respecto a criterios anteriores lo marca el hecho de que se permita ahora galvanizar los tornillos A325, tras una amplia serie de pruebas que han de-

Table 6

Bolt Size, in Inches	To Determine Required Bolt Length Add to Grip, in Inches
1/2	11/16
5/8	7/8
3/4	1
7/8	1 1/8
1	1 1/4
1 1/8	1 1/2
1 1/4	1 5/8
1 3/8	1 3/4
1 1/2	1 7/8

ESPECIFICACIONES AISC

centro de educación continua
división de estudios superiores
facultad de ingeniería, unam

PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

CONEXIONES(CONTINUACION)

ING. JOSE LUIS SANCHEZ MARTINEZ

JUNIO,1979.

COMPORTAMIENTO DE CONEXIONES ATORNILLADAS

Las normas del AISC consideran tres tipos básicos de construcción en acero permisibles. La diferencia entre ellos radica en las características de las conexiones que ligan los elementos constituyentes de la estructura.

- Tipo 1. Estructuras continuas
- Tipo 2. Conexiones libres
- Tipo 3. Conexiones semirígidas

El diseño de la estructura debe ser congruente con el tipo de conexión utilizada y viceversa.

El uso del tipo 3 supone gire la conexión una capacidad de momento <u>conocida</u> e intermedia entre la que proporciona la tipo 1 y la tipo 2 (articulación con momento = 0).

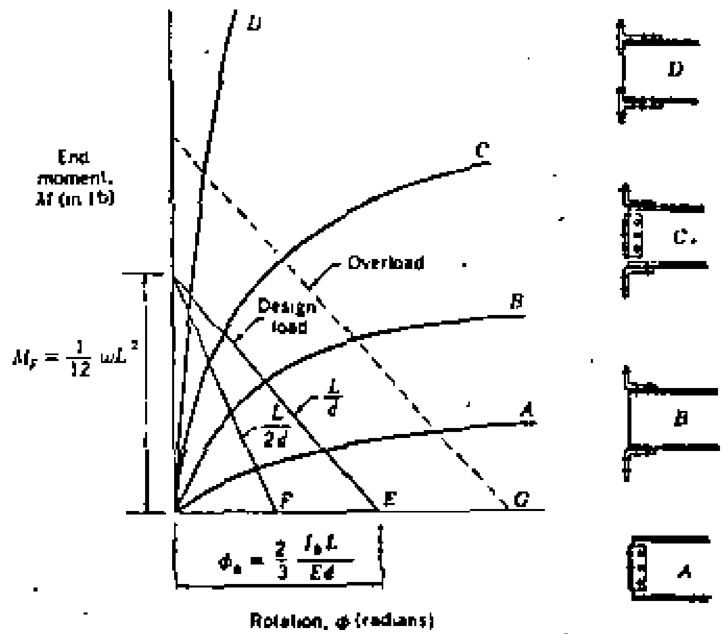


Fig. 18.14 Typical moment-rotation curves and beam-lines.

probable that the major portion of the end shear is resisted by friction at the lower tee.

Beam-Line Concept. The moment that will be developed by a particular connection when it is used on a beam of a given span and loading may be determined from the M-ϕ curve of that connection by using the beam-line concept.[18.24]

If a beam with a uniformly distributed load w has equal restraining moments M at the ends, the following relationship of end slope ϕ and end moment can be derived.

$$\phi = \frac{1}{24}\frac{wL^3}{EI} - \frac{1}{2}\frac{ML}{EI} \tag{18.7}$$

This is a linear equation in ϕ and M which is easily plotted as line E in Fig. 18.14, using the following values:

$(\phi = 0)$ $\quad M_F = \frac{1}{12}wL^2$ $\quad$ (fixed-end moment)

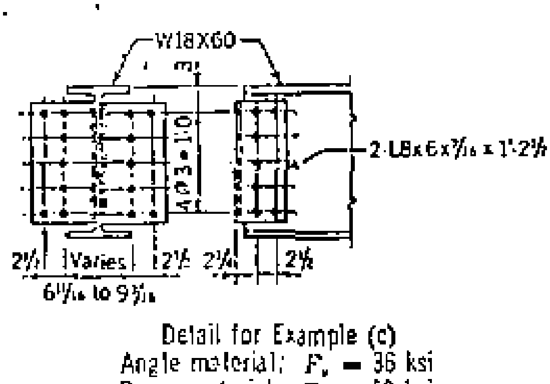
$(M = 0)$ $\quad \phi_s = \dfrac{wL^3}{24EI}$ $\quad$ (simple beam end slope) of the connection is maintained. Table II-A5 gives a shear value of 212 kips for eight 7/8"φ A325-X bolts: for seven bolts the shear will be 212 × 7/8 = 186 kips. The angle thickness required for eight bolts is 9/16". In the interest of economy this may be revised, using $t_{min} = R \div (F_v \times L \times 2)$, where F_v is the allowable shear stress in the angle (A36 steel) and L is the length of the angle: $t_{min} = 150 \div (14.5 \times 14\frac{1}{2} \times 2) = 0.357"$, or a 3/8" angle. From Table II-B5, 473 kips is allowed for 1" of $F_y = 50$ ksi beam web material using eight fasteners. With seven fasteners and a web of 0.416", the permissible bearing is 473 × 0.416 × 7/8 = 172 kips. The bearing in the two 3/8" angles (A36 steel) is not critical.

Solution, detail: Using the 2 1/4"-2 1/2" gages shown on the sketch for Table II-A5, the connection for the angle legs attaching to the web will require an additional edge distance of 1 1/8". This gives a minimum width of leg 2 1/4" + 2 1/2" + 1 1/8" = 5 7/8" or 6". A minimum gage for the outstanding legs is developed as follows:

Angle thickness required:	3/8"
Washer thickness (web bolt):	3/16"
Nut thickness (web bolt):	7/8"
Bolt projection (web bolt):	1/4"
Impact wrench clearance:	1 3/8"
	3 1/16"

A minimum leg gage of 3 1/16" to the first bolt allows bolts in both legs to be placed on the same horizontal rows and also gives sufficient clearance for the impact wrench. The minimum edge distance per AISC Specification Table 1.16.5 is 1 1/8" for 7/8"φ bolts. Thus, the minimum angle leg width for the outstanding leg will be 3 1/16 + 2 1/2 + 1 1/8 = 6 11/16".

Since a 6" leg must be used with the web and at least 6 11/16" is needed on the outstanding legs, use two angles 8 × 6 × 7/16" × 1'-2 1/2". (This size angle is not rolled in a 3/8" thickness; therefore, a 7/16" angle is selected.) The minimum inside gage that may be used across the outstanding legs is 2 × (3 1/16 + 1/16) + 7/16 beam web = 6 11/16". The maximum inside gage that may be used across the outstanding legs is (2 × 8) + 7/16 web − 2 (2 1/2" gage + 1 1/8" edge distance) = 9 3/16". The gage chosen may be anywhere between these two values and is the option of the detailer.

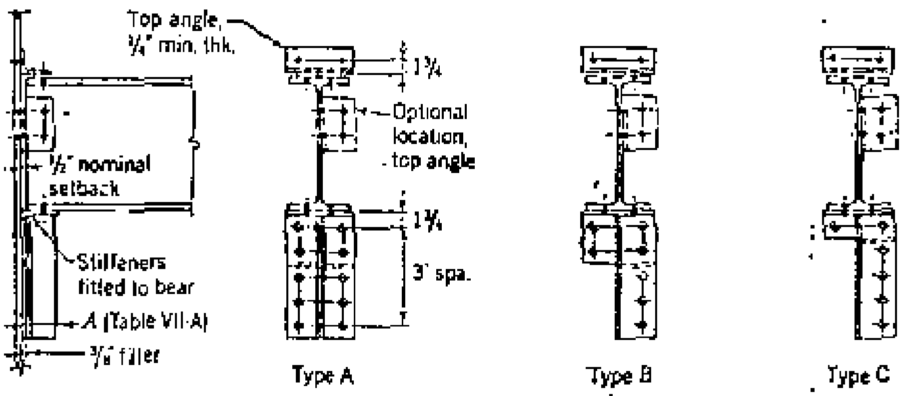


Detail for Example (c)
Angle material: $F_y = 36$ ksi
Beam material: $F_y = 50$ ksi

STIFFENED SEATED BEAM CONNECTIONS

Bolted or Riveted

TABLE VII



Use full values in Tables VII-A and VII-B

Use one-half values in Tables VII-A and VII-B

Use one half values in Tables VII-A and VII-B but limit capacity to that of 5 fasteners through stiffeners of 3½" max. OSL.

Stiffened Seat Types

Seated connections should be used only when the beam is supported by a top angle placed as shown above, or in the optional location as indicated.

Allowable capacities in Table VII-A are based on allowable bearing using steel of $F_y = 36$ ksi or $F_y = 50$ ksi in the stiffener angles. Capacities of fastener groups in Table VII-B are based on single shear. Capacity of the connection is based on the lesser of these two values in conjunction with the web crippling value of the supported beam.

Effective length of stiffener bearing is assumed ½" less than length of outstanding leg.

Maximum gage in legs of stiffeners connected to columns is 4¾".

ASTM A307 bolts may be used in seated connections, providing the stipulations of AISC Specification Sect. 1.15.12 are observed.

Vertical spacing of fasteners in stiffener angles may be arranged to suit conditions, provided they conform to Sections 1.16.4 and 1.16.5 with respect to minimum pitch and minimum edge distances.

Paired stiffener angles shown in contact may be separated to accommodate column gages, but should not exceed 2 × (k − stiffener thickness), with a minimum opening of 1", where the k value is for the supported beam (see tables of dimensions, Part 1 of this Manual). If it is not required to paint the connection parts, the 1" minimum may be ignored.

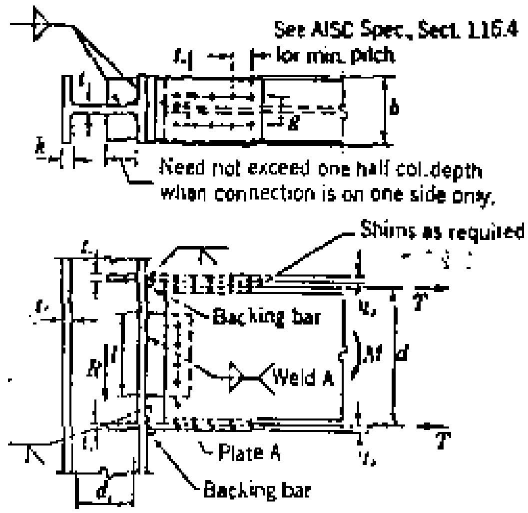
To permit selection of the most economical seated beam connection, the beam reactions should be shown on the contract drawings. If they are not shown, the connections should be selected to support half the total uniform load capacity shown in the beam load tables for the given shape, span, and steel of the beam in question. The effect of concentrated loads near an end connection must also be considered.

For loads in excess of tabulated capacities it is necessary to design special seated connections.

MOMENT CONNECTIONS

Shop welded—field bolted

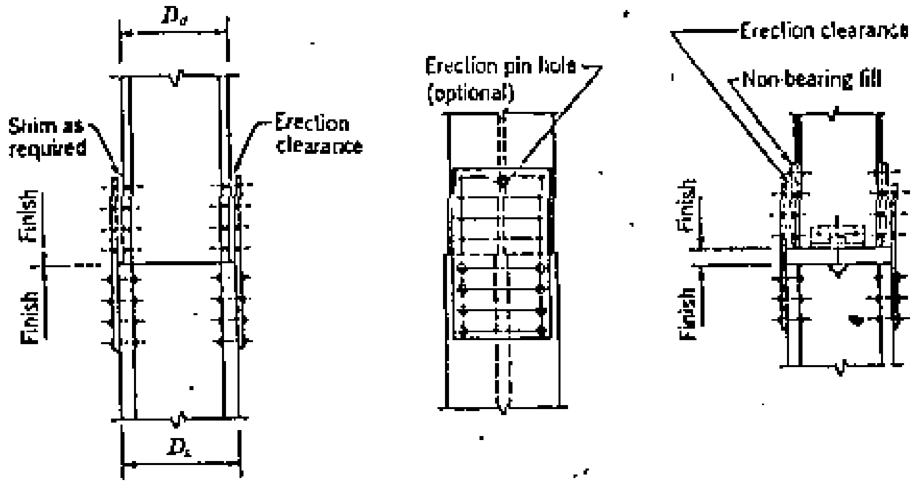
Many framing systems are designed as Type 1 (rigid-frame) and the connections must be designed to develop the inherent frame moments. The following example illustrates the design of a moment connection that may be used in rigid-frame construction and the method shown is recommended for the design of such a connection. For nomenclature, see "Moment Connections, Welded".



The moment is assumed to be resisted by the flange plates shop welded to the column and field fastened to the beam flanges. The shear is assumed to be transferred to the column by a vertical plate shop welded to the column and field fastened to the beam web.

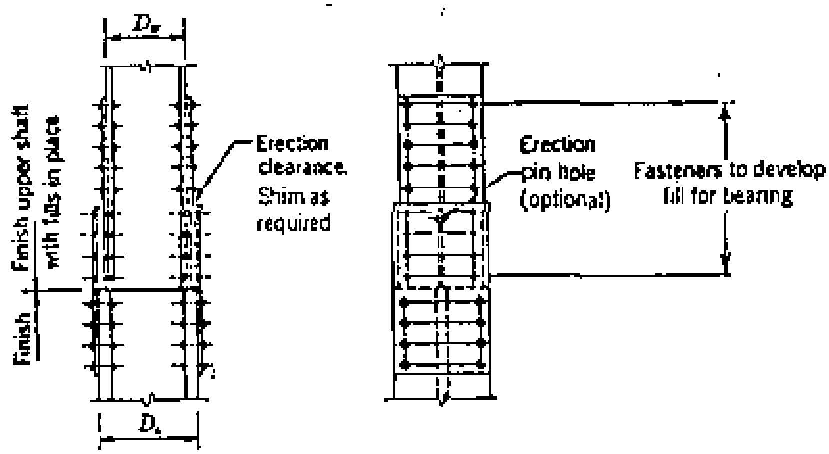
	AISC Specification Reference
1. Determine flange area reduction for fastener holes in accordance with Section 1.10.1 of the Specification.	1.10.1
2. Determine horizontal force $T = \frac{M \times 12}{d}$	
3. Design flange plates: $A_p = \frac{T}{F_t}$; $b = \frac{A_p + \text{(Area of fastener holes deducted)}}{t_p}$	
4. Determine the number of fasteners required to develop the horizontal force in the flanges. No. of fasteners $= \frac{T}{r_v}$	

SUGGESTED DETAILS
Column splices
Riveted and bolted



DEPTH OF D_U AND D_L NOMINALLY THE SAME

BUTT PLATE



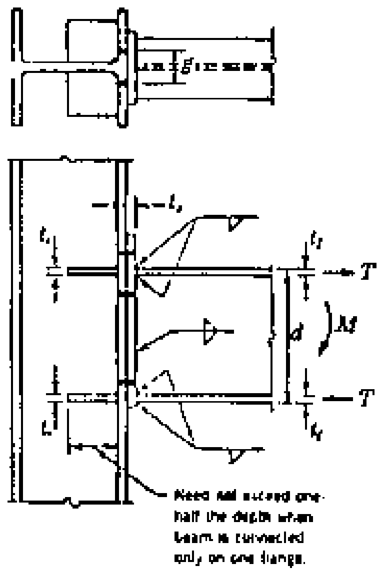
DEPTH D_U NOMINALLY 2 IN. LESS THAN D_L

Note: Erection clearance = ⅛ in.

MOMENT CONNECTIONS

End plate

DESIGN EXAMPLE



Given: A beam having an end reaction of 30 kips and an end negative moment of 1440 kip-in. frames to a W14 × 184 column. The beam-to-column connection is to be an end plate type connection using ASTM A325 bolts. F_y = 36 ksi steel is used for the beam and connection material. The end plate is to be shop welded to the beam with E70XX electrodes. The moment has been reduced in accordance with Specification Sect. 1.5.1.4.1 for members rigidly framed to columns.

Solution: Assume that the centroid of the tensile and compressive forces is at the center of the flanges of the beam. Based on the beam and column dimensions and normal gage lines, an end plate size with bolts is selected. Assume that the top bolts act as a tee connection and the bottom bolts will act in shear, but primarily serve to maintain beam alignment. Since it is more economical to fillet weld than to connect with full penetration butt welds, assume that the flanges will be welded to the end plate with fillet welds and the balance of the section will be welded with $\frac{5}{16}$ in. fillet welds, the minimum size for the thickness range of plate to be used in the connection.

	AISC Specification or Manual Reference
A. Beam selection:	
1. Required section modulus of beam: $S = \dfrac{1440}{24} = 60$ in.³	
W16 × 40 has a section modulus of 64.6 > 60 in.³	pg. 2 - 10
2. Check flange force:	
$T\,(W16 \times 40) = \dfrac{1440}{16.0 - 0.503} = 92.9$ kips	
Allowable flange force (W16 × 40) = 7.0 × 0.503 × 24 = 84.5 kips < 92.9 n.g.	
∴ Try W16 × 45: $S = 72.5$ in.³ > 60 in.³	

S O L D A D U R A

I. PROCESOS DE SOLDADURA.-

a) MANUAL (Al arco eléctrico con electrodo recubierto).

b) DE ARCO SUMERGIDO (Soldadura al arco eléctrico con electrodo sumergido).

c) SEMIAUTOMATICA DE ELECTRODO TUBULAR FLEXIBLE (Soldadura al arco eléctrico y electrodo con núcleo defundente

d) SEMIAUTOMATICA DE ARCO PROTEGIDO CON GAS.

e) ELECTRO SLAC O ELECTROGAS

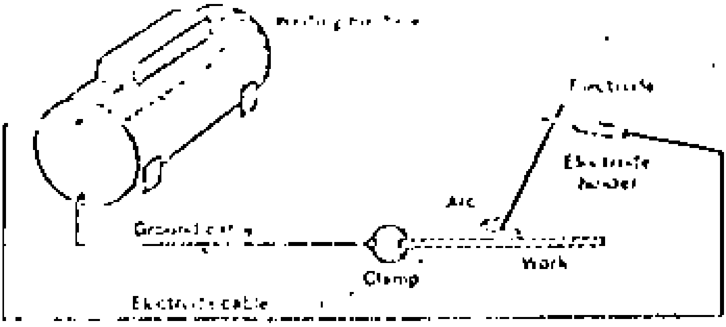


Fig. 14.1 The welding circuit.

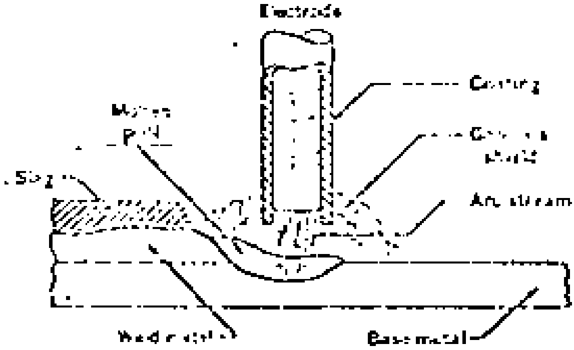


Fig. 14.3 Shielded arc-welding process.

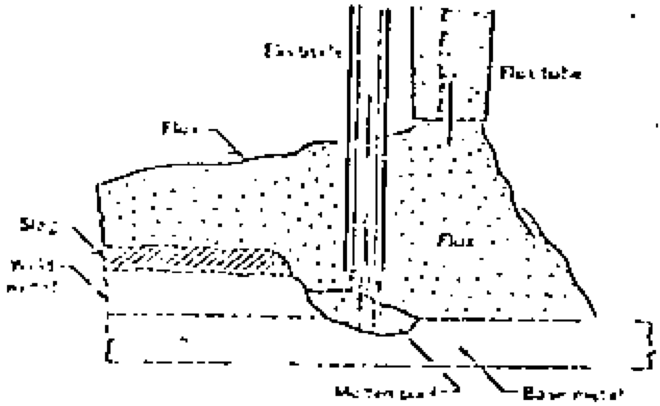


Fig. 14.5 Submerged arc-welding process.

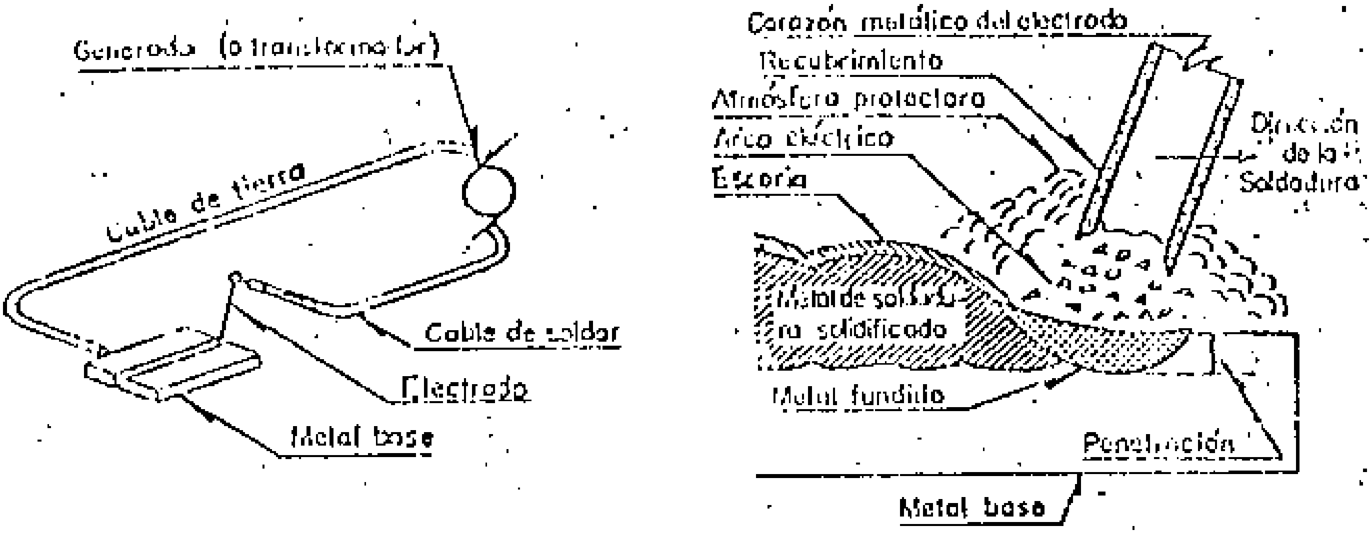


Fig 32

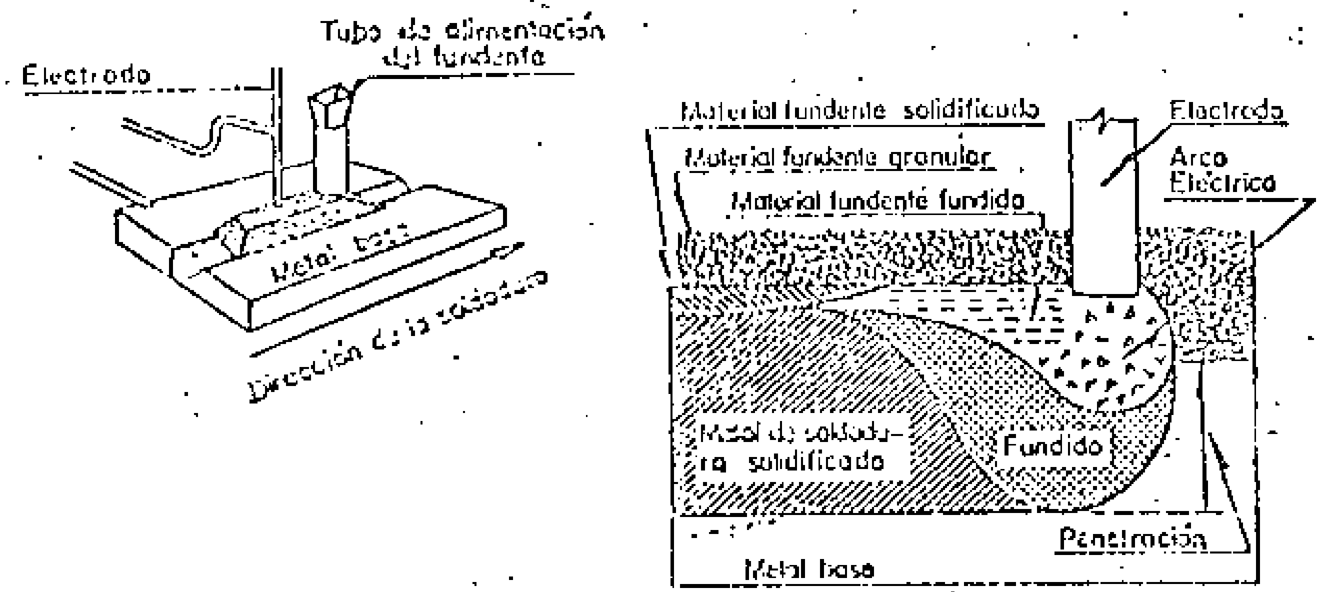


Fig 33

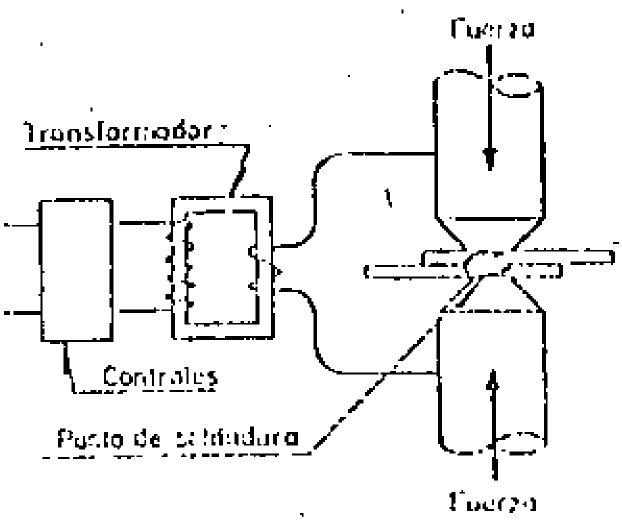


Fig 34

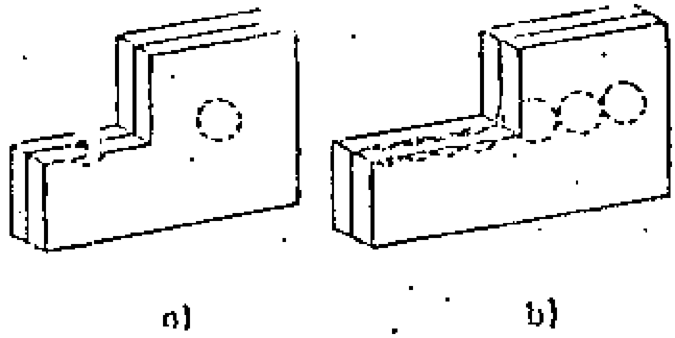


Fig 35

The Self-Shieldı
Flux-Cored Process

The self-shielded flux-cored arc-welding process is an outgrowth of shielded metal-arc welding. The versatility and maneuverability of stick electrodes in manual welding stimulated efforts to mechanize the shielded metal-arc process. The thought was that if some way could be found for putting an electrode with self-shielding characteristics in coil form and feeding it mechanically to the arc, welding time lost in changing electrodes and the material loss as electrode stubs would be eliminated. The result of these efforts was the development of the semiautomatic and full-automatic processes for welding with continuous flux-cored tubular electrode "wires." Such fabricated wires (Fig. 5-5) contain in their cores the ingredients for fluxing and deoxidizing molten metal and for generating shielding gases and vapors and slag coverings.

In essence, semiautomatic welding with flux-cored electrodes is manual shielded metal-arc welding with an electrode many feet long instead of just a few inches long. By the press of the trigger completing the welding circuit, the operator activates the mechanism that feeds the electrode to the arc (Fig. 5-6). He uses a gun instead of an electrode holder, but it is similarly light in weight and easy to maneuver. The only other major difference is that the weld metal of the electrode surrounds the shielding and fluxing chemicals, rather than being surrounded by them.

Full-automatic welding with self-shielded flux-cored electrodes is one step further in mechanization — the removal of direct manual manipulation in the utilization of the open-arc process.

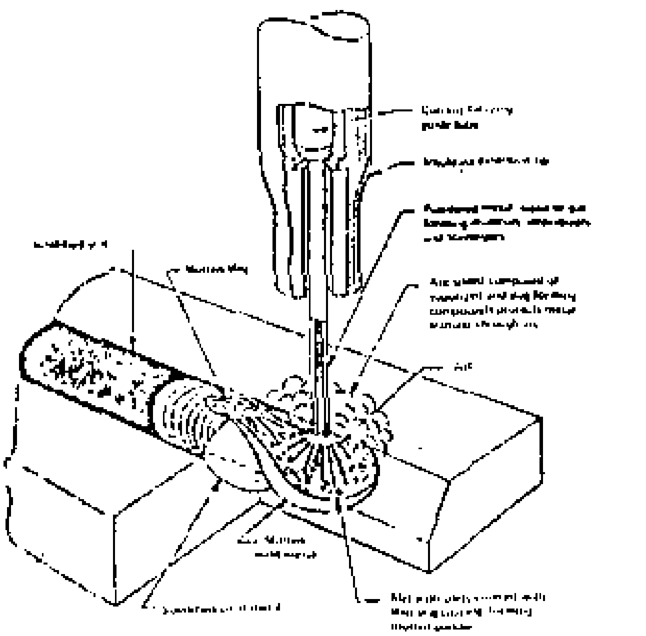


Fig. 5-5. Principles of the self shielded flux cored arc welding process. The electrode may be viewed as an "inside out" construction of the stick electrode used in shielded metal arc welding. Putting the shield generating materials inside the electrode allows the coiling of long continuous lengths of electrode and gives an outside conductive sheath for carrying the welding current from a point close to the arc.

Fig. 5-6. The operator activates electrode feed when he presses the trigger completing the welding circuit. With the semiautomatic gun he can reach into areas that are inaccessible to the semiautomatic equipment of other processes.

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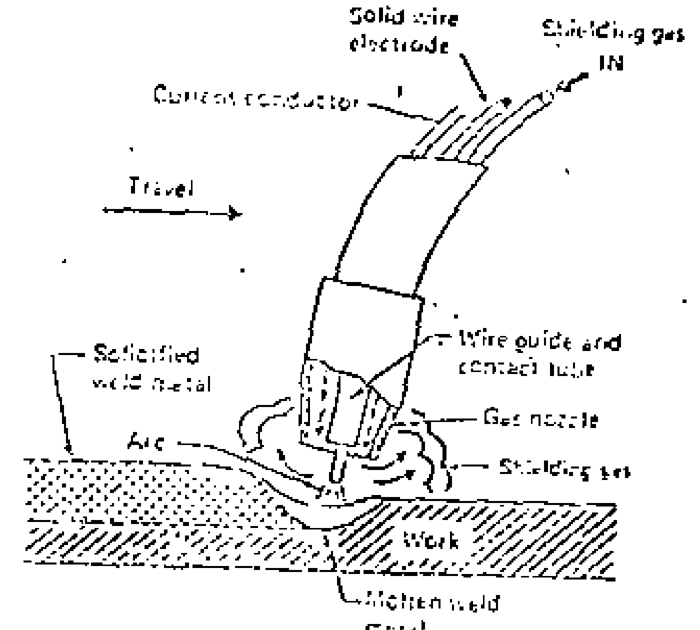

Fig. 5-13. Principle of the gas metal arc process. Continuous solid wire electrode is fed to the [illegible] arc.

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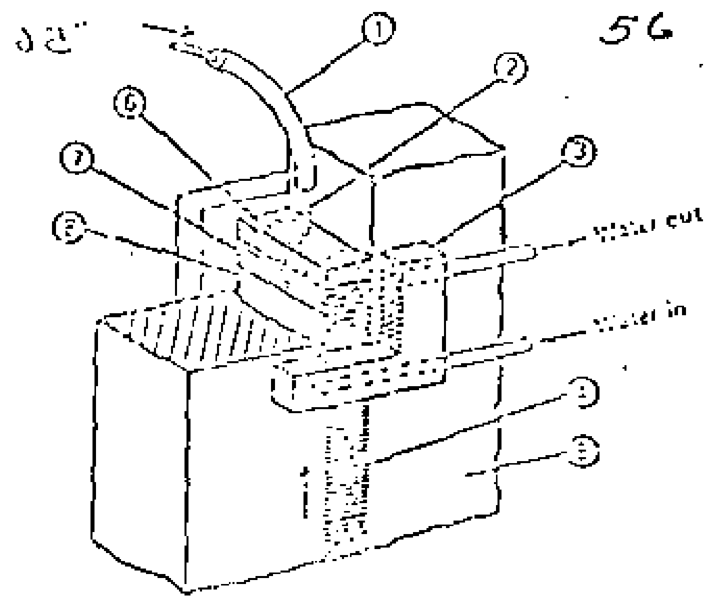


Fig. 5-21. Schematic sketch of electroslag welding: (1) electrode [illegible] (2) [illegible] (3) [illegible] (4) [illegible] (5) base metal, (6) molten slag, (7) molten weld metal, (8) solidified weld metal.

II. TIPOS DE JUNTAS

a) a tope

b) traslape

c) ente

d) de esquina

e) de borde

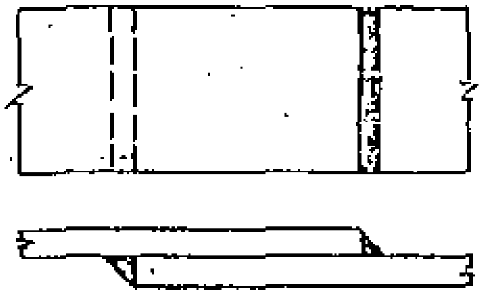
III. TIPOS DE SOLDADURAS

a) soldadura de filete

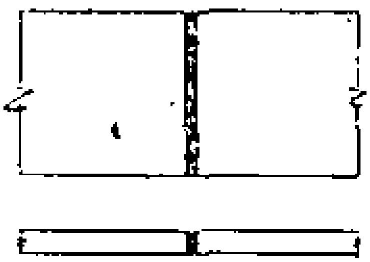
b) soldadura de penetración
   - b_1) penetración completa
   - b_2) penetración incompleta

c) soldadura de tapón

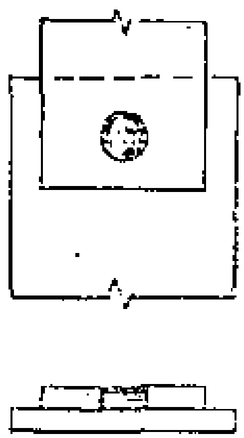
d) soldadura de ranura



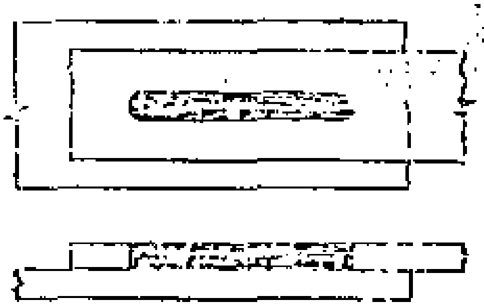
SOLDADURA DE FILETE



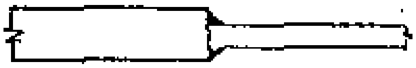
SOLDADURA DE PENETRACIÓN



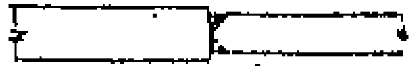
SOLDADURA DE TAPÓN



SOLDADURA DE RANURA

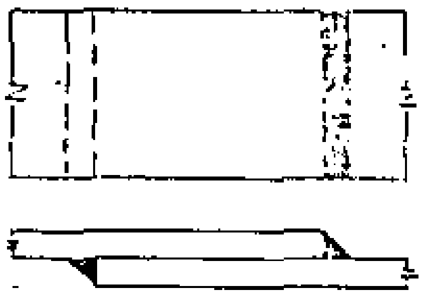


a1. SOLDADURAS DE FILETE

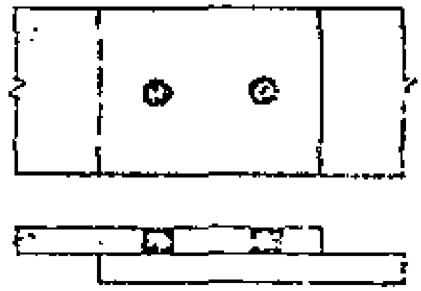


a2. SOLDADURAS DE PENETRACIÓN

a. JUNTAS A TOPE

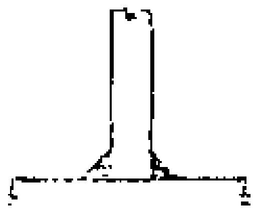


b1. SOLDADURAS DE FILETE

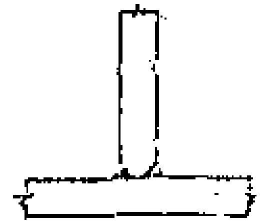


b2. SOLDADURAS DE TAPÓN

b. JUNTAS TRASLAPADAS

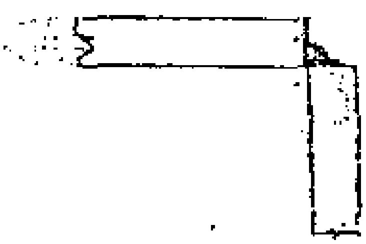


c1. SOLDADURAS DE FILETE

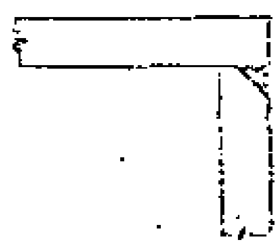


c2. SOLDADURAS DE PENETRACIÓN

c. JUNTAS EN TE



d1. SOLDADURA DE FILETE



d2. SOLDADURA DE PENETRACIÓN

d. JUNTAS DE ESQUINA

IV. POSICIONES DE LAS SOLDADURAS

a) plana

b) horizontal

c) vertical

d) sobre cabeza

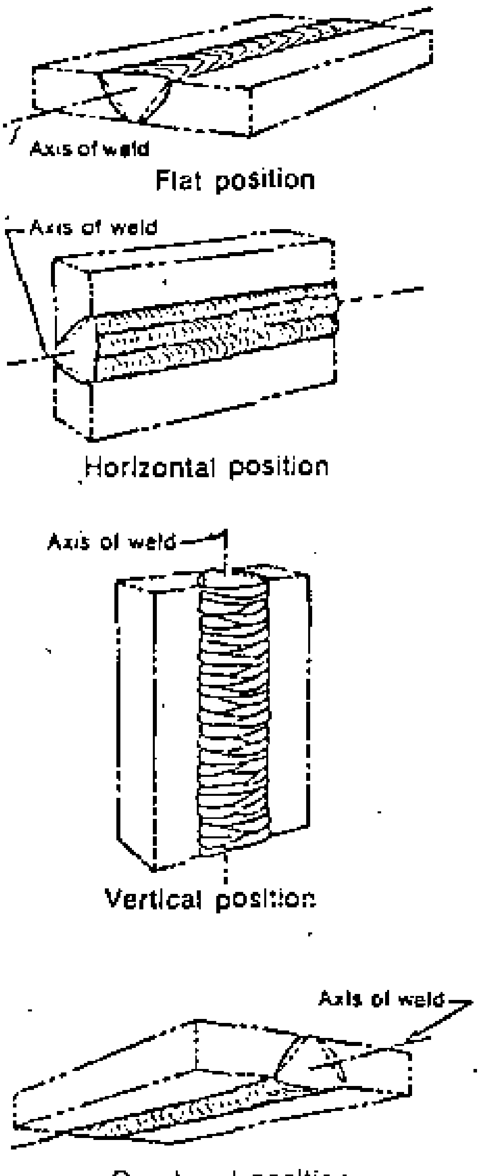


Fig. 2—Positions of welding for groove welds

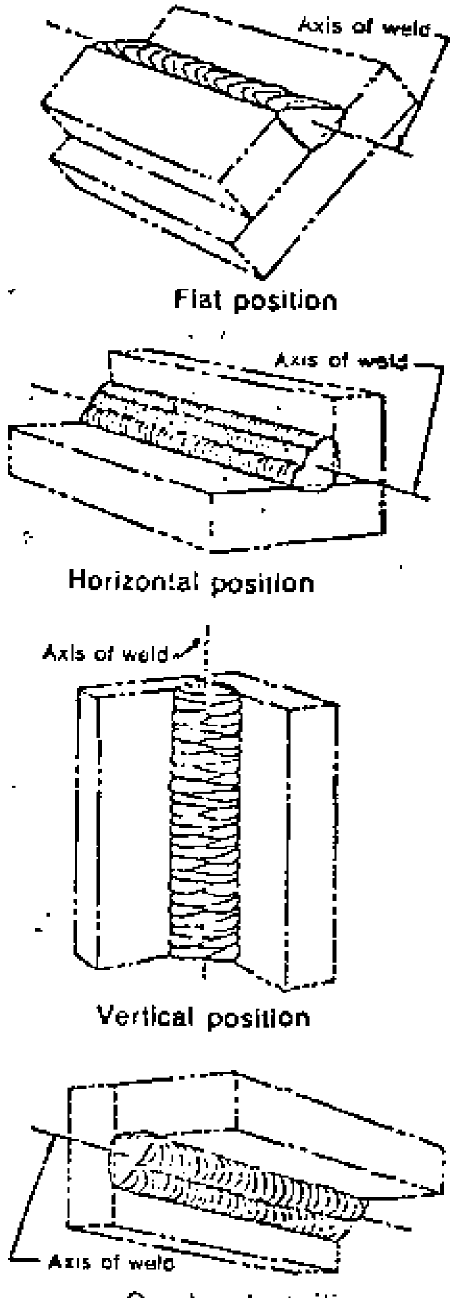
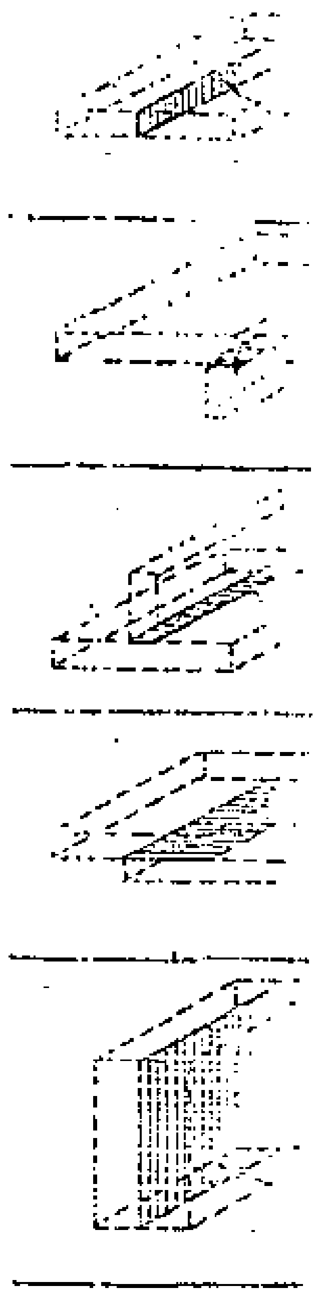


Fig. 3—Positions of welding for fillet welds



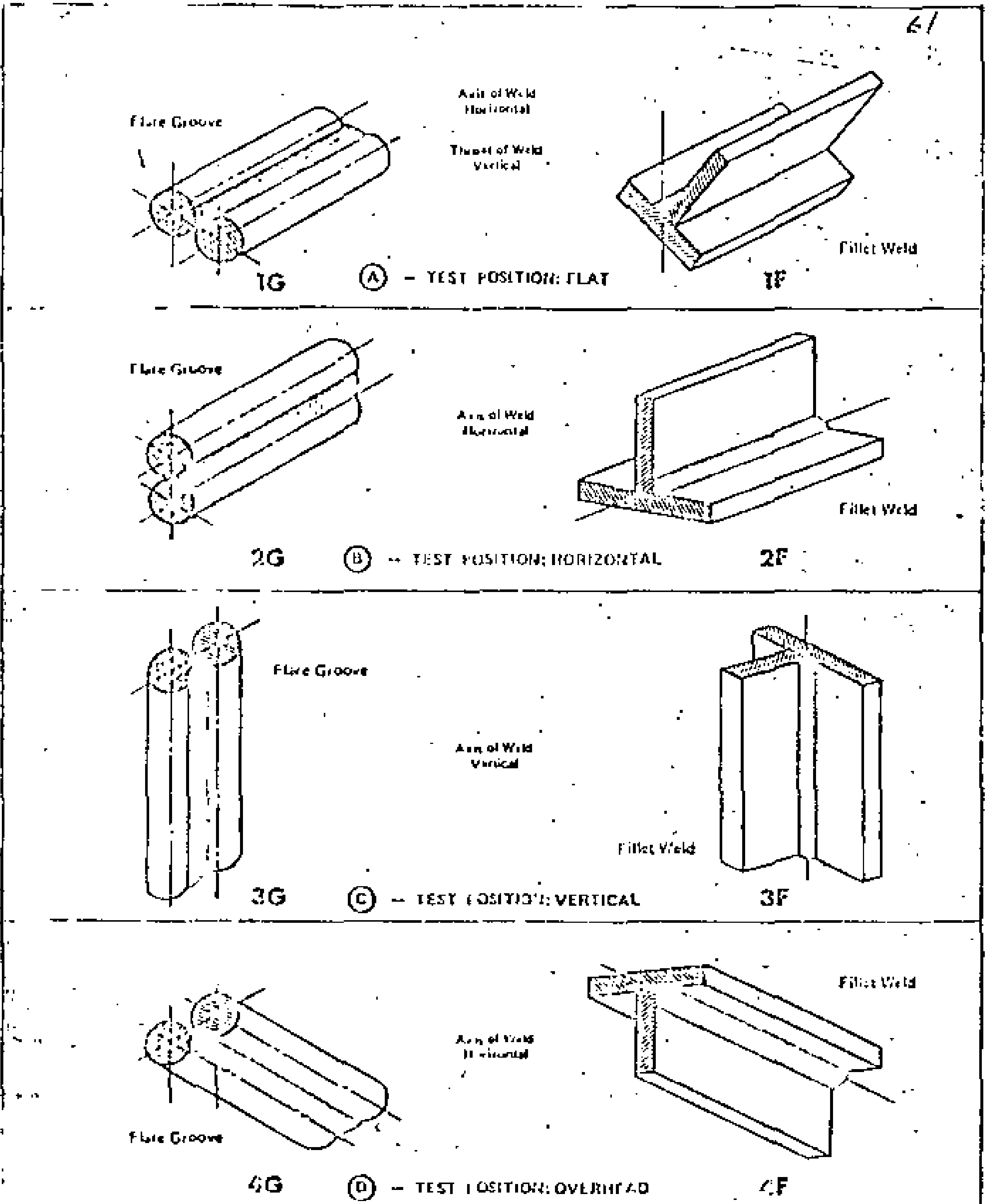


Fig. 6.2.4.2 — Indirect butt splice test positions for flare groove welds. (Positions for fillet welds are for information only.)

V. SOLDADURAS DE FILETE

a) secciones transversales

a¹) características

a²) secciones aceptables

a³) secciones inaceptables

b) defectos

c) tamaño mínimo de filetes

d) tamaño máximo de soldaduras de filete

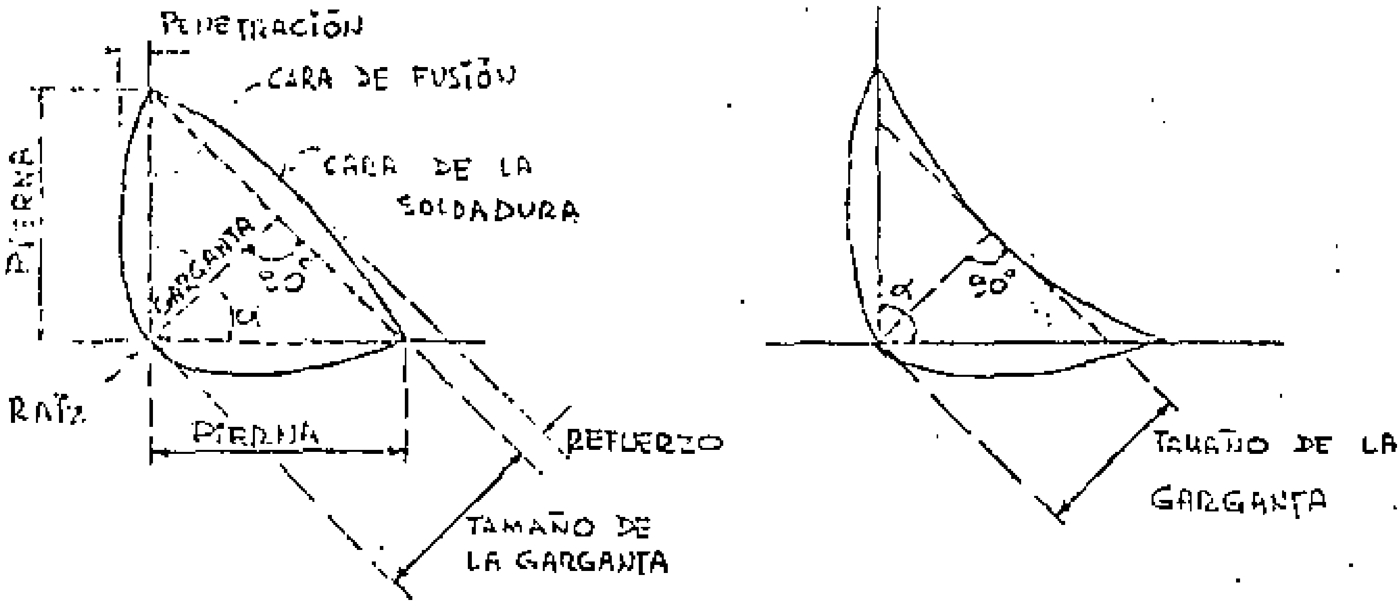
e) longitud de soldaduras de filete

f) juntas traslapadas

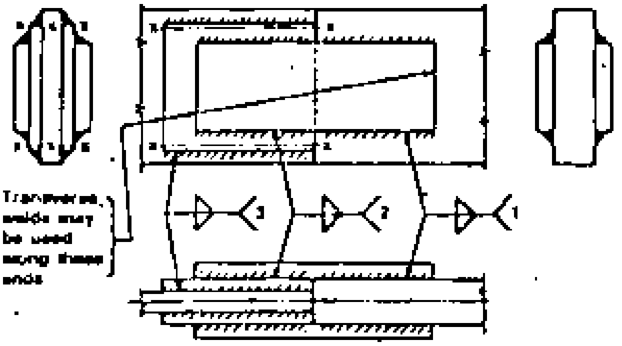
g) retorno en extremos de filetes

h) filetes en agujeros y ranuras

i) resistencia de soldaduras de filete



SOLDADURAS DE FILETE ($60° \leq \alpha \leq 90°$)



Effective area of weld 2 shall equal that of weld 1. The length of weld 2 shall be sufficient to avoid overstressing the filler in shear along planes x-x.

Effective area of weld 3 shall at least equal that of weld 1 and there shall be no overstress of the ends of weld 3 resulting from the eccentricity of the forces acting on the filler.

Fig. 2.4.3—Fillers 1/4 in. or thicker.

Part C Details of Welded Joints

2.6 Joint Qualification

2.6.1 Joints meeting the following requirements are designated as prequalified:

(1) Conformance with the details specified in 2.7 through 2.14 and 10.13.

(2) Use of one of the following welding processes in accordance with the requirements of Sections 3, 4, and 10 as applicable: shielded metal arc, submerged arc, gas metal arc (except short circuiting transfer) or flux cored arc welding.

Joints meeting these requirements may be used without performing the joint welding procedure qualification tests prescribed in 5.2.

2.6.1.1 The joint welding procedure for all joints welded by short circuiting transfer gas metal arc welding (see Appendix D) shall be qualified by tests prescribed in 5.2.

2.6.2 Joint details may depart from the details prescribed in 2.9 through 2.14 and in 10.13 only if the contractor submits to the Engineer his proposed joints and joint welding procedures and at his own expense demonstrates their adequacy in accordance with the requirements of 5.2 of this code and their conformance with applicable provisions of Sections 3 and 4.

2.7 Details of Fillet Welds

2.7.1 The details of fillet welds made by shielded metal arc, submerged arc, gas metal arc or flux cored arc welding to be used without joint welding procedure qualification are listed in 2.7.1.1 through 2.7.1.5 and detailed in Figs. 2.7.1 and 10.13.1.3.

2.7.1.1 The minimum fillet weld size, except for fillet welds used to reinforce groove welds, shall be as shown in the following table:

Table 2.7—Minimum fillet weld size

Base Metal Thickness of Thicker Part Joined (T)		Minimum Size of Fillet Weld*		
in.	mm	in.	mm	
T ⩽ 1/4	T ⩽ 6.4	1/8**	3	single pass welds must be used
1/4 < T ⩽ 1/2	6.4 < T ⩽ 12.7	3/16	5	
1/2 < T ⩽ 3/4	12.7 < T ⩽ 19.0	1/4	6	
3/4 < T	19.0 < T	5/16	8	

*Except that the weld size need not exceed the thickness of the thinner part joined. For this exception particular care should be taken to provide sufficient preheat to ensure weld soundness.
**Minimum size for bridge application 3/16 in.

2.7.1.2 The maximum fillet weld size permitted along edges of material shall be:

(1) The thickness of the base metal, for metal less than 1/4 in. (6.4 mm) thick (see Fig. 2.7.1, detail A).

(2) 1/16 in. (1.6 mm) less than the thickness of base metal, for metal 1/4 in. (6.4 mm) or more in thickness (see Fig. 2.7.1, detail B), unless the weld is designated on the drawing to be built out to obtain full throat thickness.

2.7.1.3 Fillet welds in holes, or slots in lap joints, may be used to transfer shear or to prevent buckling or separation of lapped parts. These fillet welds may overlap, subject to the provisions of 2.3.2.2. Fillet welds in holes or slots are not to be considered as plug or slot welds.

2.7.1.4 Fillet welds may be used in skew joints that have an included angle of not less than 60 degrees. (See Fig. 2.7.1, details C and D).

2.7.1.5 The minimum length of an intermittent fillet weld shall be 1-1/2 in. (38.1 mm).

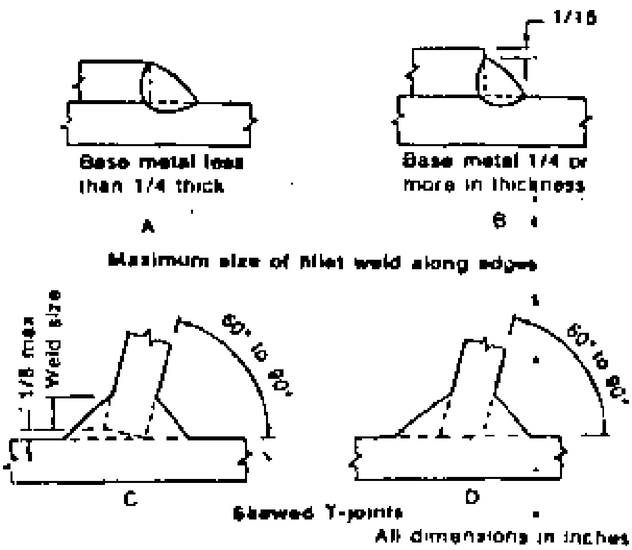
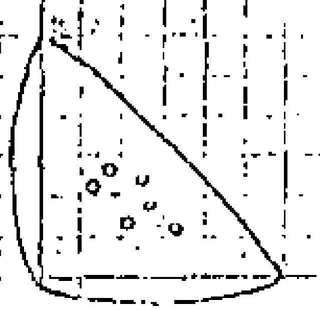
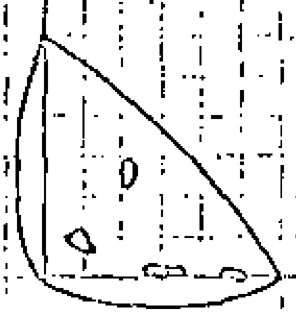


Fig. 2.7.1—Details for fillet welds.



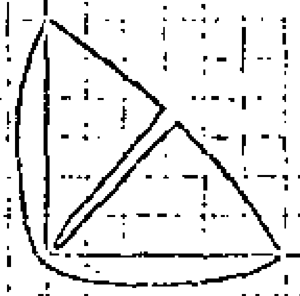
POROSIDAD



INCLUSIONES DE ESCORIA

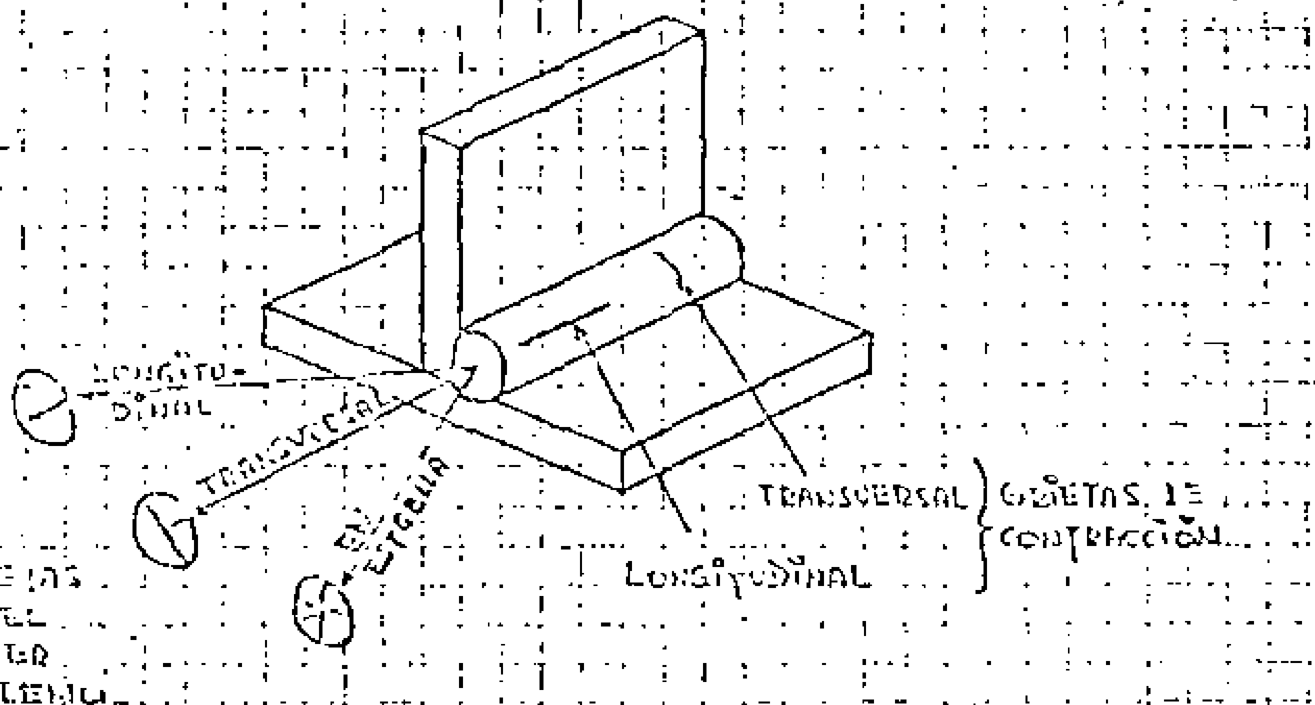
FUSIÓN INCOMPLETA

FALTA DE PENETRACIÓN



GRIETA LONGITUDINAL

GRIETA EN EL METAL BASE



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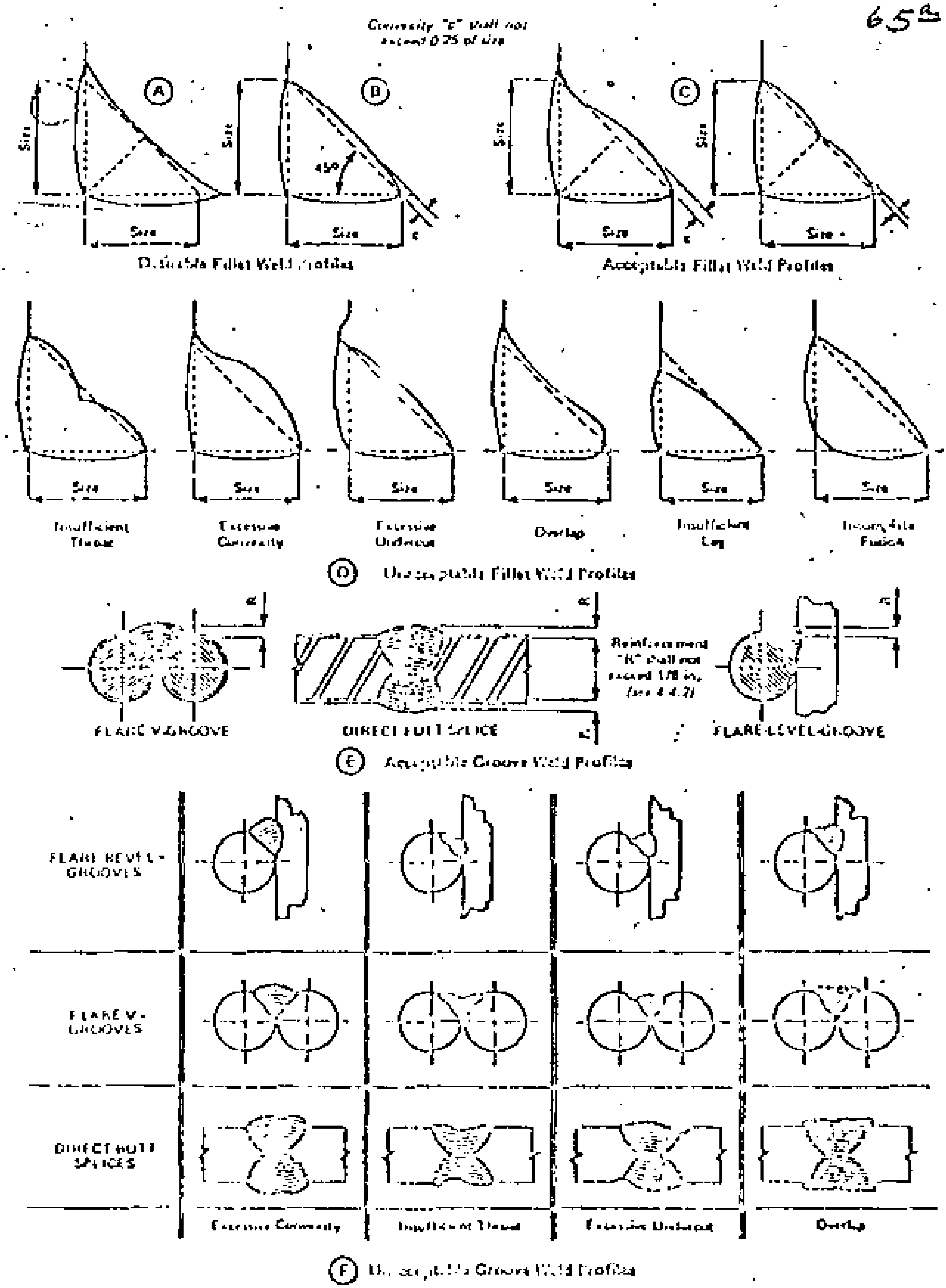


Fig. 4.4 — Acceptable and unacceptable weld profiles.

VI. SOLDADURAS DE PENETRACION

a) Características generales

b) Secciones aceptables e inaceptables

c) Precalificación

d) Soldaduras de penetración completa

e) Soldaduras de penetración incompleta

f) Tamaño mínimo en soldaduras de penetración parcial

g) Resistencia de soldaduras de penetración

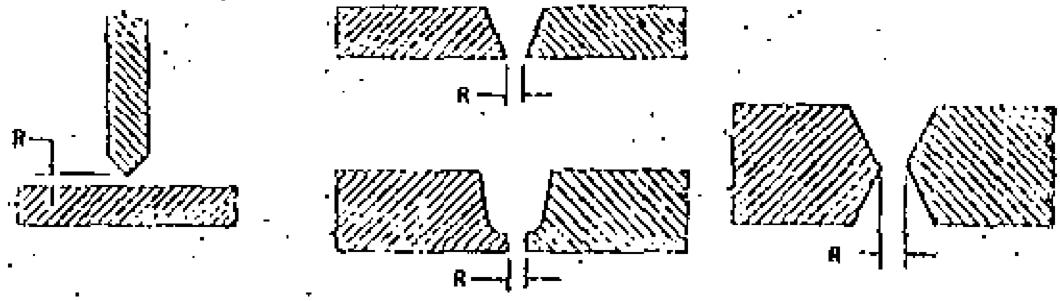


FIGURE 1

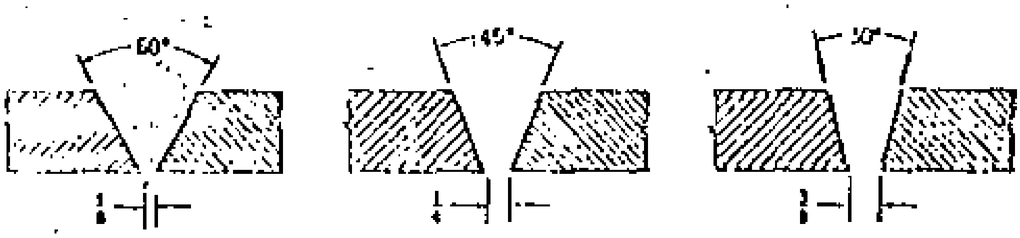


FIGURE 2

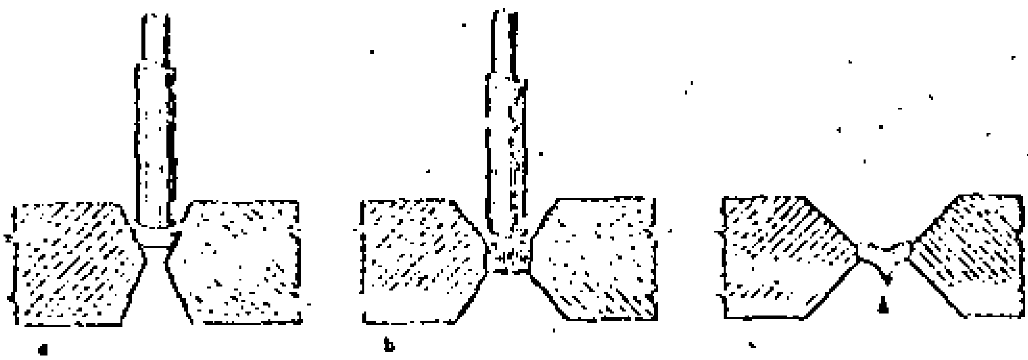


FIGURE 3

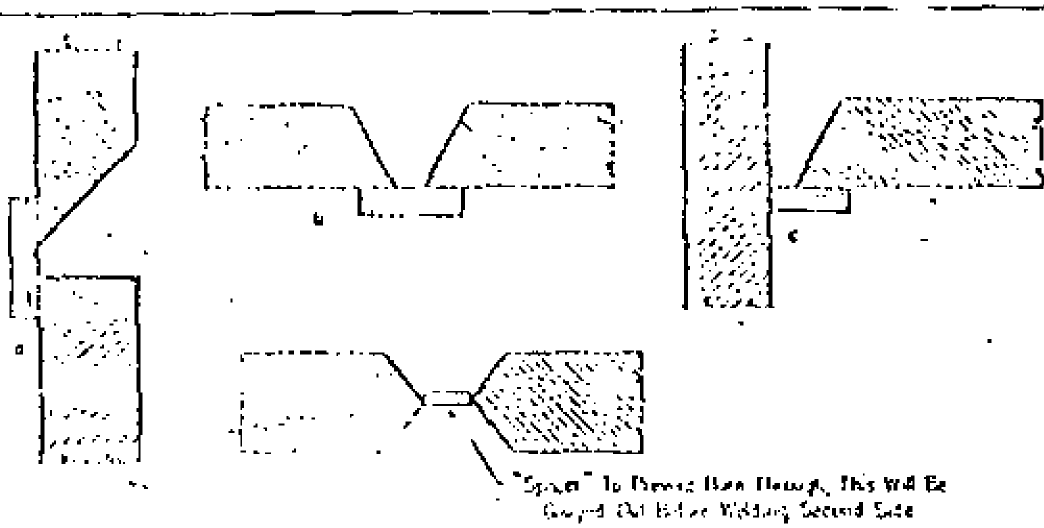


FIGURE 4

FIGURE 6

FIGURE 7

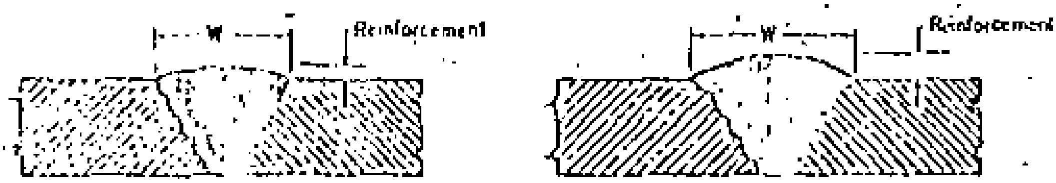


FIGURE 8

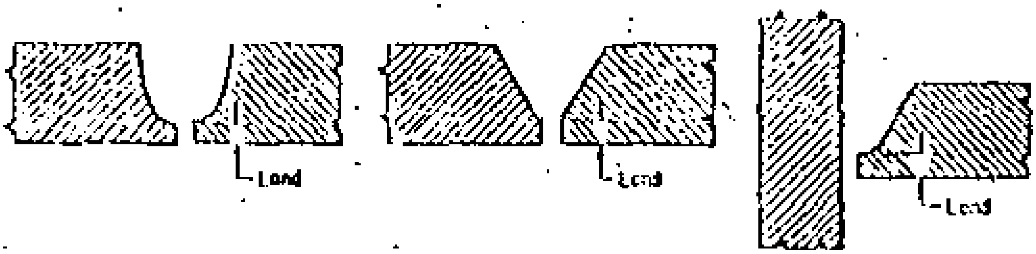


FIGURE 9

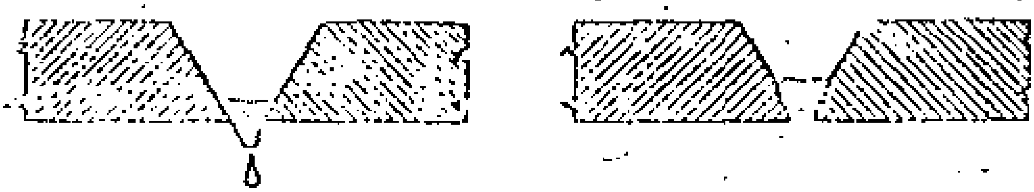
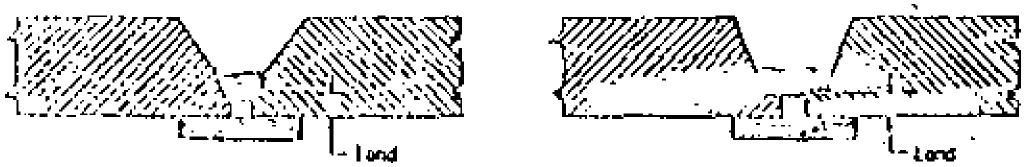


FIGURE 10



Not Recommended

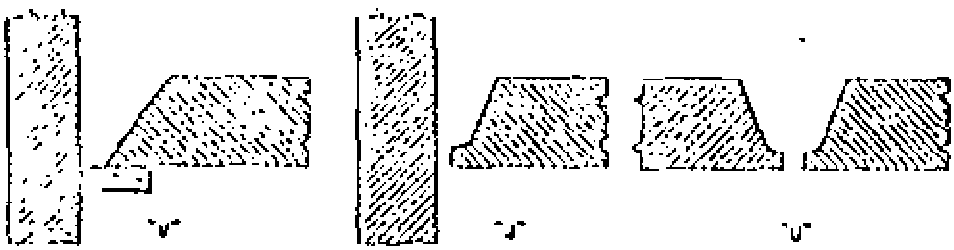


FIGURE 13

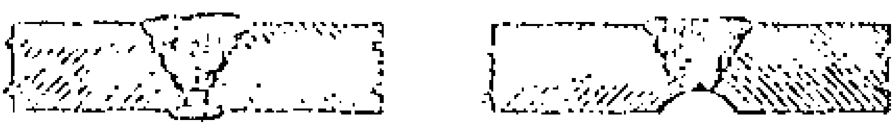
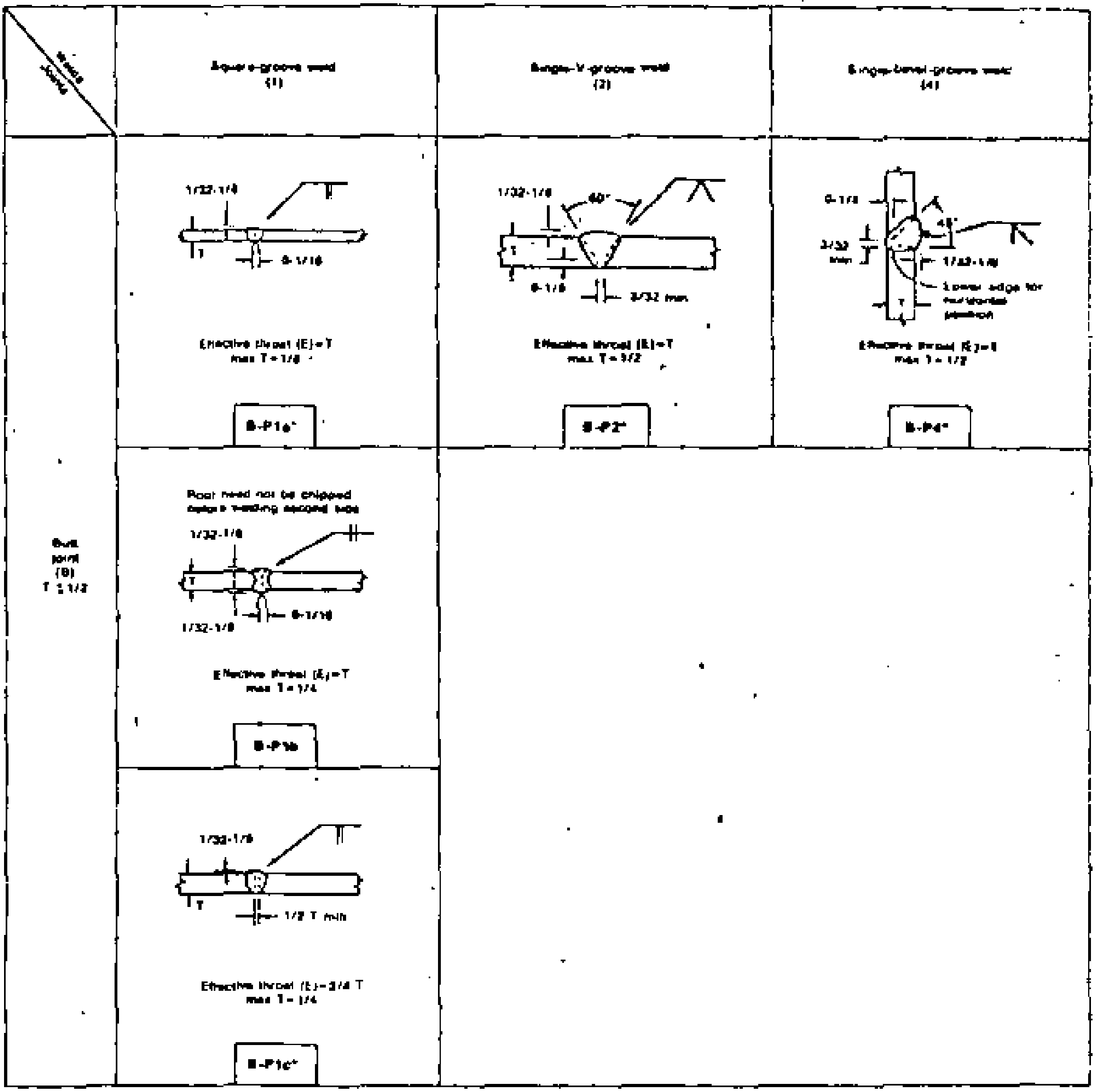


FIGURE 14

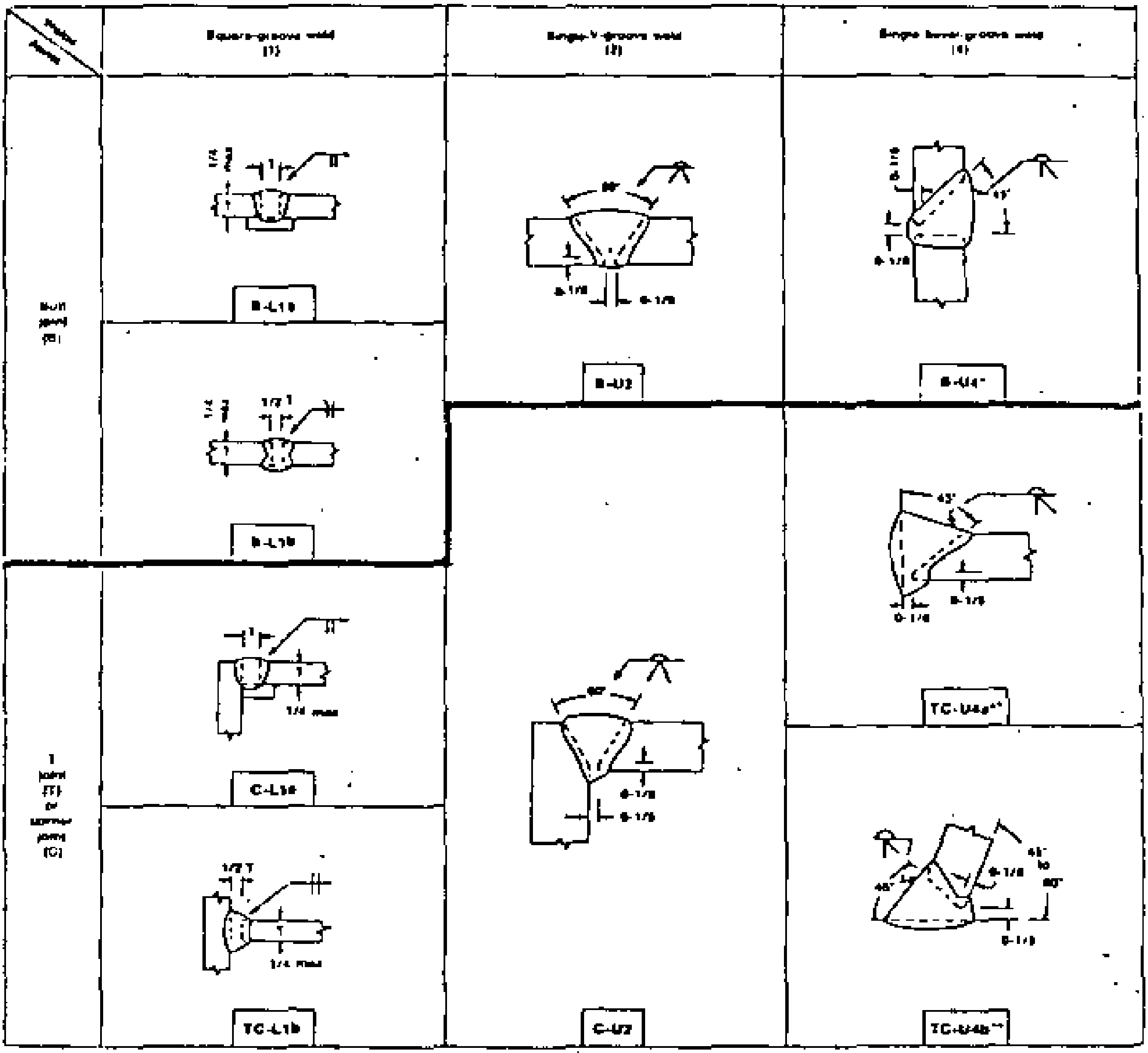
FIGURE 15



All dimensions in inches.

1. See 2.10.2 for allowable variation of dimensions and 3.3.4 for workmanship tolerances.
*Joints welded from one side.

Fig. 2.10.1—Partial joint penetration (P) prequalified shielded metal arc welded joints.



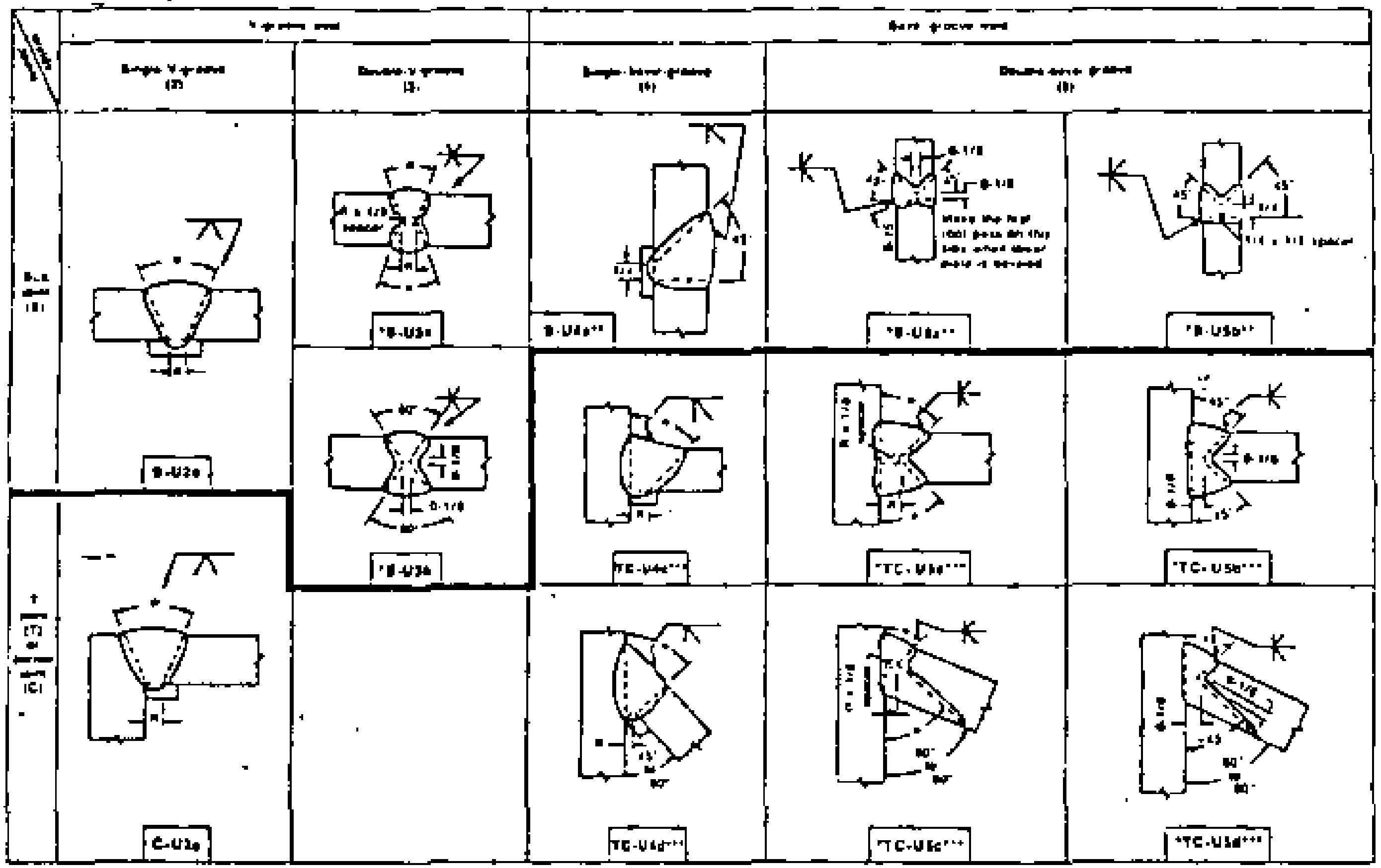
All dimensions in inches.

1. Gouge the roots of joints without backing before welding the other side (see 4.10.8).
2. See 2.9.2 for allowable variation of dimensions and 3.3.4 for workmanship tolerances.
3. If fillet welds are used in buildings to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in. Groove welds in T and corner joints of bridges shall be reinforced with fillet welds equal to T/4 but not more than 3/8 in. T is the thickness of the groove weld.

*Bridge application limits the use of these joints to the horizontal position (see 9.12.1.5).

**For corner joints, the outside groove preparation may be in either or both members, provided the basic groove configuration is not changed and adequate edge distance is maintained to support the welding operation without excessive edge melting.

Fig. 2.9.1—Complete joint penetration prequalified shielded metal arc welded joints—base metal of limited thickness (L) and unlimited thickness (U)



Limitations for joints
B-U3a, B-U3a and C-U3a

α	R	Permitted welding positions
45°	1/4	All positions
30°	3/8	Flat and overhead only
20°	1/2	Flat and overhead only

Limitations for joints
TC-U4c, TC-U4d, TC-U5a and TC-U5c

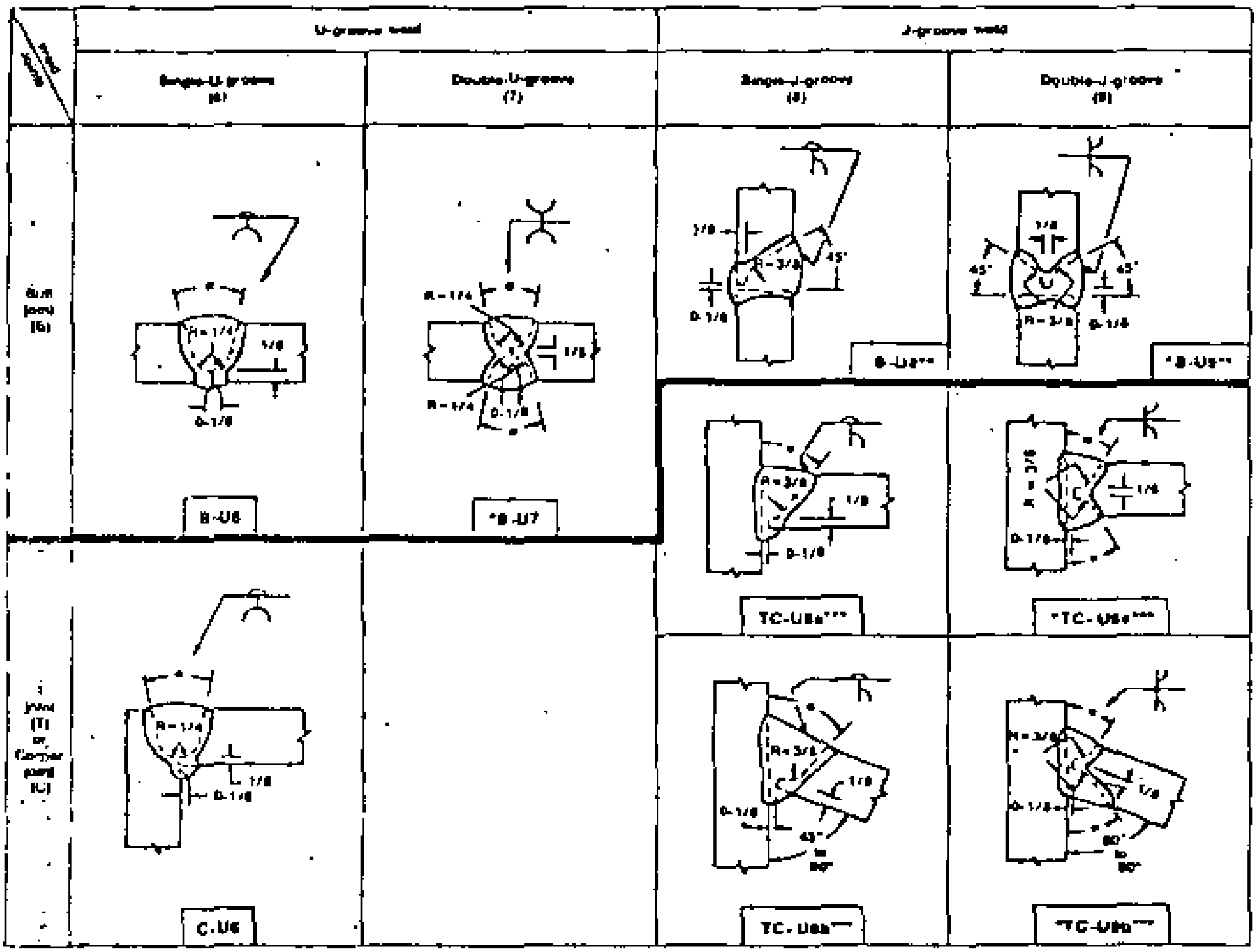
α	R	Permitted welding positions
45°	1/4	All positions
30°	3/8	Flat and overhead only

All dimensions in inches.

1. Gouge roots of joints without backing before welding other side (see 4.10.8).
2. See 2.9.2 for allowable variation of dimensions and 3.3.4 for workmanship tolerances.
3. If fillet welds are used in buildings to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in. Groove welds in T and corner joints of bridges shall be reinforced with fillet welds equal to T/4 but not more than 3/8 in. T is the thickness of the groove weld.

*The use of these welds shall preferably be limited to base metal thickness of 5/8 in. or larger.
**Bridge application limits the use of these joints to the horizontal position (see 9.12.1.5).
***For corner joints, the outside groove preparation may be in either or both members, provided the basic groove configuration is not changed and adequate edge distance is maintained to support the welding operations without excessive edge melting.

Fig. 2.9.1 cont —Complete joint penetration prequalified shielded metal arc welded joints—base metal of unlimited thickness (1/).



Limitations for joints
B-U6, B-U7 and C-U6

α	Permitted welding positions
45°	All positions
20°	Flat and overhead only

Limitations for joints
TC-U8a, TC-U8b, TC-U9a and TC-U9b

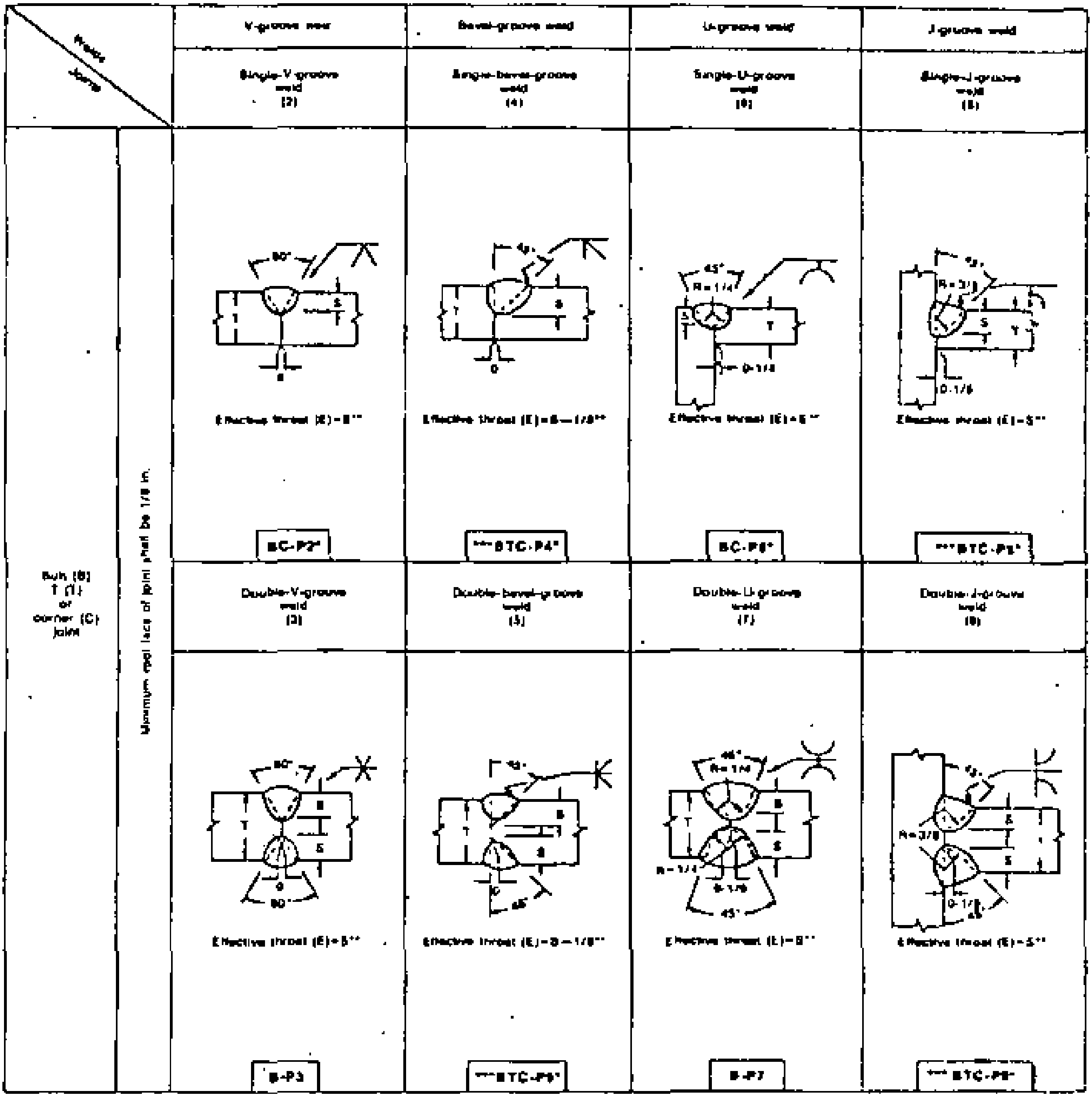
α	Permitted welding positions
45°	All positions
30°	Flat and overhead only

All dimensions in inches.

1. Gouge roots of joints without backing before welding other side (See 4.10.8)
2. See 2.9.2 for allowable variation of dimensions and 3.3.4 for workmanship tolerances.
3. If fillet welds are used in buildings to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in. Groove welds in T and corner joints of bridges shall be reinforced with fillet welds equal to T/4 but not more than 3/8 in. T is the thickness of the groove weld.

*The use of these welds shall preferably be limited to base metal thickness of 5/8 in. or larger.
** Bridge application limits the use of these joints to the horizontal position (see 9.12.1.5)
***For corner joints, the outside groove preparation may be in either or both members, provided the basic groove configuration is not changed and adequate edge distance is maintained to support the welding operations without excessive edge melting.

Fig. 2.9.1 cont.—Complete joint penetration prequalified shielded metal arc welded joints—base metal of unlimited thickness (U).



All dimensions in inches.

1. See 2.10.2 for allowable variation of dimensions and 3.3.4 for workmanship tolerances.
*Only corner joints C-P2, C-P4, C-P5, C-P6, C-P8 and C-P9 are prequalified for bridge application (see 9.12.1.2).
**Minimum effective throat as shown in Table 2.10.3
***For corner joints, the outside groove preparation may be in either or both members provided the basic groove configuration is not changed and adequate edge distance is maintained to support the welding operations without excessive edge inclus...

Fig. 2.10.1 cont.—Partial joint penetration (P) prequalified shielded metal arc welded joints.

TABLE 1.17.2B

MINIMUM EFFECTIVE THROAT THICKNESS OF PARTIAL-PENETRATION GROOVE WELD

Material Thickness of Thicker Part Joined (Inches)	Minimum Effective* Throat Thickness (Inches)
To 1/4 inclusive	1/8
Over 1/4 to 1/2	3/16
Over 1/2 to 3/4	1/4
Over 3/4 to 1 1/2	5/16
Over 1 1/2 to 2 1/4	3/8
Over 2 1/4 to 6	1/2
Over 6	5/8

* See Sect. 1.14.6.

1.5.3 Welds

Except as modified by the provisions of Sect. 1.7, welds shall be proportioned to meet the stress requirements given in Table 1.5.3.

TABLE 1.5.3

ALLOWABLE STRESS ON WELDS

Type of Weld and Stress[a]	Allowable Stress	Required Weld Strength Level[b,c]
Complete-Penetration Groove Welds		
Tension normal to effective area	Same as base metal	"Matching" weld metal must be used.
Compression normal to effective area	Same as base metal	Weld metal with a strength level equal to or less than "matching" weld metal may be used.
Tension or compression parallel to axis of weld	Same as base metal	
Shear on effective area	0.30 × nominal tensile strength of weld metal (ksi), except shear stress on base metal shall not exceed 0.40 × yield stress of base metal	
Partial-Penetration Groove Welds[d]		
Compression normal to effective area	Same as base metal	Weld metal with a strength level equal to or less than "matching" weld metal may be used.
Tension or compression parallel to axis of weld[e]	Same as base metal	
Shear parallel to axis of weld	0.30 × nominal tensile strength of weld metal (ksi), except shear stress on base metal shall not exceed 0.40 × yield stress of base metal	
Tension normal to effective area	0.30 × nominal tensile strength of weld metal (ksi), except tensile stress on base metal shall not exceed 0.60 × yield stress of base metal	

TABLE 1.14.6.1.2

EFFECTIVE THROAT THICKNESS OF PARTIAL-PENETRATION GROOVE WELDS

Welding Process	Welding Position	Included Angle at Root of Groove	Effective Throat Thickness
Shielded metal arc or submerged arc	All	$<60°$ but $\geq 45°$	Depth of chamfer minus 1/8-inch
		$\geq 60°$	Depth of chamfer
Gas metal arc or flux cored arc	All	$\geq 60°$	Depth of chamfer
	Horizontal or flat	$<60°$ but $\geq 45°$	Depth of chamfer
	Vertical or overhead	$<60°$ but $\geq 45°$	Depth of chamfer minus 1/8-inch
Electrogas	All	$\geq 60°$	Depth of chamfer

TABLE 1.14.6.1.3

EFFECTIVE THROAT THICKNESS OF FLARE GROOVE WELDS

Type of Weld	Radius (R) of Bar or Bend	Effective Throat Thickness
Flare-bevel groove	All	5/16 R
Flare-V-groove	All	1/2 R[a]

[a] Use 3/8 R for Gas Metal Arc Welding (except short circuiting transfer process) when $R \geq 1$ inch

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La distancia entre piezas que han de soldarse de filete, no será mayor de 5 m.m. AWS (3.3.1)

Las partes a soldarse a tope se alinearan sin un error mayor del 10% de la placa más delgada pero no mayor de 3 m.m. ; AWS (3.3.3)

VII. METAL DE APORTACION

a) Características generales

b) Clasificación de los electrodos

c) Electrodos para soldadura manual al arco eléctrico.

c^{1}) nomenclatura

c^{2}) papel del recubrimiento

c^{3}) tipos de electrodos

c^{4}) uso de los electrodos

d) Electrodos para soldadura de arco sumergido.

Table 1—Electrode Classification

AWS Classification	Type of Covering	Capable of Producing Satisfactory Welds in Positions Shown[a]	Type of Current[b]
E60 Series—Minimum Tensile Strength of Deposited Metal in As-Welded Condition 60 000 psi (or Higher—see Table 4)			
E6010	High cellulose sodium	F, V, OH, H	dc, reverse polarity
E6011	High cellulose potassium	F, V, OH, H	ac or dc, reverse polarity
E6012	High titania sodium	F, V, OH, H	ac or dc, straight polarity
E6013	High titania potassium	F, V, OH, H	ac or dc, either polarity
E6020	High iron oxide	H-Fillets	ac or dc, straight polarity
		F	ac or dc, either polarity
E6027	Iron powder, iron oxide	H-Fillets	ac or dc, straight polarity
		F	ac or dc, either polarity
E70 Series—Minimum Tensile Strength of Deposited Metal in As-Welded Condition 70 000 psi (or Higher—see Table 4)			
E7014	Iron powder, titania	F, V, OH, H	ac or dc, either polarity
E7015	Low hydrogen sodium	F, V, OH, H	dc, reverse polarity
E7016	Low hydrogen potassium	F, V, OH, H	ac or dc, reverse polarity
E7018	Iron powder, low hydrogen	F, V, OH, H	ac or dc, reverse polarity
E7024	Iron powder, titania	H-Fillets, F	ac or dc, either polarity
E7028	Iron powder, low hydrogen	H-Fillets, F	ac or dc, reverse polarity

[a] The abbreviations F, V, OH, H, and H-Fillets indicate welding positions (Figs. 1 and 2) as follows:
F = Flat
H = Horizontal
H-Fillets = Horizontal Fillets
V = Vertical }
OH = Overhead } For electrodes 3/16 in. and under, except 5/32 in. and under for classifications E7014, E7015, E7016 and E7018.
[b] Reverse polarity means electrode is positive, straight polarity means electrode is negative.

Table 2—Chemical Requirements

AWS Classification	Chemical Composition, max, per cent[a]					
	Manganese[b]	Silicon	Nickel	Chromium	Molybdenum	Vanadium
E7014, E7015, E7016, E7018, E7024, E7028	1.25[a]	0.90	0.30[a]	0.20[a]	0.30[a]	0.08[a]
E6010, E6011, E6012, E6013, E6020, E6027	No chemical requirements					

[a] The sum total of all elements with the asterisk shall not exceed 1.50 per cent.
[b] For obtaining the chemical composition, dc, straight polarity only may be used where dc, both polarities, is specified.

...BLA COMPARATIVA DE ELECTRODOS PARA SOLDAR

SEGUN VARIOS FABRICANTES

WESTING HOUSE	ZL-610	ACP-611	FP-6012 FP-7612	SW-611 SW-?M	AP-?O	CASTING WELD			HARDEN TOUGH 2?0	HARDEN TOUGH 4?0	HARDEN TOUGH ?0
[illegible]	AP 610	AC-1	PFA 612P	AC-11	CH ?1	HARCAST	HARMO MANGA	HARNE MANGA	HARTOP BROWN	HARTOP RED	HARTOP YELLOW
LINCOLN	FLEETWELD 5	FLEETWELD 11	FLEETWELD 7	FLEETWELD 13	SHIELD ARC ?1	FERROWELD	MANGANWELD ?	MANGANWELD AC	ABRASO WELD	FACEWELD 1	FACEWELD 12
HOBART	10	111	12	15	?1	HARCAST	CD MANGANWELD	V MANGANWELD	TUFANHARD 2?0	TUFANHARD 4?0	TUFANHARD 6?0
GENERAL ELECTRIC	W 610 A	W 611 A	W 612 A	W 613 A	W 718 A	W 41			W 9?	W 91	W 9?
[illegible]	610	611	612	613	7018	4?5	7?0	7?4	1?0	3?0	?0
CHAMPION	DIABLO AZUL	DIABLO AZUL ALTERNO	DIABLO GRIS No. 2	DIABLO LIGERO	DIABLO AZUL ?1		DIABLO DE MANGANESO			DIABLO DURO	DIABLO RESISTENTE
AGA INTEC	FERROMATIC 10	FERROMATIC 11	FERROMATIC 1?	FERROMATIC 1?	CELLOCORD 7?	SUTEC ARC 1?	CITO MANGAN		SUTEHEX 2?	SUTEHEX 4?	SUTEHEX 6?
A.O. SMITH	SW-14	SW 10	SW 11 SW 12	SW 15 SW 16	SW 7?	SW ?	SW MN?	SW 11?0	D WELD ?	D WELD E	D WELD F
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TUBO VACIADO	RECUBRIMIENTOS DUROS				

Arc-Welding Consumables

Arc-welding consumables are the materials used up during welding, such as electrodes, filler rods, fluxes, and externally applied shielding gases. With the exception of the gases, all of the commonly used consumables are covered by AWS specifications.

Twenty specifications in the AWS A5.x series prescribe the requirements for welding electrodes, rods, and fluxes. This section briefly reviews some of the important requirements of the A5.x series, with the intent of serving as a guide to the selection of the proper specification. When detailed information is required, the actual AWS specification should be consulted.

ELECTRODES, RODS, AND FLUXES

The first specification for mild steel covered electrodes, A5.1, was written in 1940. As the welding industry expanded and the number of types of electrodes for welding steel increased, it became necessary to devise a system of electrode classification to avoid confusion. The system used applies to both the mild steel A5.1 and the low-alloy steel A5.5 specifications.

Classifications of mild and low-alloy steel electrodes are based on an "E" prefix and a four or five-digit number. The first two digits (or three, in a five-digit number) indicate the minimum required tensile strength in thousands of pounds per square inch. For example, 60 = 60,000 psi, 70 = 70,000 psi, and 100 = 100,000 psi. The next to the last digit indicates the welding position in which the electrode is capable of making satisfactory welds: 1 = all positions — flat, horizontal, vertical, and overhead; 2 = flat and horizontal fillet welding (see Table 4-1). The last two digits indicate the type of current to be used and the type of covering on the electrode (see Table 4-2).

Originally a color identification system was developed by the National Electrical Manufacturers Association (NEMA) in conjunction with the American Welding Society to identify the electrode's classification. This was a system of color markings applied in a specific relationship on the electrode, as in Fig. 4-1(a). The colors and their significance are listed in Tables 4-3 and 4-4. The NEMA specification also included the choice of imprinting the classification number on the electrode, as in Fig. 4-1(b).

TABLE 4-1. AWS A5.1-69 and A5.5-69 Designations for Manual Electrodes

a. The prefix "E" designates arc welding electrode.	
b. The first two digits of four digit numbers and the first three digits of five digit numbers indicate minimum tensile strength:	
E60XX	60,000 psi Minimum Tensile Strength
E70XX	70,000 psi Minimum Tensile Strength
E110XX	110,000 psi Minimum Tensile Strength
c. The next-to-last digit indicates position:	
EXX1X	All positions
EXX2X	Flat position and horizontal fillets
d. The suffix (Example: EXXXX-A1) indicates the approximate alloy in the weld deposit:	
– A1	0.5% Mo
– B1	0.5% Cr, 0.5% Mo
– B2	1.25% Cr, 0.5% Mo
– B3	2.25% Cr, 1% Mo
– B4	2% Cr, 0.5% Mo
– B5	0.5% Cr, 1% Mo
– C1	2.5% Ni
– C2	3.25% Ni
– C3	1% Ni, 0.35% Mo, 0.15% Cr
– D1 and D2	0.25-0.45% Mo, 1.75% Mn
– G	0.5% min. Ni, 0.3% min. Cr, 0.2% min. Mo, 0.1% min. V, 1% min. Mn (only one element required)

TABLE 4-2. AWS A5.1 69 Electrode Designations for Covered Arc Welding Electrodes

Designation	Current	Covering Type
EXX10	DC+ only	Organic
EXX11	AC or DC+	Organic
EXX12	AC or DC-	Rutile
EXX13	AC or DC±	Rutile
EXX14	AC or DC±	Rutile, iron powder (approx. 30%)
EXX15	DC+ only	Low-hydrogen
EXX16	AC or DC+	Low-hydrogen
EXX18	AC or DC+	Low-hydrogen, iron-powder (approx. 25%)
EXX20	AC or DC±	High iron oxide
EXX24	AC or DC±	Rutile, iron-powder (approx. 50%)
EXX27	AC or DC±	Mineral, iron powder (approx. 50%)
EXX28	AC or DC+	Low-hydrogen, iron-powder (approx. 50%)

TABLE 4-3. Color Identification for Covered MILD-STEEL and LOW-ALLOY Steel Electrodes

GROUP COLOR – NO COLOR				
XX10, XX11, XX14, XX24, XX27, XX28 and all 60 XX				
Spot Color \ End Color	No Color	Blue	Black	Orange
No Color	E6010	E7010G		EST
White	E6012	E7010-A1		ECI
Brown	E6013		E7014	
Green	E6020			
Blue	E6011	E7011G		
Yellow		E7011-A1	E7024	
Black			E7028	
Silver	E6027			
GROUP COLOR – SILVER				
All XX13 and XX20 except E6013 and E6020				
Brown				
White				
Green		E7020G		
Yellow		E7020-A1		

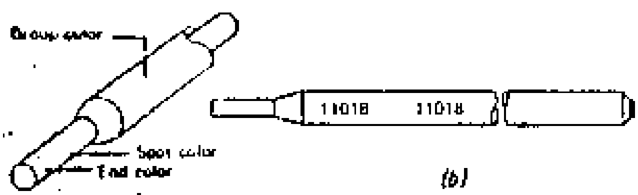


Fig. 4-1. (a) National Electrical Manufacturers Association color-code method to identify an electrode's classification: (b) American Welding Society imprint method.

Starting in 1964, AWS new and revised specifications for covered electrodes required the classification number be imprinted on the covering, as in Fig. 4-1(b). However, some electrodes can be manufactured faster than the imprinting equipment can mark them and some sizes are too small to be legibly marked with an imprint. Although AWS specifies an imprint, the color code is accepted on electrodes if imprinting is not practical.

TABLE 4-4. Color Identification for Covered Low-Hydrogen Low-Alloy Steel Electrodes

GROUP COLOR – GREEN										
XX15, XX16 and XX18 except E8015 and E8016										
Spot Color \ End Color	No Color	Blue	Black	White	Gray	Brown	Violet	Green	Red	Orange
Red	E7015G	E7015			E8015G	E9015G		E10015G		E12015G
White		E7015 A1	E9015-B3L			E9015-D1				
Brown										
Green			E8015-B2L			E9015-B3				
Bronze			E8015 B4L			E8015 B4				
Orange	E7016G	E7016	E7018	E8016-C3		E9016G		E10016G		E12016G
Yellow		E7016-A1	E7018-A1	E8016G		E9016-D1		E10015-D2	E11016G	
Black			E8018 C3	E8016-B1	E8018-B1		E9018-B3			
Blue	E7018G		E8018G	E8016-C1	E8018-C1	E9016-B3	E9018G	E10018G	E11018G	E12018G
Violet				E8016-C2	E8018-C2	E8016-B4	E9018-D1	E10018-D2		
Gray			E8018-B4	E8016-B2	E8018-B2			E10016 D2		
Silver			Mil-12018							

TABLE 4-5. AWS A5.1-69 Minimum Mechanical Property and Radiographic Requirements for Covered Arc-Welding Electrode Weld Metal

AWS Classification	Tensile Strength, min, psi	Yield Point, min, psi	Elongation in 2 in., min, percent	Radiographic Standard [a]	V-Notch Impact [d]
E60 Series [b]					
E6010	62,000	50,000	22	Grade II	20 ft/lb at −20°F
E6011	62,000	50,000	22	Grade II	20 ft/lb at −20°F
E6012	67,000	55,000	17	Not required	Not required
E6013	67,000	55,000	17	Grade II	Not required
E6020	62,000	50,000	25	Grade I	Not required
E6027	62,000	50,000	25	Grade II	20 ft/lb at −20°F
E70 Series [c]					
E7014	72,000	60,000	17	Grade II	Not required
E7015			22	Grade I	20 ft/lb at −20°F
E7016			22	Grade I	20 ft/lb at −20°F
E7018			22	Grade I	20 ft/lb at −20°F
E7024			17	Grade II	Not required
E7028			22	Grade II	20 ft/lb at 0°F

a See AWS A5.1-69, Fig 3

b For each increase of one percentage point in elongation over the minimum, the yield point or tensile strength, or both, may decrease 1,000 psi to a minimum of 60,000 psi for the tensile strength and 48,000 psi for the yield point for all classifications of the 60-series except E6012 and E6013. For the E6012 and E6013 classifications the yield point and tensile strength may decrease to a minimum of 65,000 psi for the tensile strength and 53,000 psi for the yield point.

c For each increase of one percentage point in elongation over the minimum, the yield point or tensile strength, or both, may decrease 1,000 psi to a minimum of 70,000 psi for the tensile strength and 58,000 psi for the yield point.

d The extreme lowest value and the extreme highest value obtained in the test shall be disregarded. Two of the three remaining values shall be greater than the specified 20 ft/lb energy level; one of the three may be lower but shall not be less than 15 ft/lb. The computed average value of the three remaining values shall be equal to or greater than the 20 ft/lb energy level.

Mild Steel Covered Arc-Welding Electrodes, AWS A5.1-69

The scope of this specification prescribes requirements for covered mild steel electrodes for shielded metal-arc welding of carbon and low-alloy steels.

The minimum mechanical property requirements are shown in Table 4-5. Radiographic standard Grade I has less and smaller porosity than Grade II. The actual standards are not contained herein, and, if a comparison is required, the standard in AWS A5.1-69 should be used.

Standard electrode sizes and lengths are given in Table 4-6. Not all classifications, however, are manufactured in all sizes.

Low-Alloy Steel Covered Arc-Welding Electrodes, AWS A5.5-69

This specification prescribes covered electrodes for shielded metal-arc welding of low-alloy steel.

The same classification system is used as for mild steel covered electrodes, with an added suffix that indicates the approximate chemistry of the deposited weld metal (see Table 4-1).

The chemical composition of the deposited weld metal is shown in Table 4-7. The electrodes with the suffix "G" need have only one alloy above the minimum to qualify for the chemical requirements.

TABLE 4-6. AWS A5.1-69 Standard Covered Arc-Welding Electrode Sizes and Lengths

Core-Wire Diam. (in.)	Standard Lengths (in.)	
	E6010, E6011, E6012, E6013, E7014, E7015, E7016, E7018	E6020 E7024 E6027 E7028
1/16	9	...
5/64	9 or 12	...
3/32	12	12
1/8	14	14
5/32	14	14
3/16	14	14 or 18
7/32	14 or 18	18
1/4	18	18
5/16	18	18

TABLE 4-7. Composition Requirements of Low-Alloy Weld Metal AWS A5.5-69

Electrode Classification	Composition (%) C	Mn	P	S	Si	Ni	Cr	Mo	V
Carbon-Molybdenum Steel									
E7010-A1 E7011-A1 E7015-A1 E7016-A1 E7018-A1 E7020-A1 E7027-A1	0.12	0.60 0.60 0.90 0.90 0.90 0.60 1.00	0.03	0.04	0.40 0.40 0.60 0.60 0.80 0.40 0.40	...	...	0.40 to 0.64	...
Chromium Molybdenum Steel									
E8016-B1 E8018-B1	0.12	0.90	0.03	0.04	0.60 0.80	...	0.40 to 0.65	0.40 to 0.65	...
E8015-B2L	0.05	0.90	0.03	0.04	1.00	...	1.00 to 1.50	0.40 to 0.65	...
E8016-B2 E8018-B2	0.12	0.90	0.03	0.04	0.60 0.80	...	1.00 to 1.50	0.40 to 0.65	...
E8018-B2L	0.05	0.90	0.03	0.04	0.80	...	1.00 to 1.50	0.40 to 0.65	...
E9015-B3L	0.05	0.90	0.30	0.04	1.00	...	2.00 to 2.50	0.90 to 1.20	...
E9015-B3 E9016-B3 E9018-B3	0.12	0.90	0.03	0.04	0.60 0.60 0.80	...	2.00 to 2.50	0.90 to 1.20	...
E9018-B3L E8015-B4L E8016-B5	0.05 0.05 0.07 to 0.15	0.90 0.90 0.40 to 0.70	0.03 0.03 0.03	0.04 0.04 0.04	0.80 1.00 0.30 to 0.60	... ...	2.00 to 2.50 1.75 to 2.25 0.40 to 0.60	0.90 to 1.20 0.40 to 0.65 1.00 to 1.25	... ... 0.05
Nickel Steel									
E8016-C1 E8018-C1	0.12	1.20	0.03	0.04	0.60 0.80	2.00 to 2.75	...	...	...
E8016-C2 E8018-C2	0.12	1.20	0.03	0.04	0.60 0.80	3.00 to 3.75	...	...	...
E8016-C3 E8018-C3	0.12	0.40 to 1.25	0.030	0.030	0.80	0.80 to 1.10	0.15	0.35	0.05
Manganese Molybdenum Steel									
E9015-D1 E9018-D1	0.12	1.25 to 1.75	0.03	0.04	0.60 0.80	...	...	0.25 to 0.45	...
E10015-D2 E10016-D2 E10018-D2	0.15	1.65 to 2.00	0.03	0.04	0.60 0.60 0.80	...	...	0.25 to 0.45	...
Other Low-Alloy Steel									
EXX10-G EXX11-G EXX13-G EXX15-G EXX16-G EXX18-G E7020-G	...	1.00 min	...	...	0.80 min	0.50 min	0.30 min	0.20 min	0.10 min
E9018-M E10018-M E11018-M E12018-M	0.10 0.10 0.10 0.10	0.60 to 1.25 0.75 to 1.70 1.30 to 1.80 1.30 to 2.25	0.030 0.030 0.030 0.030	0.030 0.030 0.030 0.030	0.80 0.60 0.60 0.60	1.40 to 1.80 1.40 to 2.10 1.25 to 2.50 1.75 to 2.25	0.15 0.35 0.40 0.30 to 1.50	0.35 0.25 to 0.50 0.30 to 0.55 0.30 to 0.55	0.05 0.05 0.05 0.05

Note. Single values shown are maximum percentages except where otherwise specified.

Electrodes with the suffix "M" will meet or be similar to certain military requirements.

Table 4-8 shows the tensile-strength, yield-strength, and elongation requirements. The preheat, interpass-temperature, and postheat treatments are not the same for all electrodes. For this reason, the complete AWS A5.5-69 specification should be consulted before conducting any tests.

Radiographic requirements are shown in Table 4-9. Grade I has fewer and smaller porosity than Grade II. The radiographic standards can be found in the specification.

TABLE 4-8. AWS A5.5-69 Tensile Strength, Yield-Strength, and Elongation Requirements for All-Weld-Metal Tension Test [a]

AWS Classification	Tensile Strength, min, psi	Yield Strength at 0.2 percent offset, psi	Elongation in 2 in., min, percent
E7010-X E7011-X E7015-X E7016-X E7018-X E7020-X E7027-X	70,000	57,000	22 22 25 25 25 25 25
E8010-X E8011-X E8013-X E8015-X E8016-X E8018-X	80,000	67,000	19 19 16 19 19 19
E8016-C3 E8018-C3	80,000	68,000 to 80,000	24
E9010-X E9011-X E9013-X E9015-X E9016-X E9018-X	90,000	77,000	17 17 14 17 17 17
E9018-M	90,000	78,000 to 90,000	24
E10010-X E10011-X E10013-X E10015-X E10016-X E10018-X	100,000	87,000	16 16 13 16 16 16
E10018-M	100,000	88,000 to 100,000	20
E11015-X E11016-X E11018-X	110,000	97,000	15
E11018-M	110,000	98,000 to 110,000	20
E12015-X E12016-X E12018-X	120,000	107,000	14
E12018-M	120,000	108,000 to 120,000	18

a For the E8016-C3, E8018-C3, E9018-M, E10018-M, E11018-M, and E12018-M electrode classifications the values shown are for specimens tested in the as-welded condition. Specimens tested for all other electrodes are in the stress relieved condition.

TABLE 4-9. AWS A5.5-69 Radiographic Requirements

AWS Classification	Radiographic Standard
EXX15-X EXX16-X EXX18-X E7020-X	Grade I
EXX10-X EXX11-X EXX13-X E7027-X	Grade II

Table 4-10 shows the impact requirements. The impact test specimens receive the same heat treatment as the tension test specimens.

TABLE 4-10. AWS A5.5-69 Impact-Property Requirements

AWS Classification	Minimum V-Notch Impact Requirement [a]
E8016-C3 E8018-C3	20 ft/lb at −40°F [b]
E9015-D1 E9018-D1 E10015-D2 E10016-D2 E10018-D2	20 ft/lb at −60°F [c]
E9018-M E10018-M E11018-M E12018-M	20 ft/lb at −60°F [b]
E8016-C1 E8018-C1	20 ft/lb at −75°F [c]
E8016-C2 E8018-C2	20 ft/lb at −100°F [c]
All other classifications	Not required

a The extreme lowest value obtained together with the extreme highest value shall be disregarded for this test. Two of the three remaining values shall be greater than the specified 20 ft/lb energy level; one of the three may be lower but shall not be less than 15 ft/lb. The computed average value of the three remaining values shall be equal to or greater than the 20 ft/lb energy level.

b As-welded impact properties.

c Stress-relieved impact properties.

Bare Mild Steel Electrodes and Fluxes for Submerged-Arc Welding, AWS A5.17-69

Since the electrode and flux are two separate consumable items, they are classified separately. Electrodes are classified on the basis of chemical composition, as shown in Table 4-11. In the classifying system, the letter "E" indicates an electrode, as in the other classifying systems, but here the similarity stops. The next letter "L," "M," or "H," indicates low, medium, or high-manganese, respectively. The following number or numbers indicate the approximate carbon content in hundredths of one percent. If there is a suffix "K," this indicates a silicon-killed steel.

Table 4-12 gives the standard electrode sizes and tolerances.

TABLE 4-11. AWS A5.17-69 Chemical-Composition Requirements for Submerged-Arc Electrodes

AWS Classification	Chemical Composition, percent						
	Carbon	Manganese	Silicon	Sulfur	Phosphorus	Copper[a]	Total other Elements
Low Manganese Classes							
EL8	0.10	0.30 to 0.55	0.05				
EL8K	0.10	0.30 to 0.55	0.10 to 0.20				
EL12	0.07 to 0.15	0.35 to 0.60	0.05				
Medium Manganese Classes							
EM5K[b]	0.06	0.90 to 1.40	0.40 to 0.70	0.035	0.03	0.15	0.50
EM12	0.07 to 0.15	0.85 to 1.25	0.05				
EM12K	0.07 to 0.15	0.85 to 1.25	0.15 to 0.35				
EM13K	0.07 to 0.19	0.90 to 1.40	0.45 to 0.70				
EM15K	0.12 to 0.20	0.85 to 1.25	0.15 to 0.35				
High Manganese Class							
EH14	0.10 to 0.18	1.75 to 2.25	0.05				

a The copper limit is independent of any copper or other suitable coating which may be applied to the electrode.

b This electrode contains 0.05 to 0.15 percent titanium, 0.02 to 0.12 percent zirconium, and 0.05 to 0.15 percent aluminum, which is exclusive of the "Total Other Elements" requirement.

Note 1 — Analysis shall be made for the elements for which specific values are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of the limits specified for "Total Other Elements" in the last column of the table.

Note 2 — Single values shown are maximum percentages.

Fluxes are classified on the basis of the mechanical properties of the weld deposit made with a particular electrode (see Table 4-13). The classification designation given to a flux consists of a prefix "F" (indicating a flux) followed by a two-digit number representative of the tensile-strength and impact requirements for test welds made in accordance with the specification. This is then followed by a set of letters and numbers corresponding to the classification of the electrode used with the flux.

Test welds are radiographed and must meet the Grade I standard of AWS A5.1 specification.

Mild Steel Electrodes for Flux-Cored Arc-Welding, AWS A5.20-69

This specification prescribes requirements for mild steel composite electrodes for flux-cored arc welding of mild and low-alloy steels.

Electrodes are classified on the basis of single or multiple-pass operation, chemical composition of the deposited weld metal, mechanical properties, and whether or not carbon dioxide is required as a separate shielding gas. Table 4-14 and 4-15 show the

TABLE 4-12. AWS A5.17-69 Standard Sizes and Tolerances for Submerged-Arc Electrodes

Standard Electrode Size, dia., in.	Tolerance on Dia., in. ±
1/16 (0.063)	0.0015
5/64 (0.078), 3/32 (0.094)	0.002
1/8 (0.125)	0.003
5/32 (0.156), 3/16 (0.188), 7/32 (0.219) 1/4 (0.250), 5/16 (0.312), 3/8 (0.375)	0.004

minimum mechanical-property requirements.

Gas-shielded flux-cored electrodes are available for welding the low-alloy high-tensile steels. Self-shielded flux-cored electrodes are available for all-position welding, as in building construction. Fabricators using or anticipating using the flux-cored arc-welding processes should keep in touch with the electrode manufacturers for new or improved electrodes not included in the present specifications.

Mild Steel Electrodes for Gas Metal-Arc Welding, AWS A5.18-69

This specification prescribes requirements for mild steel solid electrodes for gas metal-arc welding

TABLE 4-13. AWS A5.17-69 Mechanical-Property Requirements for Submerged-Arc Flux Classification

AWS Flux[a] Classification	Tensile Strength psi	Yield Strength at 0.2% Offset, min, psi	Elongation in 2 in., min, %	Charpy V-Notch Impact Strength[b]
F60-XXXX				Not required
F61-XXXX[c]	62,000			20 ft/lb at 0°F
F62-XXXX[c]	to	50,000	22[d]	20 ft/lb at −20°F
F63-XXXX[c]	80,000			20 ft/lb at −40°F
F64-XXXX[c]				20 ft/lb at −60°F
F70-XXXX				Not required
F71-XXXX[c]	72,000			20 ft/lb at 0°F
F72-XXXX[c]	to	60,000	22[e]	20 ft/lb at −20°F
F73-XXXX[c]	95,000			20 ft/lb at −40°F
F74-XXXX[c]				20 ft/lb at −60°F

a The letters "XXXX" as used in this table stand for the electrode designations EL8, EL8K, etc. (see Table 4-11).

b The extreme lowest value obtained, together with the extreme highest value obtained, shall be disregarded for this test. Two of the three remaining values shall be greater than the specified 20 ft/lb energy level; one of the three may be lower but shall not be less than 15 ft/lb. The computed average value of the three values shall be equal to or greater than the 20 ft/lb energy level.

c Note that if a specific flux electrode combination meets the requirements of a given F6X-xxxx classification, this classification also meets the requirements of all lower numbered classifications in the F6X-xxxx series. For instance, a flux-electrode combination meeting the requirements of the F63-xxxx classification, also meets the requirements of the F62-xxxx, F61-xxxx, and F60-xxxx classifications. This applies to the F7X-xxxx series also.

d For each increase of one percentage point in elongation over the minimum, the yield strength or tensile strength, or both, may decrease 1000 psi to a minimum of 60,000 psi for the tensile strength and 48,000 psi for the yield strength.

e For each increase of one percentage point in elongation over the minimum, the yield strength or tensile strength, or both, may decrease 1000 psi to a minimum of 70,000 psi for the tensile strength and 58,000 psi for the yield strength.

TABLE 4-14. AWS A5.20-69 Mechanical-Property Requirements for Flux-Cored Arc-Welding Weld Metal[a]

AWS Classification	Shielding Gas[b]	Current and Polarity[c]	Tensile Strength min.[f], psi	Yield Strength at 0.2% Offset, min.[f], psi	Elongation in 2 inches, min.[f], psi
E60T-7	None	DC, straight polarity	67,000	55,000	22
E60T-8	None	DC reverse polarity	62,000	60,000	22
E70T-1	CO_2		72,000	60,000	22
E70T-2			72,000	Not required	
E70T-3	None		72,000	Not required	
E70T-4	None		72,000	60,000	22
E70T-5[g]	CO_2 None		72,000	60,000	22
E70T-6	None		72,000	60,000	22
E70T-G	not spec.	not spec.	72,000[d]	Not required	
			72,000[e]	60,000[e]	22[e]

a As-welded mechanical properties.

b Shielding gases are designated as follows:
  CO_2 = carbon dioxide
  None = no separate shielding gas

c Reverse polarity means electrode is positive; straight polarity means electrode is negative.

d Requirement for single pass electrodes.

e Requirement for multiple pass electrodes.

f For each increase of one percentage point in elongation over the minimum, the minimum required yield strength or the tensile strength, or both, may decrease 1000 psi, for a maximum reduction of 2000 psi in either the required minimum yield strength or the tensile strength, or both.

g Where CO_2 and None are indicated as the shielding gases for a given classification, chemical analysis pads and test assemblies shall be prepared using both CO_2 and no separate shielding gas.

TABLE 4-15. AWS A5.20-69 Impact-Property Requirements for Flux-Cored Arc-Welding Weld Metal

AWS Classification	Minimum V-Notch Impact Requirement [e]
E70T-5	20 ft/lb at −20°F
E60T-8 E70T-1 E70T-6	20 ft/lb at 0°F
E60T-7 E70T-2 E70T-3 E70T-4 E70T-G	Not required

e The extreme lowest value obtained, together with the extreme highest value obtained, shall be disregarded for this test. Two of the three remaining values shall be greater than the specified 20 ft/lb energy level; one of the three may be lower but shall not be less than 15 ft/lb. The computed average value of the three values shall be equal to or greater than the 20 ft/lb energy level.

of mild and low-alloy steel. The electrodes are classified on the basis of their chemical composition and the as-welded mechanical properties of the deposited weld metal (see Tables 4-16 and 4-17). For the chemical-composition requirements of the deposited weld metal, see Table 4-18.

Table 4-18 includes a Group B classification, entitled "Low-Alloy Steel Electrodes." The alloy additions here do not meet the accepted definitions of mild steel. The basis for including this classification in a mild steel specification is that the alloy additions are for deoxidation and usability improvement and not for the purpose of upgrading the mechanical properties.

Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes, AWS A5.4-69

These electrodes are commonly called the "stainless" or "corrosion-resisting" electrodes and are classified on the basis of the chemical composition of the deposited weld metal and usability characteristics.

Chemical composition requirements are shown in Table 4-19. The specification does not include tests for corrosion resistance. The deposited weld metal can be expected to have the same corrosion resistance as the base metal of the same composition. However, due to the heat of welding or subsequent heat treatment, metallurgical changes can occur that may affect the corrosion resistance of the

TABLE 4-16. AWS A5.18-69 Mechanical-Property Requirements for Gas Metal-Arc Welding Weld Metal[a]

AWS Classification	Shielding Gas[b]	Current and Polarity [c]	Tensile Strength min., psi	Yield Strength at 0.2% Offset, min.	Elongation in 2 inches, min. %
GROUP A – MILD STEEL ELECTRODES					
E70S-1	AO	DC reverse polarity	72,000 [e,f]	60,000 [e,f]	22 [e,f]
E70S-2 E70S-3	AO & CO_2 [d]				
E70S-4 E70S-5 E70S-6	CO_2				
E70S-G	not spec.	not spec.			
GROUP B – LOW-ALLOY STEEL ELECTRODES					
E70S-1B E70S-GB	CO_2 not spec.	DC, reverse polarity not spec.	72,000 [e,f] 72,000 [e,f]	60,000 [e,f] 60,000 [e,f]	17 [e,f] 22 [e,f]
GROUP C – EMISSIVE ELECTRODE					
E70U-1	AO & A [d]	DC, straight polarity	72,000 [e]	60,000 [e]	22 [e]

a As welded mechanical properties

b Shielding gases are designated as follows:
AO = argon, plus 1 to 5 percent oxygen
CO_2 = carbon dioxide
A = argon

c Reverse polarity means electrode is positive, straight polarity means electrode is negative.

d Where two gases are listed as interchangeable (that is, AO and CO_2 and AO & A) for classification of a specific electrode, the classification tests may be conducted using either gas.

e Mechanical properties as determined from an all-weld metal tension test specimen.

f For each increase of one percentage point in elongation over the minimum, the yield strength or tensile strength, or both, may decrease 1,000 psi to a minimum of 70,000 psi for the tensile strength and 58,000 psi for the yield strength.

TABLE 4-17. AWS A5.18-69 Impact-Property Requirements for Gas Metal-Arc Welding Weld Metal

AWS Classification	Minimum V-Notch Impact Requirement[a]
E70S-2 E70S-6 E70S-1B E70U-1	20 ft/lb at −20°F
E70S-3	20 ft/lb at 0°F
E70S-1, E70S-4, E70S-5, E70S-G, E70S-GB	Not required

The extreme lowest value obtained, together with the extreme highest value obtained, shall be disregarded for this test. Two of the three remaining values shall be greater than the specified 20 ft/lb energy level; one of the three may be lower but shall not be less than 15 ft/lb. The computed average value of the three values shall be equal to or greater than the 20 ft/lb energy level.

weld and base metals. For this reason, corrosion tests should be made on critical applications.

Mechanical property requirements are shown in Table 4-20.

The usability of the electrodes is indicated by a suffix to the classification number in Table 4-20. A suffix "-15" indicates the electrode is to be used with DC reverse polarity (DC+). If the suffix is "-16" the electrode can be used with AC or DC reverse polarity (DC+).

Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes, AWS 5.9-69

This specification covers corrosion-resisting chromium and chromium-nickel steel (stainless

TABLE 4-18. AWS A5.18-69 Chemical-Composition Requirements for Gas Metal-Arc Welding Electrode

AWS Classification	Chemical Composition, percent											
	Carbon	Manganese	Silicon	Phosphorus	Sulfur	Nickel[a]	Chromium[a]	Molybdenum[a]	Vanadium[a]	Titanium	Zirconium	Aluminum
GROUP A – MILD STEEL ELECTRODES												
E70S-1	0.07 to 0.19	0.90 to 1.40	0.30 to 0.50	0.025	0.035							
E70S-2	0.06	0.90 to 1.40	0.40 to 0.70	0.025	0.035					0.05 to 0.15	0.02 to 0.12	0.05 to 0.15
E70S-3	0.06 to 0.15	0.90 to 1.40	0.45 to 0.70	0.025	0.035							
E70S-4	0.07 to 0.15	0.90 to 1.40	0.65 to 0.85	0.025	0.035							
E70S-5	0.07 to 0.19	0.90 to 1.40	0.30 to 0.60	0.025	0.035							0.50 to 0.90
E70S-6	0.07 to 0.15	1.40 to 1.85	0.80 to 1.15	0.025	0.035							
E70S-G	no chemical requirements[b]											
GROUP B – LOW-ALLOY STEEL ELECTRODES												
E70S-1B	0.07 to 0.12	1.60 to 2.10	0.50 to 0.80	0.025	0.035	0.15		0.40 to 0.60				
E70S-GB	no chemical requirements											
GROUP C – EMISSIVE ELECTRODE												
E70U-1	0.07 to 0.15	0.80 to 1.40	0.15 to 0.35	0.025	0.035							

Note – Single values shown are maximums.

a For Groups A and C these elements may be present but are not intentionally added.

b For this classification there are no chemical requirements for the elements listed with the exception that there shall be no intentional addition of Ni, Cr, Mo or V.

TABLE 4-19. AWS A5.4-69 Chemical Requirements for Stainless Covered Electrode All-Weld Metal

AWS Classification	Carbon,[a] percent	Chromium, percent	Nickel, percent	Molybdenum, percent	Columbium Plus Tantalum, percent	Manganese, percent	Silicon percent	Phosphorus, percent	Sulfur, percent	Tungsten, percent
E308	0.08	18.0 to 21.0	9.0 to 11.0	...	...	2.5	0.90	0.04	0.03	...
E308L	0.04	18.0 to 21.0	9.0 to 11.0	...	...	2.5	0.90	0.04	0.03	...
E309	0.15	22.0 to 25.0	12.0 to 14.0	...	...	2.5	0.90	0.04	0.03	...
E309Cb	0.12	22.0 to 25.0	12.0 to 14.0	...	0.70 to 1.00	2.5	0.90	0.04	0.03	...
E309Mo	0.12	22.0 to 25.0	12.0 to 14.0	2.0 to 3.0	...	2.5	0.90	0.04	0.03	...
E310	0.20	25.0 to 28.0	20.0 to 22.5	...	...	2.5	0.75	0.03	0.03	...
E310Cb	0.12	25.0 to 28.0	20.0 to 22.0	...	0.70 to 1.00	2.5	0.75	0.03	0.03	...
E310Mo	0.12	25.0 to 28.0	20.0 to 22.0	2.0 to 3.0	...	2.5	0.75	0.03	0.03	...
E312	0.15	28.0 to 32.0	8.0 to 10.5	...	...	2.5	0.90	0.04	0.03	...
E16-8-2	0.10	14.5 to 16.5	7.5 to 9.5	1.0 to 2.0	...	2.5	0.60	0.03	0.03	...
E316	0.08	17.0 to 20.0	11.0 to 14.0	2.0 to 2.5	...	2.5	0.90	0.04	0.03	...
E316L	0.04	17.0 to 20.0	11.0 to 14.0	2.0 to 2.5	...	2.5	0.90	0.04	0.03	...
E317	0.08	18.0 to 21.0	12.0 to 14.0	3.0 to 4.0	...	2.5	0.90	0.04	0.03	...
E318	0.08	17.0 to 20.0	11.0 to 14.0	2.0 to 2.5	6 x C, min. to 1.00 max.	2.5	0.90	0.04	0.03	...
E320[e]	0.07	19.0 to 21.0	32.0 to 36.0	2.0 to 3.0	8 x C, min. to 1.00 max.	2.5	0.60	0.04	0.03	...
E330	0.25	14.0 to 17.0	33.0 to 37.0	...	...	2.5	0.90	0.04	0.03	...
E347[b]	0.08	18.0 to 21.0	9.0 to 11.0	...	8 x C, min.,[c] to 1.00 max.	2.5	0.90	0.04	0.03	...
E349[d]	0.13	18.0 to 21.0	8.0 to 10.0	0.35 to 0.65	0.75 to 1.2	2.5	0.90	0.04	0.03	1.25 to 1.75
E410	0.12	11.0 to 13.5	0.60	...	...	1.0	0.90	0.04	0.03	...
E430	0.10	15.0 to 18.0	0.60	...	...	1.0	0.90	0.04	0.03	...
E502	0.10	4.0 to 6.0	0.40	0.45 to 0.65	...	1.0	0.90	0.04	0.03	...
E505	0.10	8.0 to 10.5	0.40	0.85 to 1.20	...	1.0	0.90	0.04	0.03	...
E7Cr	0.10	6.0 to 8.0	0.40	0.45 to 0.65	...	1.0	0.90	0.04	0.03	...

Note 1 — Analysis shall be made for the elements for which specific values are shown in the table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements, except iron, is not present in excess of 0.70 percent.

Note 2 — Single values shown are maximum percentages except where otherwise specified.

a Carbon shall be analyzed to the nearest 0.01 percent.
b Chromium shall be 1.9 × Ni, min., when so specified.
c Tantalum shall be 0.10 max., when so specified.
d Titanium shall be 0.15 max.
e Copper shall be 3.0 to 4.0.

steel) welding rods for use with atomic hydrogen and gas tungsten-arc processes and bare electrodes for use with submerged-arc and gas metal-arc welding processes.

Rods and electrodes are classified on the basis of the chemical composition. The requirements for solid electrodes and rods are based on the chemical analysis of the filler metal as manufactured. For composite electrodes and rods, the requirements are based on the chemical analysis of a pad of undiluted metal made by melting the filler metal with the TIG process, using argon shielding gas. The analysis of composite electrodes and rods may also be made by any suitable method agreed upon by the purchaser and the supplier. Table 4-21 lists the chemical requirements.

Rods and electrodes are available in a wide variety of diameters and spool sizes. Rods are also available in straight lengths (see Table 4-22).

Welding Rods and Covered Electrodes for Welding Cast Iron, AWS A5.15-69.

This specification prescribes requirements for welding rods for oxyacetylene and carbon-arc weld-

TABLE 4-20. AWS A5.4-69 Mechanical-Property Requirements for Stainless Covered Electrode All-Weld Metal

AWS Classification	Tensile Strength min, psi	Elongation in 2 in., min, percent	Heat Treatment
E308	80,000	35	none
E308L	75,000	35	none
E309	80,000	30	none
E309Cb	80,000	30	none
E309Mo	80,000	30	none
E310	80,000	30	none
E310Cb	80,000	25	none
E310Mo	80,000	30	none
E312	95,000	22	none
E16-8-2	80,000	35	none
E316	75,000	30	none
E316L	70,000	30	none
E317	80,000	30	none
E318	80,000	25	none
E320	80,000	30	none
E330	75,000	25	none
E347	80,000	30	none
E349	100,000	25	none
E410	70,000	20	a
E430	70,000	20	b
E502	60,000	20	a
E505	60,000	20	a
E7Cr	60,000	20	a

a Specimen shall be heated to between 1550 and 1600°F and held for 2 hr., furnace cooled at a rate not exceeding 100°F per hr, to 1100°F, and air-cooled.
b Specimen shall be heated to between 1400 and 1450°F and held for 4 hr., furnace-cooled at a rate not exceeding 100°F per hr. to 1100°F, and air-cooled.

TABLE 4-21. AWS A5.9-69 Chemical Requirements for Bare Stainless Welding Rods and Electrodes

AWS Classification	Carbon, percent	Chromium, percent	Nickel, percent	Molybdenum percent	Columbium plus Tantalum, percent	Manganese percent	Silicon, percent	Phosphorus percent	Sulfur, percent	Tungsten, percent
ER308 [a,f]	0.08	19.5 to 22.0	9.0 to 11.0	...	...	1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER308L [a,f]	0.03	19.5 to 22.0	9.0 to 11.0	...	...	1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER309 [f]	0.12	23.0 to 25.0	12.0 to 14.0	...	...	1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER310	0.08 to 0.15	25.0 to 28.0	20.0 to 22.5	...	...	1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER312	0.15	28.0 to 32.0	8.0 to 10.5	...		1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER316 [f]	0.08	18.0 to 20.0	11.0 to 14.0	2.0 to 3.0		1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER316L [f]	0.03	18.0 to 20.0	11.0 to 14.0	2.0 to 3.0		1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER317	0.08	18.5 to 20.5	13.0 to 15.0	3.0 to 4.0	...	1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER318	0.08	18.0 to 20.0	11.0 to 14.0	2.0 to 3.0	8 × C, min. to 1.0, max.	1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER320 [e]	0.07	19.0 to 21.0	32.0 to 36.0	2.0 to 3.0	8 × C, min. to 1.0, max.	2.5	0.60	0.04	0.03	...
ER321 [c]	0.08	18.5 to 20.5	9.0 to 10.5	0.5 max.	...	1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER347 [a,f]	0.08	19.0 to 21.5	9.0 to 11.0	...	10 × C, min. to 1.0, max.	1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER348 [a]	0.08	19.0 to 21.5	9.0 to 11.0	...	10 × C, min. to 1.0, max.[b]	1.0 to 2.5	0.25 to 0.60	0.03	0.03	...
ER349 [d]	0.07 to 0.13	19.0 to 21.5	8.0 to 9.5	0.35 to 0.65	1.0 to 1.4	1.0 to 2.5	0.25 to 0.60	0.03	0.03	1.25 to 1.75
ER410	0.12	11.5 to 13.5	0.6	0.6	...	0.6	0.50	0.03	0.03	...
ER420	0.25 to 0.40	12.0 to 14.0	0.6	...	...	0.6	0.50	0.03	0.03	...
ER430	0.10	15.5 to 17.0	0.6	...	...	0.6	0.50	0.03	0.03	...
ER502	0.10	4.5 to 6.0	0.6	0.45 to 0.65	...	0.6	0.25 to 0.60	0.03	0.03	...

Note 1. — Analysis shall be made for the elements for which specific values are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements, except iron, is not present in excess of 0.70 percent.

Note 2. — Single values shown are maximum percentages except where otherwise specified.

a Chromium, min. = 1.9 × nickel, when so specified.
b Tantalum, max. = 0.10 percent.
c Titanium = 9 × C, min. to 1.0, max.
d Titanium = 0.10 to 0.30.
e Copper = 3.0 to 4.0.
f These grades are available in high silicon classifications which shall have the same chemical composition requirements as given above with the exception that the silicon content shall be 0.50 to 1.0 percent. These high silicon classifications shall be designated by the addition of "Si" to the standard classification designations listed above. The fabricator should consider carefully the use of high silicon filler metals in highly restrained or fully austenitic welds.

ing and covered electrodes for shielded metal-arc welding of cast irons. These filler metals are suitable for welding gray cast iron, malleable iron, and some alloy cast irons. With the exception of the nickel-base alloys, classification is based on the chemical composition of the bare welding rod and the core wire of the covered electrodes. The chemical composition of the nickel-base alloys ENi-CI, ENiFe-CI, ENiCu-A, and ENiCu-B is based on the composition of the deposited weld metal (see Table 4-23).

Aluminum and Aluminum-Alloy Welding Rods and Bare Electrodes, AWS A5.10-69

This specification prescribes aluminum and aluminum alloy welding rods for use with TIG welding and bare electrodes for use with MIG welding.

Rods and electrodes are classified on the basis of the chemical composition of the as-manufactured filler metal (see Table 4-24). Electrodes must also meet a usability test. For electrodes 3/32 in. and smaller, a butt joint is welded in the overhead position. For 1/8-in. electrodes, the weld is made in the flat position. The welds are radiographed and must meet an X-ray standard available from AWS. The usability test for rods consists of making a bead on a plate in the flat position with a gas flame or TIG welding. The bead must be uniform in appearance and be free from specified defects.

Copper and Copper Alloy Arc-Welding Electrodes, AWS A5.6-69

This specification covers the requirements for solid and stranded bare and covered copper and

TABLE 4-22. AWS A5.9-69 Standard Sizes

Form	Diameter [a], in.
Welding rods in straight lengths	0.045, 1/16 (0.062), 5/64 (0.078), 3/32 (0.094), 1/8 (0.125), 5/32 (0.156), 3/16 (0.188)
Filler metal in coils with or without support	0.045, 1/16 (0.062), 5/64 (0.078), 3/32 (0.094), 7/64 (0.109), 1/8 (0.125), 5/32 (0.156), 3/16 (0.188), 1/4 (0.250)
Filler metal wound on standard 12-in. O.D. spools	0.030, 0.035, 0.045, 1/16 (0.052), 5/64 (0.078), 3/32 (0.094), 7/64 (0.109)
Electrodes wound on lightweight 1-1/2 and 2-1/2-lb 4-in. O.D. spools	0.020, 0.025, 0.030, 0.035, 0.045

a Electrodes and welding rods of diameters up to and including 0.045 in. shall not vary more than ± 0.001 from the nominal. Diameters greater than 0.045 in. shall not vary more than ± 0.002 from the nominal.

TABLE 4-23. AWS A5.15-69 Chemical Requirements for Covered Electrodes for Cast Iron

AWS Classification	Carbon percent	Silicon percent	Manganese, percent	Phosphorus, percent	Sulfur percent	Iron percent	Molybdenum, percent	Nickel[a] percent	Copper,[b] percent	Zinc, percent	Tin, percent	Aluminum, percent	Lead percent	Cerium percent	Total Other Elements,[c] percent
CAST-IRON FILLER METALS[d]															
RCI ECI	3.25 to 3.50	2.75 to 3.00	0.60 to 0.75	0.50 to 0.75	0.10	remainder	trace	trace	...	...	...	...	...	...	...
RCI-A	3.25 to 3.50	2.00 to 2.50	0.50 to 0.70	0.20 to 0.40	0.10	remainder	0.25 to 0.45	1.20 to 1.60		...	...	...	...	...	
RCI-B	3.25 to 4.00	3.25 to 3.75	0.10 to 0.40	0.05	0.03	remainder	...	0.50		...	...	...	...	0.20	
COPPER-BASE FILLER METALS[d]															
RBCuZn-A[e]	...	c	c	...	...	c	...	...	57.0 to 61.0	remainder	0.25 to 1.00	0.01[c]	0.05[c]	...	0.50
RCuZn-B[f]	...	0.04 to 0.15	0.01 to 0.50	c	...	0.25 to 1.2	...	0.2 to 0.8	56.0 to 60.0	remainder	0.8 to 1.1	0.01[c]	0.05[c]	...	0.50
RCuZn-C[f]	...	0.04 to 0.15	0.01 to 0.50	...	...	0.25 to 1.2	...	...	56.0 to 60.0	remainder	0.8 to 1.1	0.01[c]	0.05[c]	...	0.50
RBCuZn-D[e]	...	0.04 to 0.25	...	0.25	...	...	...	9.00 to 11.00	46.0 to 50.0	remainder	...	0.01[c]	0.05[c]	...	0.50
ECuSn-A[g]	...	c	c	0.10 to 0.35	...	c	...	c	remainder	c	4.0 to 6.0	0.01[c]	0.02[c]	...	0.50
ECuSn-C[g]	...	c	c	0.05 to 0.35	...	c	...	c	remainder	c	7.0 to 9.0	0.01[c]	0.02[c]	...	0.50
ECuAl-A2[g]	...	0.10	...	...	...	1.5	...	...	remainder	0.02	...	9.0 to 11.0	0.02	...	0.50
MILD STEEL ELECTRODE[d]															
ESt	0.15	0.03	0.30 to 0.60	0.04	0.04	remainder	...	...	...	...	...	...	...	...	...
NICKEL-BASE ELECTRODES[h]															
ENi-CI	2.00	4.00	1.00	...	0.03	8.00	...	85.00 min	2.50	...	...	...	...	...	1.00
ENiFe-CI	2.00	4.00	1.00	...	0.03	remainder	...	45.0 to 60.0	2.50	...	...	...	...	...	1.00
ENiCu-A	0.35 to 0.55	0.75	2.25	...	0.025	3.0 to 6.0	...	50.0 to 60.0	35.0 to 45.0	...	...	...	...	...	1.00
ENiCu-B	0.35 to 0.55	0.75	2.25	...	0.025	3.0 to 6.0	...	60.0 to 70.0	25.0 to 35.0	...	...	...	...	...	1.00

Note 1 — Analysis shall be made for the elements for which specific values are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of the limits specified for "Total Other Elements" in the last column of this table.

Note 2 — Single values shown are maximum percentages, except where otherwise specified.

a Nickel plus incidental cobalt.
b Copper plus incidental silver.
c Total Other Elements, including the elements marked with footnote c, shall not exceed the value specified.
d Chemical requirements for the cast iron, copper-base and mild steel filler metals are based on the as-manufactured composition of the bare welding rod and the core wire of the covered electrode.
e This AWS classification is intended to be identical with the same classification that appears in the latest editions of the Specification for Copper and Copper-Alloy Welding Rods (AWS Designation: A5.7) and Specification for Brazing Filler Metal (AWS Designation: A5.8) (The chemical analysis shown is that which appears in the 1969 edition of AWS A5.7 and the 1969 edition of AWS A5.8.)
f This AWS classification is intended to be identical with the same classification that appears in the Specification for Copper and Copper Alloy Welding Rods, latest edition, (AWS Designation: A5.7) (The chemical analysis shown is that which appears in the 1969 edition of AWS A5.7.)
g This AWS classification is intended to be identical with the same classification that appears in the Specifications for Copper and Copper Alloy Welding Electrodes, latest edition, (AWS Designation: A5.6) (The chemical analysis shown is that which appears in the 1969 edition of AWS A5.6.)
h Ch[illegible] requirements for the nickel base electrodes are based on deposited weld metal anal[illegible]

TABLE 4-24. AWS A5.10-69 Chemical Requirement for Bare Welding Rods and Electrodes for Aluminum and Aluminum Alloys

AWS Classification	Silicon, percent	Iron, percent	Copper percent	Manganese, percent	Magnesium, percent	Chromium, percent	Nickel, percent	Zinc, percent	Titanium, percent	Other Elements,[g] percent Each	Other Elements,[g] percent Total	Aluminum, percent
ER1100	b	b	0.05-0.20	0.05	...	...	...	0.10	...	0.05	0.15	99.00 min.[h]
ER1260	c	c	0.04	0.01	...	...	...	...	...	0.03	...	99.60 min.[h]
ER2319[i]	0.20	0.30	5.8-6.8	0.20-0.40	0.02	...	...	0.10	0.10-0.20	0.05	0.15	remainder
ER4145	9.3-10.7	0.8	3.3-4.7	0.15	0.15	0.15	...	0.20	...	0.05	0.15	remainder
ER4043	4.5-6.0	0.8	0.30	0.05	0.05	...	...	0.10	0.20	0.05	0.15	remainder
ER4047	11.0-13.0	0.8	0.30	0.15	0.10	...	...	0.20	...	0.05	0.15	remainder
ER5039	0.10	0.40	0.03	0.30-0.50	3.3-4.3	0.10-0.20	...	2.4-3.2	0.10	0.05	0.10	remainder
ER5554	c	c	0.10	0.50-1.0	2.4-3.0	0.05-0.20	...	0.25	0.05-0.20	0.05	0.15	remainder
ER5654[j]	d	d	0.05	0.01	3.1-3.9	0.15-0.35	...	0.20	0.05-0.15	0.05	0.15	remainder
ER5356	e	e	0.10	0.05-0.20	4.5-5.5	0.05-0.20	...	0.10	0.06-0.20	0.05	0.15	remainder
ER5556	c	c	0.10	0.50-1.0	4.7-5.5	0.05-0.20	...	0.25	0.05-0.20	0.05	0.15	remainder
ER6183	0.40	0.40	0.10	0.50-1.0	4.3-5.2	0.05-0.25	...	0.25	0.15	0.05	0.15	remainder
R-C4A[a]	1.5	1.0	4.0-5.0	0.35	0.03	...	...	0.35	0.25	0.05	0.15	remainder
R-CN42A[a]	0.7	1.0	3.5-4.5	0.35	1.2-1.8	0.25	1.7-2.3	0.35	0.25	0.05	0.15	remainder
R-SC51A[a]	4.5-5.5	0.8[f]	1.0-1.5	0.50[f]	0.40-0.60	0.25	...	0.35	0.25	0.05	0.15	remainder
R-SG70A[a]	6.5-7.5	0.6	0.25	0.35	0.20-0.40	...	...	0.35	0.25	0.05	0.15	remainder

Note 1 – Single values shown are maximum percentages, except where a minimum is specified.

Note 2 – For purposes of determining conformance to these limits, an observed value or a calculated value obtained from analysis shall be rounded off to the nearest unit in the last righthand place of figures used in expressing the specified limit, in accordance with Recommended Practices for Designating Significant Places in Specified Limiting Values (ASTM Designation: E29), 1968 Book of ASTM Standards, Part 32.

Note 3 – Analysis shall be made for the elements for which specific limits are shown. If, however, the presence of other elements is suspected, or indicated in the course of routine analysis, further analysis shall be made to determine that these other elements are not in excess of the limits specified for "other elements."

a For repair of castings.
b Silicon plus iron shall not exceed 1.0 percent.
c Silicon plus iron shall not exceed 0.40 percent.
d Silicon plus iron shall not exceed 0.45 percent.
e Silicon plus iron shall not exceed 0.50 percent.
f If iron exceeds 0.45 percent, manganese should be present in an amount equal to one half the iron.
g Beryllium shall not exceed 0.0008 percent.
h The aluminum content is the difference between 100.00 percent and the sum of all other metallic elements present in amounts of 0.010 percent or more each, expressed to the second decimal.
i Vanadium content shall be 0.05-0.15 percent. Zirconium content shall be 0.10-0.25 percent.
j Effective with the 1969 revision, ER5654 has replaced filler metal composition ER5154, ER5254, and ER5652.

TABLE 4-25. AWS A5.6-69 Chemical Requirements for Copper and Copper Alloy Arc-Welding Electrodes

Common Name	AWS Classification	Copper, Including Silver, percent	Zinc, percent	Tin, percent	Manganese, percent	Iron, percent	Silicon, percent	Nickel Incl. Cobalt, percent	Phosphorus, percent	Aluminum, percent	Lead percent	Titanium, percent	Total Other Elements, percent[a]
Copper	ECu	98.0 min	*	1.0	0.5	*	0.50	*	0.15	0.01*	0.02*	...	0.50
Copper-silicon (silicon bronze)	ECuSi	remainder	*	1.5[b]	1.5[b]	0.5	2.8 to 4.0	*	*	0.01*	0.02*	...	0.50
Copper-tin (phosphor bronze)	ECuSn-A	remainder	*	4.0 to 6.0	*	*	*	*	0.10 to 0.35	0.01*	0.02*	...	0.50
	ECuSn-C	remainder	*	7.0 to 9.0	*	*	*	*	0.05 to 0.35	0.01*	0.02*	...	0.50
Copper-nickel	ECuNi[c]	remainder	*	*	1.00[c]	0.40 to 0.75	0.50	29.0 min	...	...	0.02*	0.15[c] to 1.00	0.50
Copper-aluminum (aluminum bronze)	ECuAl-A1	remainder	0.20	...	...	...	0.10	...	...	6.0 to 9.0	0.02	...	0.50
	ECuAl-A2[d,e]	remainder	0.02	...	...	1.5	0.10	...	...	9.0 to 11.0	0.02	...	0.50
	ECuAl-B[d]	remainder	0.20	...	...	3.0 to 4.25	0.10	...	...	11.0 to 12.0	0.02	...	0.50

Note 1 – Analysis shall be made for the elements for which specific values are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of the limits specified for "total other elements" in the last column in the table.

Note 2 – Single values shown are maximum percentages, except where otherwise specified.

a Total other elements, including the elements marked with an asterisk (*), shall not exceed the value specified.
b One or both of these elements may be present within the limits specified.
c The composition of weld metal deposited by this electrode using the shielded metal arc welding process may contain up to 2.50 percent Mn. The titanium content will be 0.50 percent max.
d This electrode also available as a bare electrode for the gas metal arc process.
e This electrode also available as a bare electrode for submerged arc welding.

TABLE 4-26. AWS A5.6-69 Tensile-Strength Requirements for Copper and Copper Alloy Weld Metal

AWS Classification	Tensile Strength, min, psi
ECu	25,000
ECuSi	50,000
ECuSn-A	35,000
ECuSn-C	40,000
ECuNi	50,000
ECuAl-A1	55,000
ECuAl-A2	60,000
ECuAl-B	65,000

copper-alloy arc-welding electrodes for use with the shielded metal arc, gas metal-arc, and submerged-arc welding processes. The specification is not intended to cover rods used with the TIG process. Such rods are covered in "Specification for Copper and Copper-Alloy Welding Rods, AWS A5.7."

Electrodes are classified on the basis of the chemical composition of the bare electrode or core wire for covered electrodes (see Table 4-25). The

TABLE 4-28. AWS A5.7-69 Tensile-Strength Requirements for Copper and Copper Alloy Weld Metal

AWS Classification	Tensile Strength, min, psi		Applicable Processes[a]
	Copper-Alloy Base Plate	Steel Base Plate	
RCu	25,000	...	OAW, GTAW
RCuSi-A	50,000	...	OAW, GTAW
RCuSn-A	35,000	...	GTAW
RCuNi	50,000	...	OAW, GTAW
RBCuZn-A	50,000	40,000	OAW
RCuZn-B	56,000	50,000	OAW
RCuZn-C	56,000	50,000	OAW
RBCuZn-D	...	60,000	OAW
RCuAl-A2,	65,000	...	GTAW
RCuAl-B	70,000	...	GTAW

a OAW = oxyacetylene welding
GTAW = gas tungsten-arc welding

TABLE 4-27. AWS A5.7-69 Chemical Requirements for Copper and Copper Alloy Welding Rods

Common Name	AWS Classification	Copper Including Silver, percent	Zinc, percent	Tin, percent	Manganese, percent	Iron, percent	Silicon, percent	Nickel Incl. Cobalt, percent	Phosphorus, percent	Aluminum percent	Lead percent	Titanium, percent	Total Other Elements, percent[a]
Copper	RCu	98.0 min	...	1.0	0.5	*	0.50	*	0.15	0.01*	0.02*	..	0.50
Copper-silicon (silicon bronze)	RCuSi-A	98.0 min	1.5[b]	1.5[b]	1.5[b]	0.5	2.8 to 4.0	*	*	0.01*	0.02*	...	0.50
Copper-tin (phosphor bronze)	RCuSn-A	93.5 min	*	4.0 to 6.0	*	*	*	*	0.10 to 0.35	0.01*	0.02*	...	0.50
Copper nickel	RCuNi	remainder	*	*	1.00	0.40 to 0.70	0.15	29.0 to 32.0	...	...	0.02*	0.20 to 0.50	0.50
Naval brass	RBCuZn-A[c]	57 to 61	remainder	0.25 to 1.00	*	*	*	..	...	0.01*	0.05*	...	0.50
Low-fuming bronze (nickel)	RCuZn-B	56 to 60	remainder	0.8 to 1.1	0.01 to 0.50	0.25 to 1.2	0.04 to 0.15	0.2 to 0.8	...	0.01*	0.05*	...	0.50
Low-fuming bronze	RCuZn-C	56 to 60	remainder	0.8 to 1.1	0.01 to 0.50	0.25 to 1.2	0.04 to 0.15	...	...	0.01*	0.05*	...	0.50
Nickel bronze	RBCuZn-D[c]	46 to 50	remainder	..	...	...	0.04 to 0.25	9.0 to 11.0	0.25	0.01*	0.05*	...	0.50
Copper-aluminum (aluminum bronze)	RCuAl-A2	remainder	0.02	..	...	1.5	0.10	...	...	9.0 to 11.0	0.02	...	0.50
	RCuAl-B	remainder	0.02	...	...	3.0 to 4.25	0.10	...	...	11.0 to 12.0	0.02	...	0.50

Note 1 — Analysis shall be made for the elements for which specific values are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of the limits specified for "total other elements" in the last column in the table.

Note 2 — Single values shown are maximum percentages except where otherwise specified.

a Total other elements, including the elements marked with an asterisk (*) shall not exceed the value specified.
b One or more of these elements may be present within the limits specified.
c This AWS classification is intended to be identical with the same classification that appears in the latest edition of the Specification for Brazing Filler Metal, AWS Designation A5.8.

TABLE 4-29. AWS A5.13-70 CHEMICAL REQUIREMENTS FOR SURFACING WELDING RODS

AWS Classification	Carbon, percent	Manganese, percent	Cobalt, percent	Tungsten, percent	Nickel, percent	Chromium, percent	Molybdenum, percent	Iron, percent	Vanadium, percent	Copper, percent	Aluminum percent	Zinc, percent	Silicon, percent	Lead, percent	Tin, percent	Phosphorus, percent	Total Other Elements, percent[a]
RFe5-A	0.7 to 1.0	0.50	...	5.0 to 7.0	...	3.0 to 5.0	4.0 to 6.0	remainder	1.0 to 2.5	...	...	...	0.50	...	...	...	1.0
RFe5-B	0.5 to 0.9	0.50	...	1.0 to 2.5	...	3.0 to 5.0	5.0 to 9.5	remainder	0.8 to 1.3	...	...	...	0.50	...	...	...	1.0
RFeCr-A1	3.7 to 5.0	2.0 to 6.0	...	...	...	27.0 to 35.0	...	remainder	...	...	...	...	1.10 to 2.5	...	...	...	1.0
RCoCr-A	0.9 to 1.4	1.00	remainder	3.0 to 6.0	3.0	26.0 to 32.0	1.0	3.0	...	...	...	...	2.0	...	...	...	0.50
RCoCr-B	1.2 to 1.7	1.00	remainder	7.0 to 9.5	3.0	26.0 to 32.0	1.0	3.0	...	...	...	...	2.0	...	...	...	0.50
RCoCr-C	2.0 to 3.0	1.00	remainder	11.0 to 14.0	3.0	26.0 to 33.0	1.0	3.0	...	...	...	...	2.0	...	...	...	0.50
RCuZn-E	...	0.30	...	...	...	...	...	1.50	...	56.0 min	0.01[a]	remainder	0.04 to 0.25	0.05[a]	2.00 to 3.00	...	0.50
RCuSi-A[b]	...	1.5[c]	...	...	.	...	...	0.5	...	94.0 min	0.01[a]	1.5[c]	2.8 to 4.0	0.02[a]	1.5[c]		0.50
RCuAl-A2[b]	...	...	...	...	...	...	...	1.5	...	remainder	9.0 to 11.0	0.02	0.10	0.02	...	...	0.50
RCuAl-B[b]	...	...	...	...	...	...	...	3.0 to 4.25	...	remainder	11.0 to 12.0	0.02	0.10	0.02	...	...	0.50
RCuAl-C	...	...	...	...	...	...	...	3.0 to 5.0	...	remainder	12.0 to 13.0	0.02	0.04	0.02	...	...	0.50
RCuAl-D	...	...	...	...	...	...	...	3.0 to 5.0	...	remainder	13.0 to 14.0	0.02	0.04	0.02	...	...	0.50
RCuAl-E	...	...	...	...	...	...	...	3.0 to 5.0	...	remainder	14.0 to 15.0	0.02	0.04	0.02	...	...	0.50
RCuSn-A[b]	...		.	.		...	...	a	...	93.5 min	0.01[a]	a	a	0.02[a]	4.0 to 6.0	0.10 to 0.35	0.50
RCuSn-D	...	...	...	...	...	...	...	...	...	88.5 min	0.01[a]	...	...	0.05[a]	9.0 to 11.0	0.10 to 0.30	0.50
RCuSn-E	...	...	...	...	...	...	...	...	...	remainder	...	...	...	14.0 to 18.0	5.0 to 7.0	0.30 to 0.60	0.50
RNiCr-A	0.30 to 0.60	...	1.50	...	remainder	8.0 to 14.0	...	1.25 to 3.25	2.00 to 3.00 percent boron			...	1.25 to 3.25	...	...	...	0.50
RNiCr-B	0.40 to 0.80	...	1.25	...	remainder	10.0 to 16.0	...	3.00 to 5.00	2.00 to 4.00 percent boron			...	3.00 to 5.00	...	...	...	0.50
RNiCr-C	0.50 to 1.00	...	1.00	...	remainder	12.0 to 18.0	...	3.50 to 5.50	2.50 to 4.50 percent boron			...	3.50 to 5.50	...	...	...	0.50

Note 1 – Analysis shall be made for the elements for which specific values are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of the limits specified for "total other elements" in the last column in the table.

Note 2 – Single values shown are maximum percentages, except where otherwise specified.

a. Total other elements, including the elements marked with footnote[a], shall not exceed the value specified.
b. This AWS classification is intended to be identical with the same classification that appears in the latest edition of the Specification for Copper and Copper-Alloy Welding Rods, AWS Designation A5.7. (The chemical analysis shown is that which appears in the 1969 edition of AWS A5.7.)
c. One or more of these elements may be present within the limits specified.

TABLE 4.30. AWS A5.13-70 CHEMICAL REQUIREMENTS[a] FOR SURFACING ELECTRODES

AWS Classification	Carbon, percent	Manganese, percent	Cobalt, percent	Tungsten, percent	Nickel, percent	Chromium, percent	Molybdenum, percent	Iron, percent	Vanadium, percent	Copper, percent	Aluminum, percent	Zinc, percent	Silicon, percent	Lead, percent	Tin, percent	Phosphorus, percent	Total Other Elements, percent[b]
EFe5-A	0.7 to 1.0	0.50	...	5.0 to 7.0	...	3.0 to 5.0	4.0 to 6.0	remainder	1.0 to 2.5	...	...	...	0.70	...	...	...	1.0
EFe5-B	0.5 to 0.9	0.50	...	1.0 to 2.5	...	3.0 to 5.0	5.0 to 9.5	remainder	0.8 to 1.3	...	...	...	0.70	...	...	...	1.0
EFe5-C	0.3 to 0.5	0.50	...	1.0 to 2.5	...	3.0 to 5.0	5.0 to 9.0	remainder	0.5 to 1.2	...	...	...	0.70	...	...	.	1.0
EFeMn-A	0.5 to 0.9	11.0 to 16.0	...	...	2.75 to 6.0	0.50	...	remainder	...	...	...	...	1.3	...	...	0.03	1.0
EFeMn-B	0.5 to 0.9	11.0 to 16.0	...	..	...	0.50	0.6 to 1.4	remainder		.	...	...	0.3 to 1.3	...	...	0.03	1.0
EFeCr-A1	3.0 to 5.0	4.0 to 8.0	...	...	...	26.0 to 32.0	2.0	remainder	.	.	...	...	1.0 to 2.5	...	...	...	1.0
ECoCr-A	0.7 to 1.4	2.0	remainder	3.0 to 6.0	3.0	25.0 to 32.0	1.0	5.0	..	..	...	...	2.0	...	...	...	0.50
ECoCr-B	1.0 to 1.7	2.0	remainder	7.0 to 9.5	3.0	25.0 to 32.0	1.0	5.0	...	...	...	...	2.0	...	...	...	0.50
ECoCr-C	1.75 to 3.0	2.0	remainder	11.0 to 14.0	3.0	25.0 to 33.0	1.0	5.0	...	..	...	...	2.0	...	...	...	0.50
ECuSi[d,e]	...	1.5[f]	...	...	b	...	...	0.5	...	remainder	0.01[b]	b	2.8 to 4.0	0.02[b]	1.5[f]	b	0.50
ECuAl-A2[d,e]	...	...	...	...	...	...	...	1.5	...	remainder	9.0 to 11.0	0.02	0.10	0.02	...	...	0.50
ECuAl-B[d,e]	...	...	...	...	...	...	...	3.0 to 4.25	...	remainder	11.0 to 12.0	0.02	0.10	0.02	...	...	0.50
ECuAl-C[d]	...	...	...	...	...	...	...	3.0 to 5.0	...	remainder	12.0 to 13.0	0.02	0.04	0.02	...	...	0.50
ECuAl-D	...	...	...	...	...	...	...	3.0 to 5.0	...	remainder	13.0 to 14.0	0.02	0.04	0.02	...	..	0.50
ECuAl-E	...	...	...	...	...	...	...	3.0 to 5.0	...	remainder	14.0 to 15.0	0.02	0.04	0.02	...	...	0.50
ECuSn-A[d,e]	...	b	...	...	b	...	...	b	...	remainder	0.01[b]	b	b	0.02[b]	4.0 to 6.0	0.10 to 0.35	0.50
ECuSn-C[c]	...	b	...	...	b	...	...	b	...	remainder	0.01[b]	b	b	0.02[b]	7.0 to 9.0	0.05 to 0.35	0.50
ECuSn-E[c]	...	...	...	...	...	...	...	...	...	remainder	...	...	...	14.0 to 18.0	5.0 to 7.0	0.30 to 0.50	0.50
ENiCr-A	0.30 to 0.60	...	1.50	...	remainder	8.0 to 14.0	...	1.25 to 3.25	2.00 to 3.00 percent boron			...	1.25 to 3.25	...	...	...	0.50
ENiCr-B	0.40 to 0.80	...	1.25	...	remainder	10.0 to 16.0	...	3.00 to 5.00	2.00 to 4.00 percent boron			...	3.00 to 5.00	...	...	...	0.50
ENiCr-C	0.50 to 1.00	...	1.00	...	remainder	12.0 to 18.0	...	3.50 to 5.50	2.50 to 4.50 percent boron			...	3.50 to 5.50	...	...	...	0.50

Note 1 — Analysis shall be made for the elements for which specific values are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of the limits specified for "total other elements" in the last column in the table.

Note 2 — Single values shown are maximum percentages, except where otherwise specified.

a For bare electrodes the analysis given is for the as manufactured electrode, and for covered electrodes the analysis given is for deposited weld metal; except for copper alloy covered electrodes for which the analysis given is for the bare core wire.

b Total other elements, including the elements marked with footnote[b], shall not exceed the value specified.

c This electrode available only as straight length bare electrode.

d This electrode also available in bare coiled form for use with the gas metal-arc (consumable electrode) process.

e This AWS classification is intended to be identical with the same classification that appears in the latest edition of the Specification for Copper and Copper Alloy Welding Electrodes, AWS Designation A5.6. (The chemical analysis shown is that which appears in 1969 edition of AWS A5.6.)

f One or both of these elements may be present within the limits specified.

deposited weld metal must meet the tensile properties shown in Table 4-26.

Covered electrodes are available in sizes from 3/32-in. through 1/4-in. Bare electrodes for MIG welding are available in diameters from 0.035-in. to 3/16-in. in a variety of spool and coil sizes.

Copper and Copper-Alloy Welding Rods, AWS A5.7-69

This specification covers copper and copper-alloy welding rods for the oxyacetylene and gas tungsten-arc welding processes. Rods are classified on the basis of the chemical composition of the rod and the mechanical properties of the welded joint.

The chemical requirements are shown in Table 4-27. The tensile-strength requirements are shown in Table 4-28. Strength is determined by a transverse test of a welded butt joint.

Surfacing Welding Rods and Electrodes, AWS 5.13-70

This specification covers the requirements for bare and covered surfacing welding rods for use with oxyacetylene, gas tungsten-arc, carbon-arc, and atomic hydrogen welding processes. The section on electrodes deals with covered electrodes intended for surfacing with the shielded metal-arc welding process. Also, some bare metal-arc welding electrodes are included.

Weld-surfacing applications are extremely diversified, and, as a result, there are a great many different brand-name products available. This specification makes no attempt to classify all filler metals suitable for weld surfacing. Only those filler metals are covered that have gained some degree of industrial standardization and for which technical data are available.

Chemical requirements for welding rods are given in Table 4-29 and for electrodes in Table 4-30. Surfacing rods and bare electrodes are classified on the basis of the chemical composition of the as-manufactured product. Copper-base alloy covered electrodes are classified on the basis of the chemical composition of the core wire. All other covered electrodes are classified on the basis of the chemical composition of the deposited weld metal.

SHIELDING GASES

Shielding gases are consumables used with the MIG and TIG welding processes. The American Welding Society does not write specifications for gases. There are federal specifications, but the welding industry usually relies on "welding grade" to describe the required purity.

The primary purpose of a shielding gas is to protect the molten weld metal from contamination by the oxygen and nitrogen in air. The factors, in addition to cost, that affect the suitability of a gas include the influence of the gas on the arcing and metal-transfer characteristics during welding, weld penetration, width of fusion and surface shape, welding speed, and the tendency to undercut. Among the inert gases — helium, argon, neon, krypton, and xenon — the only ones plentiful enough for practical use in welding are helium and argon. These gases provide satisfactory shielding for the more reactive metals, such as aluminum, magnesium, beryllium, columbium, tantalum, titanium, and zirconium.

Although pure inert gases protect metal at any temperature from reaction with constituents of the air, they are not suitable for all welding applications. Controlled quantities of reactive gases mixed with inert gases improve the arc action and metal-transfer characteristics when welding the steels, but such mixtures are not used for the reactive metals.

Oxygen, nitrogen, and carbon dioxide are reactive gases. With the exception of carbon dioxide, these gases are not generally used alone for arc shielding. Carbon dioxide can be used alone or mixed with an inert gas for welding many carbon and low-alloy steels. Oxygen is used in small quantities with one of the inert gases — usually argon. Nitrogen is occasionally used alone, but is usually mixed with argon, as a shielding gas to weld copper. The most extensive use of nitrogen is in Europe, where helium is relatively unavailable.

Argon and Helium as Shielding Gases

As noted, the inert natures of argon and helium are not the only characteristic that makes them suitable for gas shielding. Other characteristics are important and are deciding factors in the choice of gas for TIG or MIG welding with specific materials.

For a given arc length and current, arc voltage with helium is higher than with argon. Because more heat is produced with helium than with argon, helium is more effective for welding thick materials, particularly high-conductivity metals such as copper and aluminum alloys. Argon is more suitable for welding thin materials and those with lower heat conductivity, especially in welding positions other than flat.

The heavier a gas, the more effective it is for arc shielding. Helium is very light; argon is about 10 times heavier than helium and about 30% heavier than air. When argon is discharged from the welding nozzle it forms a protective blanket over the weld area, while helium rises and disperses rapidly. For this reason, higher flow rates are generally required with helium (or with mixtures high in helium) than with argon shielding.

Shape of a weld bead and penetration pattern are determined, to a large extent, by metal-transfer characteristics which, in turn, are affected by the shielding gas used.

Metal is generally deposited either by spray transfer or by globular transfer. Spray transfer (usually the more desirable) produces relatively deep penetration at the center of the bead and shallow penetration at the edges; globular transfer produces a broader and shallower penetration pattern throughout the bead.

Argon generally promotes more spray transfer than helium and at lower current levels. But even with argon shielding, spray transfer cannot always be achieved at usable current levels — one of the problems in welding ferrous metals by the gas metal-arc process.

The physics of metal transfer across an arc is not completely understood. In an argon atmosphere with DCRP, the size of the metal droplet crossing the arc decreases as the current increases. At a critical level of current the mode of transfer changes abruptly. The tip of the electrode becomes pointed, metal transfers from the electrode to the work in a fine spray, the arc becomes very stable, and there is little or no spatter. Figure 4-2 illustrates the appearance of electrode tips in various shielding gases. A degree of spray transfer is possible with 20% argon and 80% helium. Here the argon has predominating effect because of its higher density.

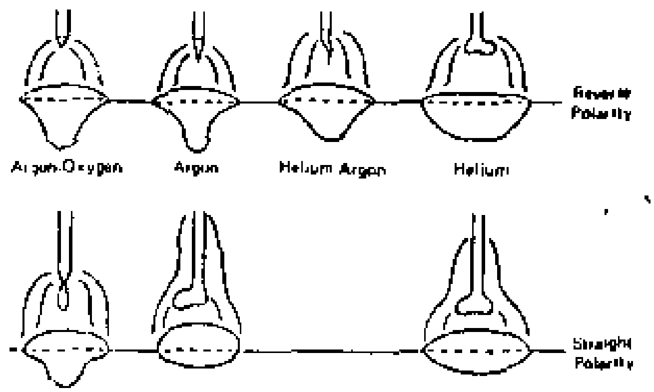


Fig. 4-2. Electrode tip shape, bead contour, and penetration patterns for various shielding gases

Inert Gases with Reactive Gas Additions

Improved metal transfer, a more stable arc, and less spatter result from the addition of oxygen or carbon dioxide to an inert shielding gas. These additions when welding carbon and low-alloy steels also promote wetting and flow of weld metal, thus reducing or eliminating undercut. Effects on penetration and bead shape of oxygen additions are illustrated in Fig. 4-2.

Noticeable change in arc action and metal-transfer characteristics in gas metal-arc welding result from addition of as little as 0.5% oxygen or carbon dioxide to argon. However, 1 to 5% oxygen is generally added. Oxygen or carbon dioxide is seldom added to helium or argon-helium mixtures.

Addition of 5% oxygen or 10 to 25% carbon dioxide to argon produces a significant pinch effect with a DC, straight-polarity arc. The filler wire tapers, the metal transfers in the form of a fast-moving stream of droplets, and the penetration pattern approaches that of reverse polarity. At the same time, melt-off rate is reduced considerably. With pure argon, melt-off rate with straight polarity is almost double that with reverse polarity. However, most MIG welding with an inert gas or carb dioxide is done with DCRP (see Tables 4-14 a.. 4-16). Mixtures of 5% oxygen or 25% carbon dioxide with argon are commercially available.

Because of oxidizing effects, addition of oxygen or carbon dioxide to argon may cause porosity in some ferrous metals, as well as loss of such alloying elements as chromium, vanadium, aluminum, titanium, manganese, and silicon. Consequently, filler wires used with oxygen-containing shielding gas require additions of deoxidizers to counteract the effects of the oxygen.

Porosity in aluminum welds can be decreased by adding a small percentage of chlorine to argon or helium. For maximum effectiveness, the chlorine should be introduced separately through the welding torch. Chlorine's disadvantages of being poisonous and corrosive discourage its widespread use. When it is used, extreme caution and all applicable safety rules should be observed.

Carbon Dioxide as a Shielding Gas

Carbon dioxide may be used as a shielding gas for the MIG welding of carbon and low alloy steels, but since it is a reactive gas the electrodes used must contain sufficient deoxidizers to counteract th effects of oxygen. Recently, stainless steel electrodes with high silicon have been developed for use with argon-25% carbon dioxide mixtures.

The low cost of carbon dioxide makes its use as a shielding gas very attractive. With the development of better electrodes, sound weld deposits with good mechanical properties can be made.

Two types of metal transfer occur with carbon dioxide shielding gas — globular and short-circuiting. The spray transfer experienced with argon or argon-oxygen mixture does not occur. Globular transfer produces a harsh arc with excessive spatter. By control of welding conditions, the short-circuiting type of metal transfer is promoted.

To promote the short-circuiting type of transfer when welding carbon and low-alloy steels, argon is often used as the dominant gas in a mixture, with the carbon dioxide content cut to 20 to 30%. Other mixtures with higher percentages of carbon dioxide also give short-circuiting transfer, with its advantages of low penetration, all-position capability, and the ability to handle poor fitup on light-gage material without burnthrough.

In the short-circuiting type of transfer, a globule of molten metal collects on the end of the electrode. The electrode is being fed toward the work and, before the globule detaches from the end of the electrode, it contacts the molten crater and forms a short circuit. The high current due to the short circuit blasts the globule from the electrode into the crater. An arc then forms in the gap between the crater and the tip of the electrode, which starts another globule forming on the tip of the electrode. This cycle of metal transfer is repeated about 20 to 200 times per second.

Shielding Gases for TIG Welding

Either argon, helium, or a mixture of the two is commonly used in gas tungsten-arc welding. Argon provides the advantage of easier arc starting, smoother arc action, better cleaning action for the AC welding of aluminum and magnesium, and superior resistance to draft. In addition, argon costs less than helium and requires a lower arc voltage for comparable currents and arc lengths.

In the manual welding of thin material, argon is recommended because its lower arc-voltage charac-

TABLE 4-31. SHIELDING GASES AND GAS MIXTURES FOR GAS METAL-ARC WELDING

Shielding Gas	Chemical Behavior	Uses, Remarks
Argon	Inert	For welding most metals, except steel
Helium	Inert	Al and Cu alloys, for greater heat and to minimize porosity
A and He (20-80 to 50-50%)	Inert	Al and Cu alloys, for greater heat input and to minimize porosity. Quieter, more stable arc than with He alone.
A and Cl (trace Cl)	Essentially inert	Al alloys, to minimize porosity
N_2	Reducing	On Cu, permits very powerful arc; used mostly in Europe.
A + 25-30% N_2	Reducing	On Cu, powerful but smoother operating, more readily controlled arc than N_2 alone; used mostly in Europe.
A + 1-2% O_2	Oxidizing	Stainless and alloy steels, also for some deoxidized copper alloys
A + 3-5% O_2	Oxidizing	Plain carbon, alloy, and stainless steels; requires deoxidized electrode
A + 20-30% CO_2	Oxidizing	Various steels, used principally with short-circuiting arc
A + 5% O_2 + 15% CO_2	Oxidizing	Various steels, requires deoxidized wire; used chiefly in Europe
CO_2	Oxidizing	Plain-carbon and low-alloy steels; deoxidized electrode is essential

teristic reduces the tendency for burnthrough. In vertical or overhead welding, this same characteristic reduces the tendency for the metal to sag and run.

Helium's higher arc-voltage characteristic is desirable when welding thick material or metals with high heat conductivity and for the high-speed mechanized welding of stainless-steel tubing. Mixtures of argon and helium are used to balance the arc characteristics.

Mixtures of argon or helium with hydrogen provide higher arc voltage and heat in the welding region than helium alone. This reactive gas, however, can damage many metals and alloys, including aluminum, copper, and magnesium-base materials. Mixtures of inert gas with hydrogen can be used in welding only a few materials, such as certain stainless steels and nickel alloys.

The rate at which some metals are joined by gas tungsten-arc welding and the quality of the resulting welds are significantly affected by gas purity. The reactive metals particularly can be degraded by gas impurities of a few hundredths of one percent. Copper, carbon steel, and stainless steels can tolerate much higher levels of impurities with no adverse affects.

Purity of commercially available argon and helium averages over 99.95%, and in some cases exceeds 99.995%. Impurities in shielding gases usually consist of water vapor, oil, oxygen, or nitrogen — usually from sources other than the original gas supply. Water vapor or atmospheric gases can diffuse through the hose lines, or contaminants can be drawn in at leaks in the lines. Tubing that is not susceptible to gas diffusion should be used to supply shielding gas for welding of materials that are sensitive to impurities.

Shielding Gases for MIG Welding

The most commonly used gases for gas metal-arc welding are given in Table 4-31.

Initially, only argon, helium, or a mixture of these inert gases were used for gas metal-arc welding. Other gases were not considered, because the primary use of the gas metal-arc process was for welding the more reactive metals, such as aluminum and magnesium, which require an inert gas shield. Today, however, the process is used for welding many metals that do not require inert-gas shielding.

Carbon dioxide shielding is widely used for MIG welding of carbon and low-alloy steels in conjunction with deoxidized electrode. Its advantage over the inert gases is its lower cost.

Power Sources

All arc-welding processes require a continuous supply of electrical current in sufficient amount (amperage) and of proper voltage to maintain an arc. This current may be either alternating (AC) or direct (DC), but it must be supplied to the welding electrode through a device that enables its precise control. Only when the welding current is carefully controlled can the desired welding arc characteristics — and thus maximum welding efficiency — be obtained. The controlling device is called a power source or welder. Current may be supplied to it from utility power lines, or developed within it by generators or alternators driven by close-coupled gasoline or diesel engines.

Various types of power sources provide a range of voltage across the welding arc from 17 — the minimum voltage for starting an arc — to approximately 45 volts. The currents supplied through the power source may range from less than 10 amp to 1500 amp or more, the higher currents for automatic welding.

For efficient welding, the power source must permit control of the arc characteristics needed for a specific job. In one job, a forceful, deeply penetrating arc may be required, while, in another, a soft, less-penetrating arc may be necessary to avoid burnthrough. Electrodes are designed for various welding positions and they help compensate for power sources that have no arc characteristic adjustment. The welding process also dictates the type of power source needed. Table 4-32 shows the power source requirements for various processes.

TABLE 4-32. Power Requirements for Arc-Welding Processes

Process	Output Characteristic	Type of Current	Polarity
Shielded metal-arc, gas tungsten-arc, submerged arc	Variable-voltage*	AC or DC	DCSP, DCRP, or AC
Flux-cored	Constant-voltage	DC	DCSP, DCRP
Gas metal-arc	Constant-voltage	DC	DCRP

*In some applications, the submerged-arc process can use constant-voltage DC.

CLASSIFICATION OF POWER SOURCES

Power sources are classified according to the type of current — AC or DC — and according to their voltage output, which may be either variable or constant. A further classification designates the method by which energy is supplied to the power source — from a power line directly or through an electric motor, or from a gasoline or diesel engine.

Whatever the type of power source, its main function is to supply the type of current needed for welding. Alternating current direct from the power line goes through a transformer in AC welders that allows control of the current. Thus, a simple AC welder is fed 230-volt single-phase current the same as a kitchen stove, and a selector switch enables the operator to use what AC current he needs for the job — say, a 225-amp output for 3/16-in. electrodes or 180-amp for 5/32-in. electrodes. A DC welder also gives similar control of the current. Direct current is produced from AC line power by either using the line power to run an electric motor that turns a DC generator (an electric motor-generator set) or running the line power through a transformer and then a rectifier (a rectifier set). Direct current may also be produced by driving a DC generator with any type of fuel-burning engine, such as a gasoline or diesel engine (engine-driven-generator set). A fuel-burning engine may also be used to produce AC current for welding by using it to drive an alternator instead of a generator. Combination welders, producing both AC and DC, are basically transformer-rectifier sets.

Arc Welding machines of all types are rated according to their current output at a rated voltage and duty cycle. This rating is generally set by manufacturers in accordance with standards established by the National Electrical Manufacturers Association (NEMA). These standards are established on a conservative bases, requiring a rating well below the maximum overload capacity of the machine so that it will provide safe operation efficiently over a long period of time.

Ratings are given with a percentage "duty cycle." The duty cycle of a welder is the percentage of a ten-minute period that a welder can operate at a given output current setting. For example, if a welder is rated 300 amp at a 60% duty cycle, it means that the machine can be operated safely at 300-amp welding current for 6 out of every 10 minutes. If this duty cycle is reduced in actual operation, the maximum permissible current is increased. Thus, at 35% duty cycle, this same 300-amp machine could be operated at 375 amp.

As noted previously, welders are classified as "variable voltage" (also called constant-current) or "constant voltage." A variable-voltage machine is one that delivers a current that changes only slightly with changes in voltage. A constant-voltage machine is one that delivers current with the voltage rising or dropping only slightly with changes in current output.

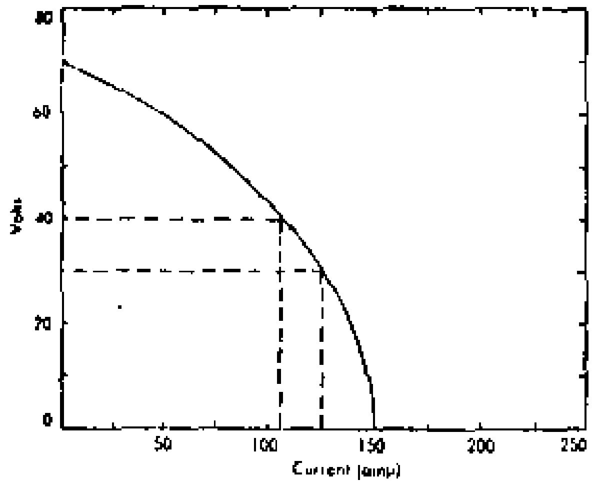


Fig. 4-3. Typical output curve for a variable-voltage power source, adjusted for minimum current variation.

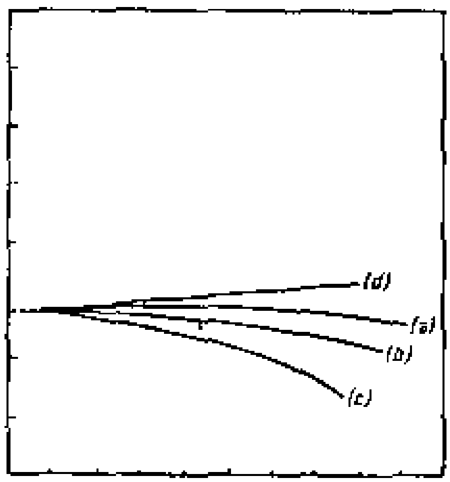


Fig. 4-4. Typical output curves for a constant voltage power source

Figure 4-3 shows a typical output curve for a variable-voltage welder. This type of output is used for submerged-arc, gas tungsten-arc, and shielded metal-arc applications. Figure 4-4 shows typical output characteristics of a constant-voltage welder. Here, the voltage in the constant-voltage curve (a) rises slightly at the low currents and drops at the high currents. Most constant-voltage welders are designed with a small downward slope, as in curve (b), and have adjustments to increase the downward slope, as in curve (c). Some welders have a rising slope, as in (d), but this type of output is becoming less common.

AC WELDERS

Transformer Welders: The transformer welder is a voltage step-down transformer that changes high-voltage, low-amperage AC input current to low-voltage, high-amperage AC welding current. Transformer welders usually operate on single-phase power. Most AC power produced in the United States is 60-hertz, and each time the polarity changes the voltage goes through zero, which tends to create an unstable condition in the arc. This problem, however, has been solved by designi better transient characteristics in the welder an better AC electrodes.

Transformer welders have controls to stabilize and adjust the welding current. A system for controlling the output current is provided either through a series of taps into the secondary windings or by a movable or saturable reactor in the output circuit. The taps provide step control. A reactor provides a continuous stepless control. Various types of starters are used and some are equipped with low-voltage contactors to reduce open-circuit

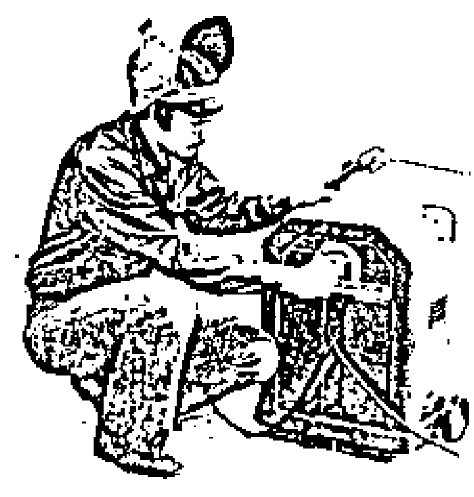


Fig. 4-5. A typical small AC transformer welder for light-duty and limited-service welding

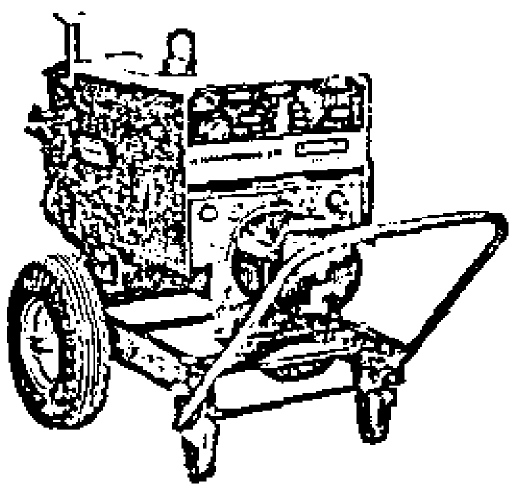


Fig.4-6. A typical engine-driven power source that supplies AC current for welding or power for lights and tools.

voltage when the machine is not operating. Some machines have an "arc booster" that gives an extra surge of current for a few seconds at the start of the arc in order to get deeper penetration at the beginning of the weld. Most welding transformers can be equipped with condensers to improve power factor and reduce the amount of input current used.

For the inert-gas shielded arc welding processes, transformer welders are equipped with necessary auxiliary controls. A device is required with TIG welding to help establish and maintain the arc.

Small, inexpensive transformer welders are widely used in light industry, maintenance work, and by farmers. Figure 4-5 illustrates a typical small (225-amp) AC welder. Rotating the switch at the center of the machine changes taps on the secondary coil, which, in turn, changes the welding current.

Small welders (180-amp or less) are available to meet Rural Electrification Administration input requirements.

Transformer welders rated at 600 amp or more are used primarily for automatic welding. Available with these machines are optional accessories required for automatic welding, such as line contactors, remote current control, and DC for control power. With single submerged-arc welding, single-phase power is used. When two AC arcs are used, the welders are connected to a three phase power system to equalize the load. Three transformers can be used with the primaries connected to the three phase line and the secondaries connected closed delta. Each transformer must have a separate reactor to adjust the welding current and the phase angle between the arc currents. The Scott connection can also be used. Two transformers with a center tap connection on one primary are connected to a three phase power line. The unique connections between the two transformers establishes the proper phase relation between the arcs. With two electrodes, it is necessary to have approximately 90°-out-of-phase operation to prevent interactions between the electrodes that would produce severe arc blow. Reactors are used to adjust the welding current. Details of the connection can be supplied by the equipment manufacturer.

TABLE 4-33. Typical Ratings and Outputs for AC Variable-Voltage Welders

NEMA Rating			Output Current Range (amp)
Rated Current (amp)	Arc Voltage	Duty Cycle (%)	
180	25	20	30-180
225	25	20	40-225
250	30	30	30-300
300	32	60	30-450
400	36	60	40-600
500	40	60	50-750
600	44	60	50-850
1000	44	60	200-1250

Note: Input power is single phase.

TABLE 4-34. Typical Ratings and Outputs for Alternator Welders and Auxiliary Power Sources

NEMA Rating			Output		Engine	
Rated Current (amp)	Arc Voltage	Duty Cycle (%)	Current (amp)	Type	Number of Cylinders	HP and Speed (rpm)
130 AC	25	30* 100†	60-130* 3500 †	Variable-voltage	1	10.0 3600
225 AC	25	50* 100†	20-225* 5000 †	Variable-voltage	2	14.2 2200

* Welding output   † Watts output when used as auxiliary power source.

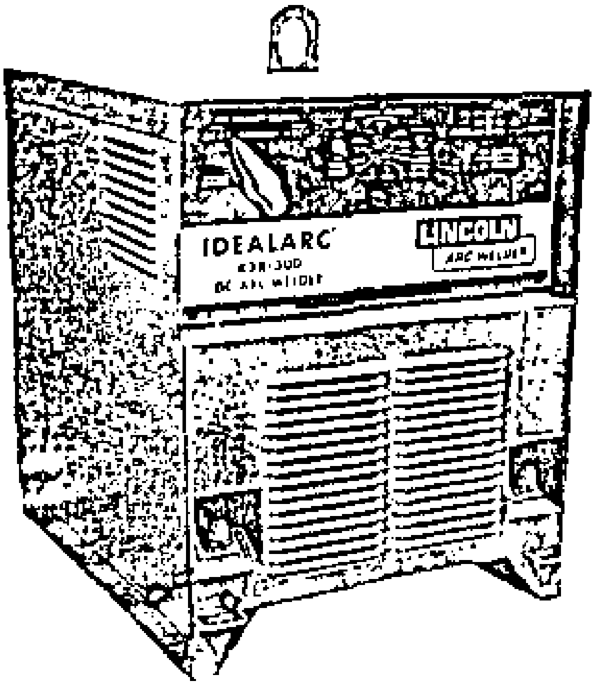


Fig. 4-7. A typical industrial type AC three phase input, DC output variable voltage welder. The heavy duty welders are available in a wide range of sizes, see Table 4-36

Table 4-33 shows typical AC welder ratings and output currents. A disadvantage of many transformer welders is that the output current changes with a change in line voltage. In most shops this is not a serious problem, but if the power-line voltage regulation is poor, the welding may not be satisfactory.

Alternators: AC welding current can also be obtained from an engine-driven alternator. A gasoline engine is usually used, and the engine-alternator set serves both as a portable welder and as an auxiliary power supply. Power output — 115 to 230 volts AC — can be used for lights, small tools, or as a standby energy source. A typical machine is illustrated in Fig. 4-6. Table 4-34 shows typical alternator ratings and output currents.

DC AND AC-DC WELDERS

Transformer-Rectifier Welders: Rectifiers for converting AC current to DC have been developed to a stage of efficiency and reliability. A result of this development has been the combination of a rectifier with a transformer to form a DC welder. Various semiconducting materials have been used in current rectifiers, but, at the time of publication, the silicon rectifier has replaced most other types in welding machines.

In principle, the single-phase rectifier welder is a transformer welder with a rectifier added to obtain a DC output. Adjustment of the welding current is through the AC section, as described for transformer welders. The output characteristic can be either constant or variable voltage. Welders built especially for gas metal-arc welding have adjustments for changing both the slope of the output curve and the reactance in the circuit for better performance when welding with short-circuiting transfer.

Transformer-rectifier welders are often designed with provisions for both AC and DC welding. These power sources, called combination welders, are especially convenient for structural work where the vertical welding is done by DC with E7018 electrodes, and flat welding is done by AC with E7028 electrodes. Combination welders are also convenient for gas tungsten-arc welding; AC is available for welding aluminum, and DC is available for welding stainless and carbon steel. Table 4-35 shows typical ratings and outputs for combination AC-DC transformer-rectifier welders.

Another type of transformer-rectifier welder is the step-down transformer, in which three-phase AC

TABLE 4-35. Typical Ratings and Outputs for Transformer-Rectifier Welders with Both AC and DC Variable-Voltage Outputs

NEMA Rating			Output Current	
Current (amp)	Voltage	Duty Cycle (%)	AC (amp)	DC (amp)
250	30	30	30-300	30-250
300	32	60	30-450	45-375
400	36	60	40-600	60-500
500	40	60	50-750	75-625
600	44	60	50-850	75-750

TABLE 4-36. Typical Ratings and Outputs for Three-Phase Transformer-Rectifier Welders

NEMA Rating			Output Current	
Current (amp)	Voltage	Duty Cycle (%)	DC Current (amp)	Type
300	32	60	45- 375	Variable-voltage
300	32	100	50- 375	Constant-voltage
400	36	60	60- 500	Variable-voltage
400	36	80	50- 500	Constant-voltage
500	40	60	75- 650	Variable-voltage
600	44	100	70- 750	Constant-voltage
600	44	60	75- 750	Variable-voltage
800	44	100	100-1000	Constant-voltage

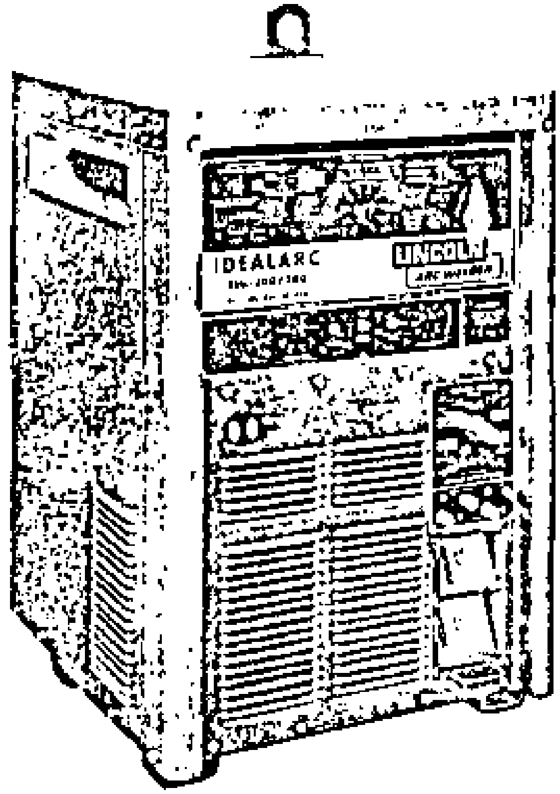


Fig. 4-8. An AC-DC transformer-rectifier welder designed for gas tungsten-arc welding.

is fed to rectifier units which, in turn, feed DC to a single output circuit. The output can be either variable or constant voltage, but only DC is available since the AC is three-phase and cannot be used for welding. Table 4-36 shows typical ratings and outputs for three-phase transformer-rectifier welders. See Fig. 4-7.

Making optimum use of some welding processes may require that accessory equipment be added to the power source. This is especially true if the process is automated. A good example is the AC-DC transformer-rectifier welder built for the gas tungsten-arc process, sometimes called a TIG welder. A typical machine is shown in Fig. 4-8.

This welder can be used for any process using AC or DC variable voltage, but the accessories are designed primarily for gas tungsten-arc. A high-frequency voltage is superimposed on the output voltage so that the arc is established without touching the electrode to the work. The high frequency also stabilizes the arc by igniting the 60-cycle current each time it goes through zero. The intensity of the high-frequency voltage can be adjusted. The welding current is adjusted electrically by a small rheostat, and a provision is made to connect a remote current control, which can be used to compensate for poor fitup or for crater filling in critical welds. The current can be adjusted to a very low value — some welding is done at less than 10 amp. Solenoid valves start and stop the flow of cooling water and gas. The gas valve has an electronic delay so that gas continues to flow after the arc is extinguished — to protect the crater and electrode from oxidation.

The transformer-rectifier welder has the same disadvantage as the transformer welder. A change in voltage on the transformer primary changes the welding current. The transformer-rectifier shown in Fig. 4-8 has line voltage compensation to eliminate the problem.

DC Generators: In the direct-current generator, an armature rotates in an electrical field. Current is generated in the armature and is taken off for use through a commutator. The armature is rotated either by an electric motor or an internal-combustion engine. The speed of rotation of the armature and the electrical design of the generator change the output characteristics. The arc characteristics of a generator can be precisely controlled. This fact lends DC welding more versatility than AC welding. Polarity of the electrode can be changed with a flip of a switch.

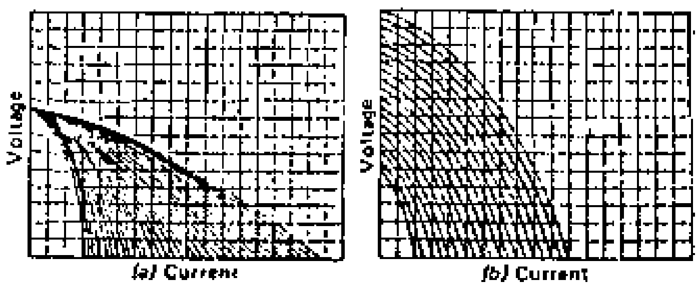


Fig. 4-9. Output for a DC generator welder having adjustments in both the series and shunt fields. Output curves produced by adjusting the series field are shown in (a), curves produced by adjusting the shunt field are shown in (b).

The DC motor-generator welder is driven by AC utility power. It can provide either variable or constant voltage, or a single unit may provide both types of output. The motor is usually a three-phase induction motor.

The variable-voltage type is a compound generator with a series field that causes the voltage to decrease as the current is increased. Two adjustments can be made to change the welding current:

1. For a given voltage, the output current can be changed by adjusting the series field. This

2. For a given current control setting, the output can be changed by adjusting the shunt field. This produces an output change as shown in Fig. 4-9(b).

produces an output change as shown in Fig. 4-9(a), and is sometimes called the "current" control.

Combining both adjustments can produce output characteristics similar to those shown in Fig. 4-3 or 4-11. A typical motor-generator welder is shown in Fig. 4-10.

DC-generator power sources, in general, have an adjustment that can provide an output of the type shown in Fig. 4-11. This output is highly suitable for vertical and overhead welding, where the operator uses a whipping motion that alternately raises and lowers the arc voltage. With the flatter characteristic shown in Fig. 4-11, there is greater change in current for a given change in voltage than with the output in Fig. 4-3. Since deposition varies with current, the weldor can vary deposition and thereby exercise more control of the molten puddle with the flatter output characteristic.

The constant-voltage motor-generator welder is a compound generator with a series field designed to keep the voltage nearly constant within the current capacity of the machine, as in Fig. 4-4(a). The slope of the output curve can be changed by an adjustment in the series field, as in curves (b) and (c). In some welders, an output shown by curve (d) can be obtained. These welders are always used with automatic or semiautomatic wire-feeding equipment, and the current is changed by changing the speed of the wire feed. The arc voltage is changed by adjusting the shunt field in the generator.

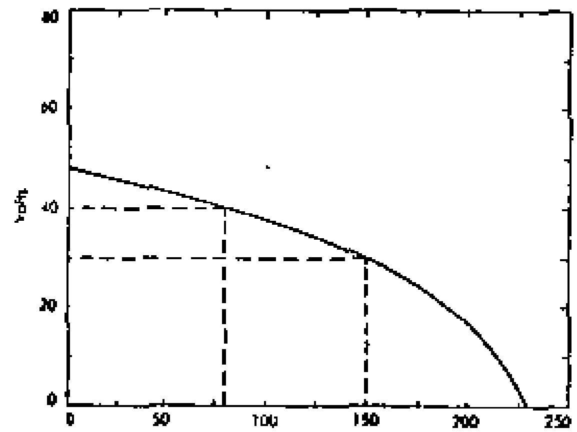


Fig. 4-11. Typical output curve preferred for vertical and overhead shielded metal arc welding

Motor-generator welders that provide both variable-voltage and constant-voltage are gaining wider application, because they can meet a wide range of process requirements. Variable voltage is used to manually tack weld an assembly, and the welding is then completed with an automatic or semiautomatic process using constant voltage. Table 4-37 shows typical ratings and outputs for these motor-generator welders.

Every type of DC welder driven by an electric motor can be duplicated with a gasoline or diesel-engine drive. On heavy-duty machines of 200 amp and larger, the engines are liquid cooled. Gas engines are equipped with governors to maintain constant engine speed and with idling devices to reduce the engine speed when welding is not being done. Machines with air-cooled engines are available for light-duty work.

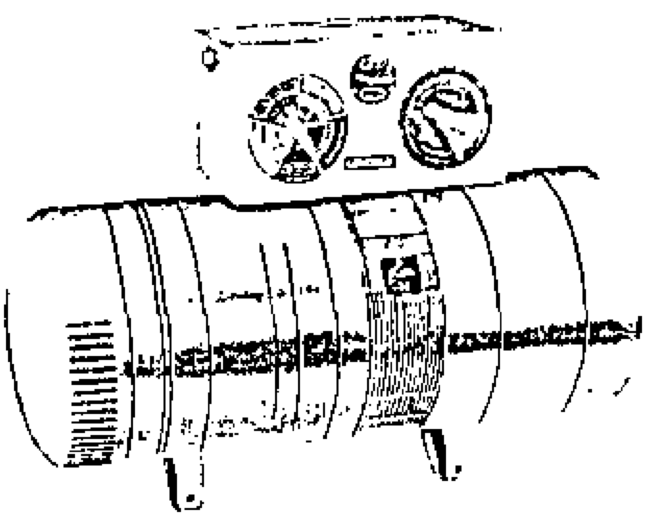


Fig. 4-10. A typical motor generator welder.

TABLE 4-37. Typical Ratings and Outputs for Motor-Generator DC Welders

Rating			Output	
Current (amp)	Voltage	Duty Cycle (%)	Variable-Voltage (amp)	Constant-Voltage (amp)
200	28	60	30-300	...
250	30	30	40-250	...
300	32	60	45-450	...
300	32	60	60-375	60-375
400	36	60	60-600	...
400	36	60	60-600	60-600
600	44	80	...	875 max
800	44	80	100-900	1000 max
1000	44	60	...	1250 max

Diesel engines cost more than gasoline engines, but the diesel has several advantages. Diesel fuel costs less than gasoline, is less hazardous to handle, and is consumed less rapidly. Less maintenance is required with diesels, and engine life is longer.

Multiple-Output Power Source: A multiple-output power source is a single welding machine capable of providing welding current to several operators simultaneously. The use of such machines is limited to manual welding where several operators are working in a relatively small area. Many factors limit the economic use of these units; when an application appears feasible, the equipment manufacturers should be consulted.

POINTERS ON SELECTING A POWER SOURCE

In selecting a power source, two important considerations are its output capacity and its suitability for the particular job.

The size or rated output of a machine required for a given job depends on the thickness of the metal to be welded and the amount of welding to be done. If a conservatively rated machine, made by a reputable manufacturer, is purchased, the selection can be made with confidence on that rating. There is no need to buy more capacity than will be required by the job, Be sure, however, to check the duty cycle. Machines with a low duty cycle should be used only for maintenance or intermittent welding. Continued operation of a machine beyond its rated capacity will shorten its service life. Of course, properly made and rated machines have large overload capacity, which means that higher than rated amperages can be used for shorter periods than the rated duty cycle allows.

In selecting the type of welder, an essential consideration is the energy source available. Motor-generator sets are generally available for only three-phase utility AC power, but can be ordered to different cycles and voltages. They are also available for DC power. AC machines are generally available for only single-phase power in various cycles, with or without power factor correction in the machine. Fortunately, in most manufacturing, the source of power does not present a limiting factor on the selection of a welder. The decision can be made on the basis of which is the most efficient and economical machine for a given job.

Where utility power service is through a 3KVA transformer on residential or rural lines, an industrial-type AC welder cannot be used. Here, it is necessary to use a limited-input transformer welder, which is designed so that no more than a specified maximum amount of input current (37.5 amp) can be drawn.

The most important factor to be considered in selecting a power source is performance — what type machine will do the job easiest and enable better welding to be done at lower costs.

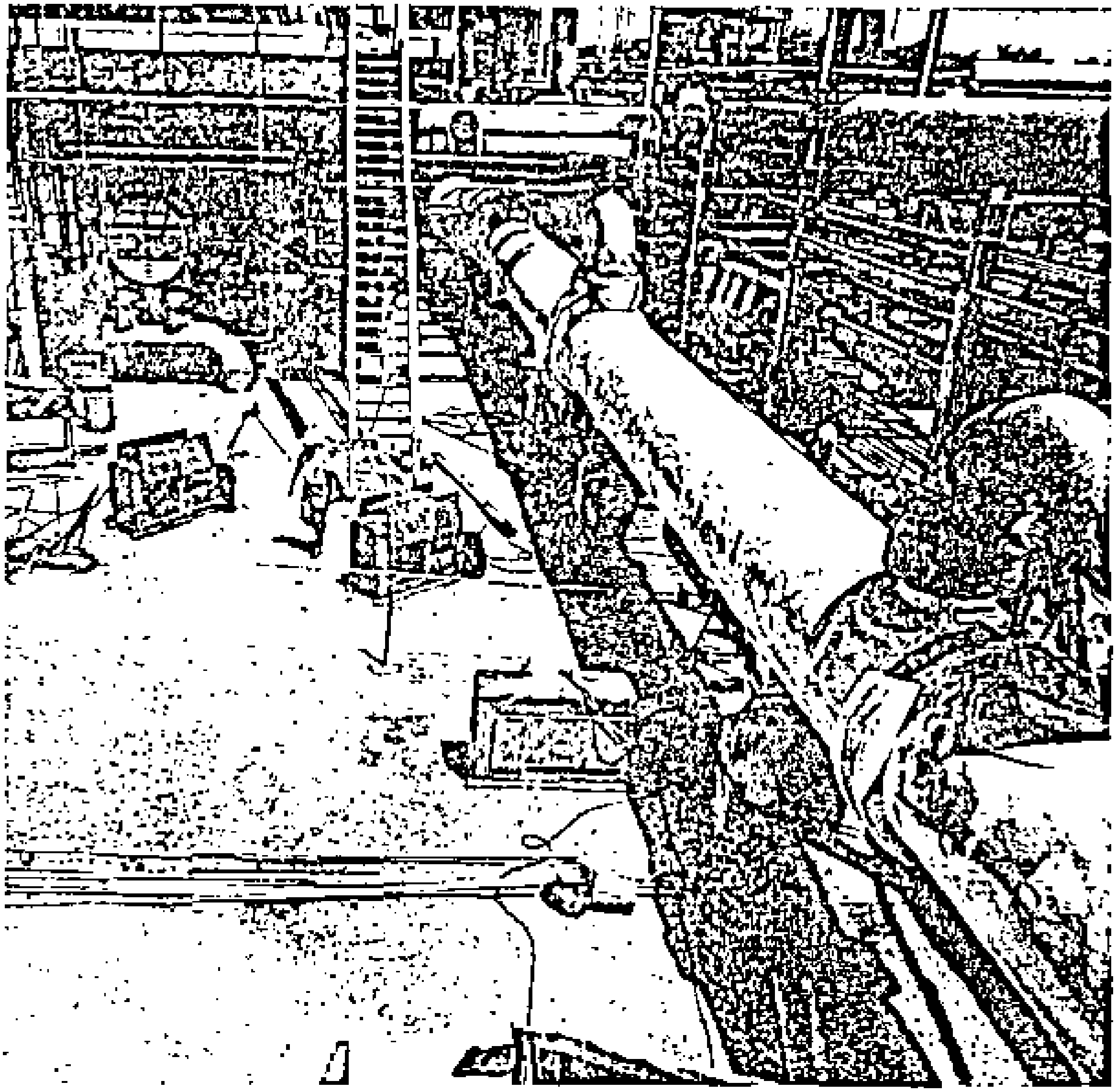
There is one best way for every welding job. Sometimes it is AC; sometimes it is DC. For one job, sensitive control may be required for maximum efficiency. For another, certain types of controls may be unnecessary. A welder should be selected, therefore, according to the job to be done.

The following may be used as a guide to select the proper power source based on the type of current.

- DC only
  - Gas metal-arc welding
  - Flux-cored arc-welding
  - Exx10 type electrodes
  - Exx15 type electrodes
- DC preferred
  - Fast freeze applications
  - Fast follow applications
  - Welding stainless steel
  - Nonferrous electrodes
  - Surfacing with high alloy electrodes
- AC preferred
  - Fast fill applications
  - Iron powder electrodes except out of position welding
  - Where arc blow is a problem
- AC or DC depending on the application
  - Gas tungsten-arc welding
  - Submerged-arc welding.

The small transformer-welder shown in Fig. 4-6 is widely used on farms, in garages and small machine shops, and by hobbyists. Obviously AC is not always the best type of welding current for such a wide variety of applications. However, the special electrodes and accessories developed for this type of welder make it very versatile even though limited to AC welding current. In this case, the selection of the power source is based on low cost, low power input requirements, and versatility rather than AC or DC.

If a job is entirely downhand in heavy plate, an AC machine will be most efficient. If the job is exclusively sheet metal welding, a DC machine will be most efficient. If the work is a combination of jobs, involving out-of-position welding, as well as straight downhand work, a combination AC-DC machine is the logical choice. These machines can be adapted to individual job requirements, combining larger AC capacity with smaller DC capacity, or in any way that is required. For most manufacturing situations, both AC and DC are needed for maximum efficiency. The combination machine, therefore, is most efficient for general purpose welding. It gives the weldor the opportunity to select for himself the type of arc and current he can use most efficiently for the job at hand.



Typical example of welded high pressure pipe in a gas processing plant. Note the engine driven welding machines

Weldability of Carbon and Low-Alloy Steels

Carbon and low-alloy steels are the work-horse materials for construction and transportation equipment and for industrial and consumer products of many types. They comprise over 90% of total steel production, and more carbon steel is used in product manufacture than all other metals combined.

Sections 6.1 through 6.7 discuss the weldability of these important materials and the various welding processes that are used for joining them. Selection and operational considerations for each process include details on electrodes, filler wires, welding techniques and procedures, process variables, qualification requirements, welding equipment, fixtures, and other necessary information for designers, welding engineers, and weldors.

Most steels can be welded, but satisfactory joints cannot be produced in all grades with equal ease. A metal is considered to have good weldability if it can be welded without excessive difficulty or the need for special and costly procedures and the weld joints are equal in all necessary respects to a similar piece of solid metal. Weldability varies with the grade, chemistry, and mechanical properties of the steel, and, when weld joining is to be a major factor in the attachment of steel parts, weldability should be given proper attention in specifying and ordering materials for the job.

STEEL SPECIFICATION

Several methods are used to identify and specify steels. These are based on chemistry, on mechanical properties, on an ability to meet a standard specification or industry-accepted practice, or on an ability to be fabricated into a certain type of product.

Specifying by Chemistry

A desired composition can be produced in one of three ways: to a maximum limit, to a minimum limit, or to an acceptable range.

For economical, high-speed welding of carbon-steel plate, the composition of the steel should be within the "preferred-analysis" ranges indicated in Table 6-1. If one or more elements varies from the

TABLE 6-1. Preferred Analyses for Steels To Be Arc-Welded

Element	Composition (%)	
	Preferred	High*
Carbon	0.06 to 0.25	0.35
Manganese	0.35 to 0.80	1.40
Silicon	0.10 or less	0.30
Sulfur	0.035 or less	0.05
Phosphorus	0.030 or less	0.04

* Additional care is required in welding of steels containing these amounts of the elements listed.

ranges shown, cost-increasing methods are usually required to produce good welding results. Thus, steels within these ranges should be used whenever extensive welding is to be done unless their properties do not meet service requirements. Published welding procedures generally apply to normal welding conditions and to the more common preferred-analysis mild steels. Low-hydrogen electrodes and processes will generally tolerate a wider range of the elements than shown in Table 6.1.

If the chemical specification of a steel falls outside of the preferred-analysis range, it is usually not necessary to use special welding procedures based on the extremes allowed by the specification. The chemistry of a specific heat, under average mill-production conditions, may be considerably below the top limits indicated in the specification. Thus, for maximum economy, welding procedures for any type of steel should be based on actual rather than allowed chemistry values. A mill test report* can be obtained that gives the analysis of a heat of steel. From this information, a welding procedure can be established that ensures production of quality welds at lowest possible cost.

Standard carbon and alloy steels are identified by AISI (American Iron and Steel Institute), SAE

*A mill test report is usually based on a ladle analysis and is an average for an entire heat. Most low-carbon steels are rimmed steels, widely used because of their excellent forming and deep-drawing properties. The analysis of a rimmed steel varies from the first ingot to the last ingot of a single heat and also from the top to the bottom of a single ingot. Thus, a mill test report is an average and should be interpreted as such.

TABLE 6-2. AISI Designation System for Alloy Steels

Alloy Series	Approximate Alloy Content (%)
13XX	Mn 1.60-1.90
40XX	Mo 0.15-0.30
41XX	Cr 0.40-1.10, Mo 0.08-0.35
43XX	Ni 1.65-2.00, Cr 0.40-0.90; Mo 0.20-0.30
44XX	Mo 0.45-0.60
46XX	Ni 0.70-2.00; Mo 0.15-0.30
47XX	Ni 0.90-1.20; Cr 0.35-0.55; Mo 0.15-0.40
48XX	Ni 3.25-3.75; Mo 0.20-0.30
50XX	Cr 0.30-0.60
51XX	Cr 0.70-1.15
E51100	C 1.00; Cr 0.90-1.15
E52100	C 1.00; Cr 0.90-1.15
61XX	Cr 0.50-1.10, V 0.10-0.15 (min)
86XX	Ni 0.40-0.70; Cr 0.40-0.60; Mo 0.15-0.25
87XX	Ni 0.40-0.70, Cr 0.40-0.60; Mo 0.20-0.30
88XX	Ni 0.40-0.70; Cr 0.40-0.60; Mo 0.30-0.40
92XX	Si 1.80-2.20

(Society of Automotive Engineers), or ASTM (American Society for Testing Materials) designation systems. In the commonly used four-digit system of the AISI and SAE (Table 6-2), the last two digits indicate the middle of the carbon range. For example, in grade 1035, the 35 represents a carbon range from 0.32 to 0.38%. The first two digits indicate these carbon-steel grades:

10xx	Nonresulfurized
11xx	Resulfurized
12xx	Resulfurized and rephosphorized

A prefix "B" indicates an acid bessemer steel, an "E" indicates an electric-furnace steel. The E steels are usually alloy or stainless-steel grades. Steels without a prefix designation may be produced by basic open hearth, basic oxygen, or electric-furnace methods.

The letter "L" between the second and third digits indicates a leaded steel. The letter "B" in the same position designates a boron-treated steel. The suffix "H" refers to steels specially produced to narrow chemical and hardenability ranges.

These four-digit AISI or SAE standard steel designations apply primarily to sheet, strip, and bar products. ASTM specifications apply to most plates and structural shapes.

Some of the commonly specified elements and their effects on weldability and other characteristics of steels follow:

Carbon is the principal hardening element in steel. As carbon content increases, hardenability and tensile strength increase, and ductility and weldability decrease. In steels with a carbon content over 0.25%, rapid cooling from the welding temperature may produce a hard, brittle zone adjacent to the weld. Also, if considerable carbon is picked up in the weld puddle through admixture from the metal being welded, the weld deposit itself may be hard. Addition of small amounts of elements other than carbon can produce high tensile strengths without a detrimental effect on weldability. In general, carbon content should be low for best weldability.

Manganese increases hardenability and strength, but to a lesser extent than carbon. Properties of steels containing manganese depend principally on carbon content. Manganese content of less than 0.30% may promote internal porosity and cracking in the weld bead; cracking can also result if the content is over 0.80%.

For good weldability, the ratio of manganese to sulfur should be at least ten to one. If a steel has a low manganese content in combination with a low carbon content, it may not have been properly deoxidized. In steel, manganese combines with sulfur to form MnS, which is not harmful. However, a steel with a low Mn/S ratio may contain sulfur in the form of FeS, which can cause cracking (a "hot-short" condition) in the weld.

In general, manganese increases the rate of carbon penetration during carburizing and is beneficial to the surface finish of carbon steels.

Sulfur increases the machinability of steels, but reduces transverse ductility, impact toughness, and weldability. Sulfur in any amount promotes hot shortness in welding, and the tendency increases with increased sulfur. It can be tolerated up to about 0.035% (with sufficient Mn), over 0.050% it can cause serious problems. Sulfur is also detrimental to surface quality in low-carbon and low-manganese steels.

A common cause of poor welding quality that is not apparent from analyses made in the usual way is segregated layers of sulfur in the form of iron sulfide. These layers, which cause cracks or other defects at the fusion line of an arc-welded joint, can be detected by examination of a deep-etched cross section as illustrated in Fig. 6-1.

Fig. 6-1. Sulfur segregations. Dark lines in etched section indicate areas of high sulfur concentration.

Silicon is a deoxidizer that is added during the making of steel to improve soundness. Silicon increases strength and hardness, but to a lesser extent than manganese. It is detrimental to surface quality, especially in the low-carbon, resulfurized grades. If carbon content is fairly high, silicon aggravates cracking tendencies. For best welding conditions, silicon content should not exceed 0.10%, but amounts up to 0.30% are not as serious as high sulfur or phosphorus content.

Phosphorus, in large amounts, increases strength and hardness, but reduces ductility and impact strength, particularly in the higher-carbon grades. In low-carbon steels, phosphorus improves machinability and resistance to atmospheric corrosion.

As far as welding is concerned, phosphorus is an impurity, and should be kept as low as possible. Over 0.04% makes welds brittle and increases the tendency to crack. Phosphorus also lowers the surface tension of the molten weld metal, making it difficult to control.

Copper improves atmospheric corrosion resistance when present in excess of 0.15%. (A minimum of 0.20% is usually specified for this purpose.) Most carbon steels contain some copper as a "tramp element," up to about 0.15%. Copper content up to about 1.50% has little or no effect on the acetylene or arc-weldability of a steel, but it affects forge-weldability adversely. Copper content over 0.50% may reduce mechanical properties, however, if the steel is heat-treated.

Copper content is detrimental to surface quality, particularly in high-sulfur grades.

Specifying by Mechanical Properties

The producer of steels specified by mechanical properties is free to alter the chemistry of the steel (within limits) to obtain the required properties. Mechanical tests are usually specified under one of these conditions: 1. Mechanical test requirements only, with no limits on chemistry. 2. Mechanical test requirements, with limits on one or more elements.

Generally, these tests have been set up according to practices approved by the SAE (Society of Automotive Engineers) or ASTM (American Society for Testing and Materials) or to the requirements of other authorized code-writing organizations, such as the ASME (American Society of Mechanical Engineers) or the API (American Petroleum Institute).

The most common tests are bend tests, hardness tests, and a series of tensile tests that evaluate modulus of elasticity, yield strength, and tensile strength. Section 1.2 discusses some of these tests and the properties they determine. Metallurgical tests are sometimes used to measure grain size, decarburization, or inclusions. Other tests relating to end-use requirements, such as burst tests for pressure tubing, may be included in some specifications.

Most carbon steels are produced to standard specifications established by regulating bodies concerned with public welfare and safety. The largest and most influential body of this type is the ASTM. Other major groups are the SAE, the ASME, the AAR (American Association of Railroads), and the AWWA (American Water Works Association). ASTM specifications are broad, covering requirements of many industries. Most other groups prepare steel specifications for the needs and interests of their particular industries.

Specifying by End-Product

Often more important than exact mechanical properties or chemical analysis is the ability of a steel to be fabricated into a specific end product. Fabricating operations such as welding or deep drawing can change the as-delivered properties of a steel, and more than one chemical analysis or steelmaking method can often produce a suitable material for the product. Consequently, many flat-rolled steel products such as plate, sheet, and strip are specified to have adequate properties for fabrication into an "identified" end product.

A specification for an identified end product tells the steel producer which fabrication processes will be used, finish requirements, and the product's service requirements.

METALLURGY OF A WELD BEAD

The heat of welding brings about certain changes, both in the structure of the steel being welded and in the weld metal. Some of these changes occur during welding; others, after the metal has cooled.

During welding, the temperature of the molten weld metal reaches 3000°F or higher. A short distance from the weld, the temperature of the plate may be only about 600°F. When the steel reaches or exceeds certain critical temperatures between these values, changes occur that affect grain structure, hardness, and strength properties. These changes and the temperatures at which they occur are illustrated by Fig. 6-2, a schematic diagram of a section through a weld bead.

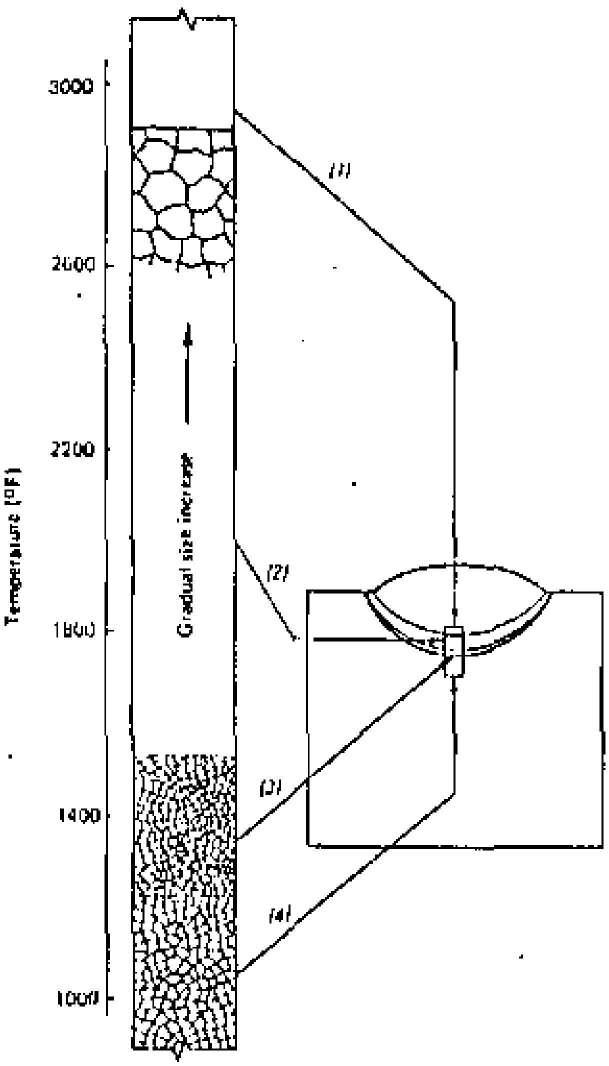


Fig. 6-2. Effect of welding heat on hardness and microstructure of an arc-welded 0.25% carbon steel plate. The schematic diagram represents a strip cut vertically through the weld shown. Significance of the four numbered zones are: 1. Metal that has been melted and resolidified. Grain structure is coarse. 2. Metal that has been heated above the upper critical temperature ($1525^\circ F$ for 0.25% carbon steel) but has not been melted. This area of large grain growth is where underbead cracking can occur. 3. Metal that has been heated slightly above the lower critical temperature ($1333^\circ F$) but not to the upper critical temperature. Grain refinement has taken place. 4. Metal that has been heated and cooled, but not to a high enough temperature for a structural change to occur.

The extent of change in structure depends on the maximum temperature to which the metal is subjected, the length of time the temperature is sustained, the composition of the metal, and the rate of cooling. The principal factor that controls these changes is the amount of heat that is put into the plate — both from preheating and from the welding process.

Cooling rate affects properties along with grain size. Rapid cooling rates produce stronger, harder, and less ductile steels; slow cooling rates produce the opposite properties. With low-carbon steels, the relatively small differences in cooling rates in normal practice have negligible effects on these properties. However, with steels of higher carbon contents or those with appreciable amounts of alloying elements, the effect can be significant.

Holding the plate material at a high temperature (above the upper critical temperature) for a long time produces a structure with large grain size. During welding, however, the metal adjacent to the weld (Zone 3 in Fig. 6-2) is at the high temperature for a very short time. The result is a slight decrease in grain size and an increase in strength and hardness, compared with the base metal.

In multipass weld joints, each bead produces a grain-refining action on the preceding bead as it is reheated. However, this refining is not likely to be uniform throughout the joint.

CRACKING — CAUSES AND CURES

Except in some weld-surfacing operations, cracks are considered deleterious. Cracking can occur either in the deposited metal or in the heat-affected zone of the base metal adjacent to the weld. The major cause of cracking in the base metal or in the weld metal is a high carbon or alloy content that increases the hardenability. High hardenability, combined with a high cooling rate, produces the brittle condition that leads to cracking. Other causes of weld cracking are: joint restraint that produces high stresses in the weld, improper shape of the weld bead, hydrogen pickup, and contaminants on the plate or electrode.

Factors Causing Underbead Cracking

Subsurface cracks in the base metal, under or near the weld, are known as underbead cracks. Underbead cracking in the heat-affected base metal is caused by: 1. A relatively high carbon or alloy content steel that is allowed to cool too rapidly from the welding temperature. 2. Hydrogen pickup during welding.

Underbead cracking seldom occurs with the preferred-analysis steels (Table 6-1). With carbon steels above 0.35% carbon content and with the low-alloy structural-grade steels, underbead cracking can be minimized by using a low-hydrogen welding process. The problem is most severe with materials such as the heat-treated structural steels having

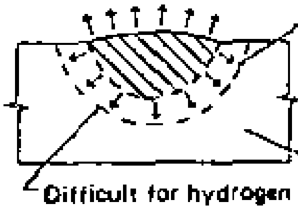


Fig. 6-3. Austenitic heat-affected zone of a weld has high solubility for hydrogen. Upon cooling, the hydrogen builds up pressure that can cause underbead cracking.

tensile strengths of 100,000 psi and higher. The discussions on specific steels include recommendations for welding these materials.

The second factor that promotes underbead cracking — the pickup and retention of hydrogen — is also influenced by the cooling rate from the welding temperature. During welding, some hydrogen — a decomposition product of moisture from the air, electrode coating, wire, flux, shielding gas, or the surface of the plate — can dissolve into the molten weld metal and from there into the extremely hot (but not molten) base metal. If cooling occurs slowly, the process reverses, and the hydrogen has sufficient time to escape through the weld into the air. But if cooling is rapid, some hydrogen may be trapped in the heat-affected zone next to the weld metal, as illustrated by Fig. 6-3. The hydrogen is absorbed and produces a condition of low ductility known as hydrogen embrittlement.

One theory suggests that the hydrogen produces a pressure, which — combined with shrinkage stresses and any hardening effect from the chemistry of the steel — causes tiny cracks in the metal immediately under the weld bead (Fig. 6-4). Similar cracks

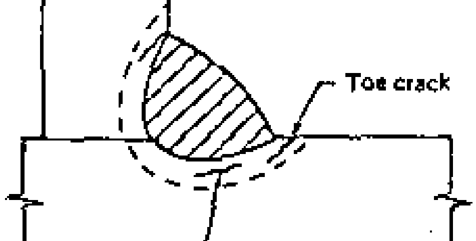


Fig. 6-4. Underbead cracking and toe cracks caused by hydrogen pickup in heat-affected zone of plate

that appear on the plate surface adjacent to the weld are called "toe cracks."

Slower cooling (by welding slower, or by preheating) allows more of the hydrogen to escape and helps control the problem. In addition, the use of low-hydrogen welding materials eliminates the major source of hydrogen and usually eliminates underbead cracking.

Rapid cooling rates occur when the arc strikes on a cold plate — at the start of a weld with no previous weld bead to preheat the metal. The highest cooling rates occur on thick plate and in short tack welds. The effect of weld length on cooling rate can be illustrated by the time required to cool welds from 1600° to 200°F on a 3/4-in. steel plate:

2-1/2-in. weld	1.5 min
4-in. weld	5 min
9-in. weld	33 min

A 9-in.-long weld made on plate at 70°F has about the same cooling rate as a 3-in. weld on a plate that has been preheated to 300°F.

Welds with large cross sections require greater heat input than smaller ones. High welding current and slow travel rates reduce the rate of cooling and decrease the likelihood of cracking.

The Effects of Section Thickness

In a steel mill, billets are rolled into plates or shapes while red hot. The rolled members are then placed on finishing tables to cool. Because a thin plate has more surface area in proportion to its mass than a thick plate, it loses heat faster (by radiation) and cools more rapidly.

If a thick plate has the same chemistry as a thin one, its slower cooling rate results in lower tensile and yield strength, lower hardness, and higher elongation. In very thick plates, the cooling rate may be so low that the properties of the steel may not meet minimum specifications. Thus, to meet specified yield-strength levels, the mill increases the carbon or alloy content of the steels that are to be rolled into thick sections.

In welding, cooling rates of thin and thick plates are just the opposite. Because of the larger mass of plate, the weld area in a thick plate cools more rapidly than the weld area in a thin one. The heat input at the weld area is transferred, by conduction, to the large mass of relatively cool steel, thus cooling the weld area relatively rapidly. (Heat is transferred more rapidly by conduction than by radiation.) The thin plate has less mass to absorb the heat, and it cools at a slower rate. The faster cooling

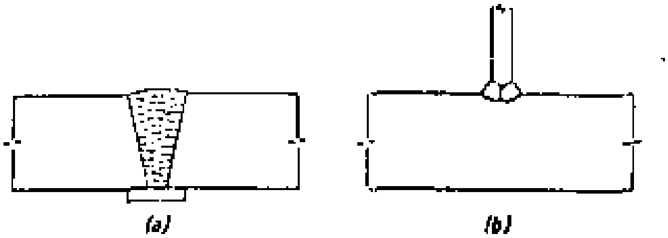


Fig. 6-5. A groove-welded butt joint in thick plate (a) requires a higher preheat, because of joint restraint, than a fillet welded joint of a thin member and a thick plate (b). See Section 2.3 for the minimum size weld required by AWS.

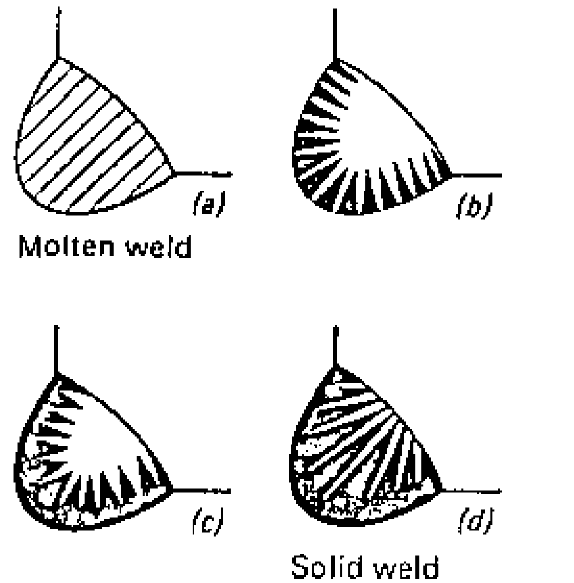


Fig. 6-7. A molten fillet weld (a) starts to solidify along the sides next to the plate (b). Solidification proceeds as shown in (c) and (d).

of the thicker plate produces higher tensile and yield strengths, higher hardness, and lower elongation.

Welds in structural-steel shapes and plate under 1/2-in. thick have less tendency toward cracking than welds in thicker plate. In addition to the favorable (slower) cooling rate of thinner members, two other factors minimize causes of cracking: 1. Thinner plate weldments usually have a good ratio (high) of weld-throat-to-plate thickness. 2. Because they are less rigid, thinner plates can flex more as the weld cools, thus reducing restraint on the weld metal.

Thicker plates and rolled sections do not have these advantages. Because a weld cools faster on a thick member, and because the thick member probably has a higher carbon or alloy content, welds on a thick section have higher strength and hardness but lower ductility than similar welds on thin plate. If these properties are unacceptable, preheating (especially for the more critical root pass) may be necessary to reduce the cooling rate. (See Section 3.3 for a discussion of preheating.)

Because it increases cost, preheating should be used only when needed. For example, a thin web to be joined to a thick flange plate by fillet welds may not require as much preheat as two highly restrained thick plates joined by a multiple-pass butt weld (Fig 6-5).

The Effect of Joint Restraint

If metal-to-metal contact exists between thick plates prior to welding, the plates cannot move — the joint is restrained. As the weld cools and contracts, all shrinkage stress must be taken up in the weld, as illustrated in Fig. 6-6(a). This restraint may cause the weld to crack, especially in the first pass on the second side of the plate.

Joint restraint can be minimized by providing a space of 1/32 to 1/16 in. between the two members to allow movement during cooling. Such spaces or gaps can be incorporated by several simple means:

1. Soft steel wire spacers may be placed between the plates, as in Fig. 6-6(b). The wire flattens out as the weld shrinks, as shown in Fig. 6-6(c). (Copper wire should not be used because it may contaminate the weld metal).
2. Rough flame-cut edges on the plate. The peaks of the cut edge keep the plates apart, yet can deform and flatten out as the weld shrinks.
3. Upsetting the edge of the plate with a heav center punch. Results are similar to those o the flame-cut edge.

Provision for a space between thick plates to be welded is particularly important for fillet welds.

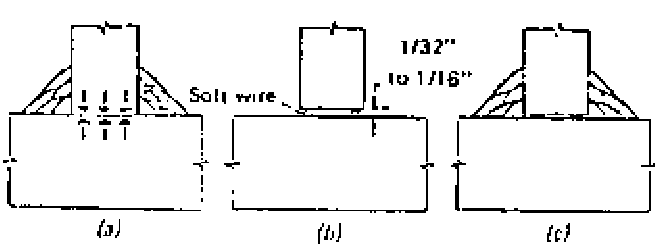


Fig. 6-6. In a restrained joint in thick plates (a), all shrinkage stress must be taken up in the weld. Separating the plates with soft wires (b) allows the plates to move slightly during cooling. The wires flatten (c) and remove most of the stress from the weld metal.

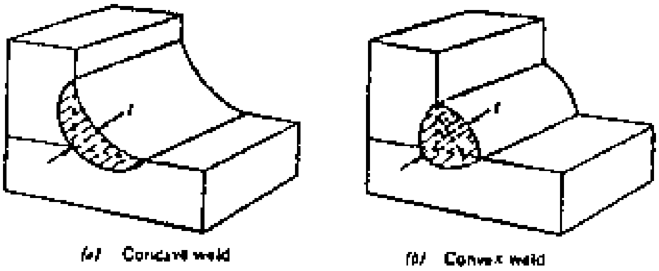


Fig. 6-8. The leg size and the surface of a concave fillet weld (a) may be larger than that of a convex bead (b), but its throat t, may be considerably smaller.

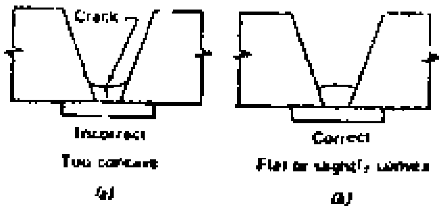


Fig. 6-10. A concave root pass (a) may crack because tensile stresses exceed the strength of the weld metal. A slightly convex root-pass bead (b) helps prevent cracking.

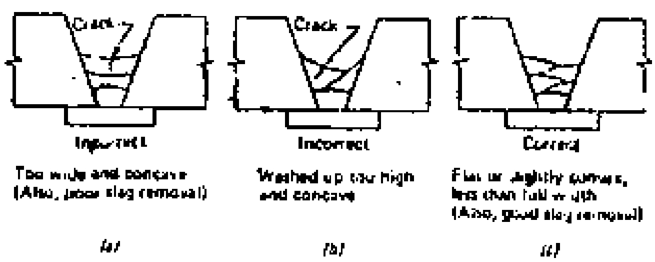


Fig. 6-11. Wide, concave passes (a and b) in a multiple-pass weld may crack. Slightly convex beads (c) are recommended.

Fillet Welds: A molten fillet weld starts to solidify, or freeze, along the sides of the joint, as in Fig. 6-7, because the heat is conducted to the adjacent plate, which is at a much lower temperature. Freezing progresses inward until the entire weld is solid. The last material to freeze is that at the center, near the surface of the weld.

Although a concave fillet weld may appear to be larger than a convex weld (Fig. 6-8), it may have less penetration into the welded plates and a smaller throat than the convex bead. Thus the convex weld may be the stronger of the two, even though it appears to be smaller.

In the past, the concave weld has been preferred by designers because of the smoother stress flow it offers to resist a load on the joint. Experience has shown, however, that single-pass concave fillet welds have a greater tendency to crack during cooling than do convex welds. This disadvantage usually outweighs the effect of improved stress distribution, especially in steels that require special welding procedures.

When a concave bead cools and shrinks, the outer surface is in tension and may crack. A convex bead has considerably reduced shrinkage stresses in the surface area, and the possibility of cracking during cooling is slight. For multiple-pass fillet welds only the first pass need be convex.

When design conditions require concave welds for smooth flow of stresses in thick plate, the first bead (usually three or more passes are required) should be slightly convex. The others are then built up to the required shape.

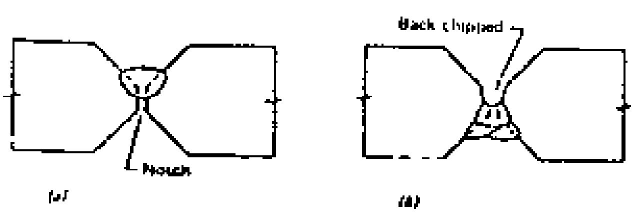


Fig. 6-9. The root pass of a double V joint is susceptible to cracking because of the notch effect (a). On high-quality work, the notch is minimized by backchipping (b).

Groove Welds: The root pass of a groove weld in heavy plate usually requires special welding procedures. For example, the root pass on the first side of a double-V joint is susceptible to cracking because of the notch, as illustrated in Fig. 6-9(a), which is a crack starter. On high-quality work, this notch is backchipped, as in Fig. 6-9(b), to: 1. Remove slag or oxides from the bottom of the groove. 2. Remove any small cracks that may have occurred in the root bead. 3. Widen the groove at the bottom so that the first bead of the second side is large enough to resist the shrinkage that it must withstand due to the rigidity of the joint.

The weld metal tends to shrink in all directions as it cools, and restraint from the heavy plates produces tensile stresses within the weld. The metal yields plastically while hot to accommodate the stresses; if the internal stresses exceed the strength of the weld, it cracks, usually along the centerline.

The problem is greater if the plate material has a higher carbon content than the welding electrode. If this is the case, the weld metal usually picks up additional carbon through admixture with the base metal. Under such conditions, the root bead is usually less ductile than subsequent beads.

A concave root bead in a groove weld, as shown in Fig. 6-10(a), has the same tendency toward crack-

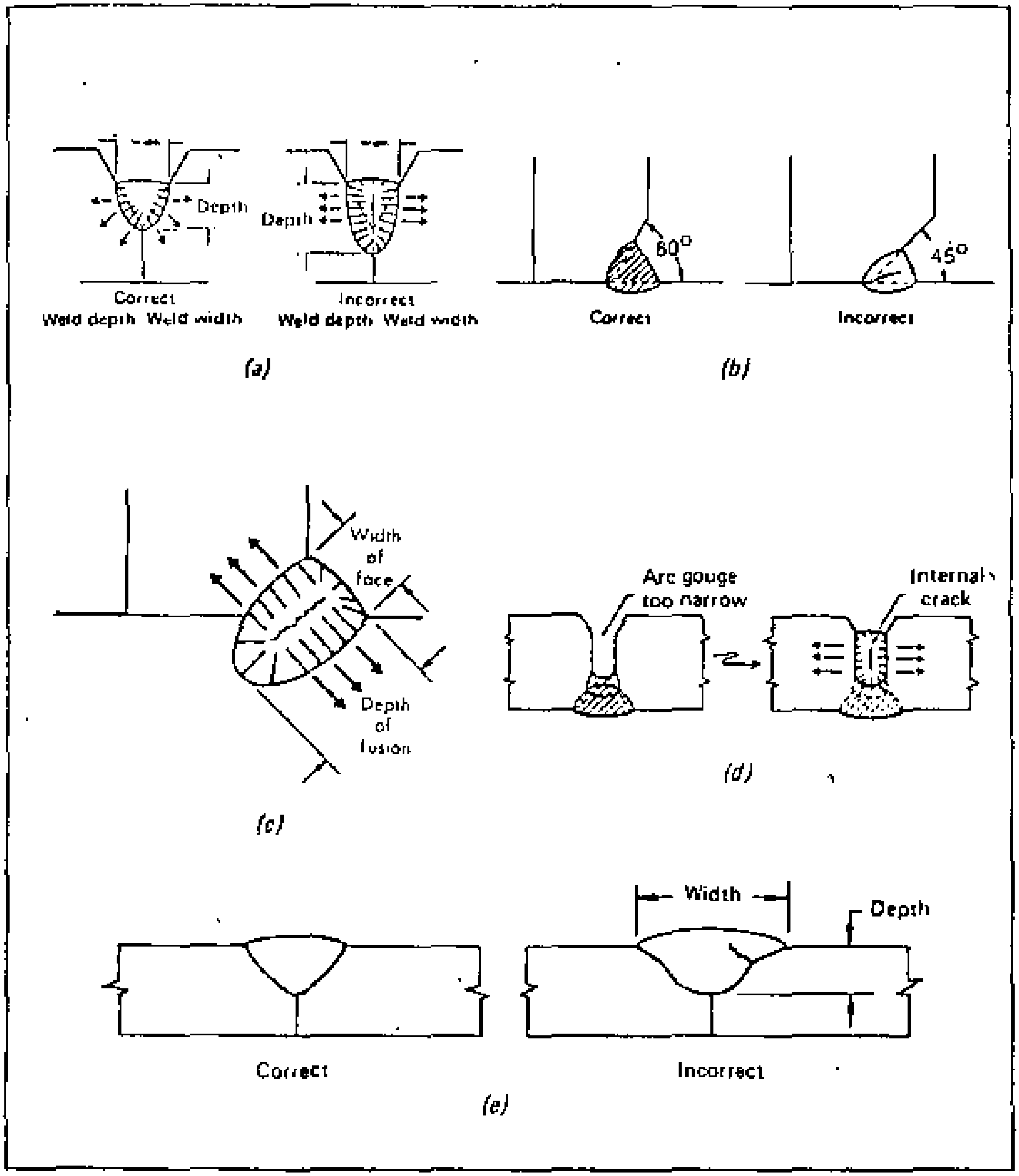


Fig. 6-12. Internal cracking can occur when weld penetration is greater than width. Correct and incorrect proportions are shown in (a), (b), and (c). Arc gouging a groove too narrow for its depth can cause a similar internal crack (d). Cracks can also occur when depth is too shallow (e). Width of a weld should not exceed twice its depth.

ing as it does in a fillet weld. Increasing the throat dimension of the root pass, as in Fig. 6-10(b), helps to prevent cracking. Electrodes and procedures should be used that produce a convex bead shape. A low-hydrogen process usually reduces cracking tendencies; if not, preheating may be required.

Centerline cracking can also occur in subsequent passes of a multiple-pass weld if the passes are excessively wide or concave. This can be corrected by putting down narrower, slightly convex beads, making the weld two or more beads wide, as in Fig. 6-11.

Width/Depth Ratio: Cracks caused by joint restraint or material chemistry usually appear at the face of the weld. In some situations, however, internal cracks occur that do not reach the surface.

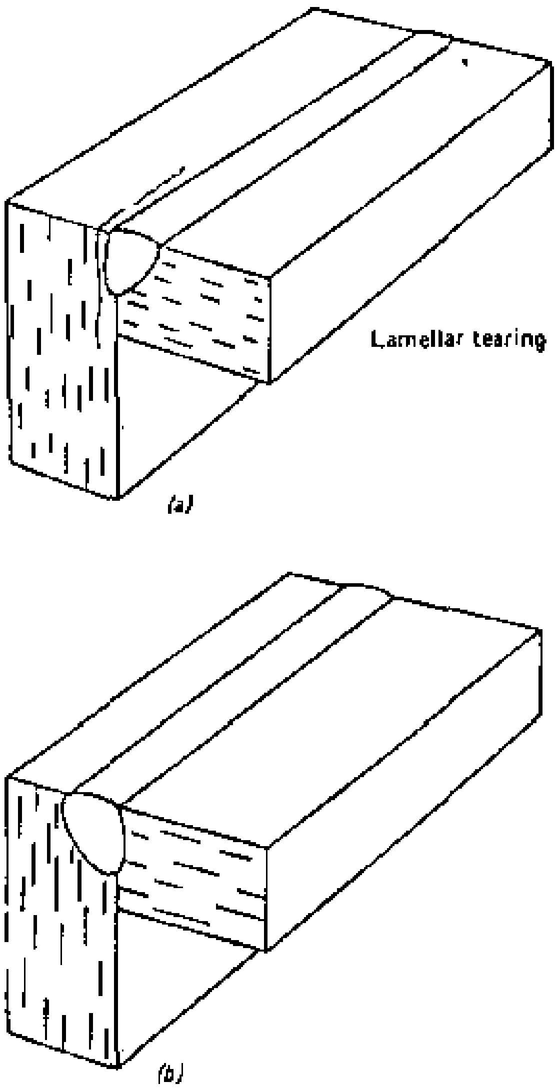


Fig. 6-13. Lamellar tearing (a) and a suggested solution (b)

These are usually caused by improper joint design (narrow, deep grooves or fillets) or by misuse of a welding process that can achieve deep penetration.

If the depth of fusion is much greater than the width of the weld face, the surface of the weld may freeze before the center does. When this happens, the shrinkage forces act on the almost-frozen center (the strength of which is lower than that of the frozen surface) and can cause a crack that does not extend to the surface. Figure 6-12(a) is illustrative.

Internal cracks can also be caused by improper joint design or preparation. Results of combining thick plate, a deep-penetrating welding process, and a 45° included angle are shown in Fig. 6-12(b). A similar result on a fillet weld made with deep penetration is shown in Fig. 6-12(c). A too-small bevel, and arc-gouging a groove too narrow for its depth on the second-pass side of a double-V groove weld, can cause the internal crack shown in Fig. 6-12(d).

Internal cracks are serious because they cannot be detected by visual inspection methods. But they can be eliminated if preventive measures are used. Penetration and volume of weld metal deposited in each pass can be controlled by regulating welding speed and current and by using a joint design which establishes reasonable depth-of-fusion requirements. Recommended ratios of width of each individual bead to depth of fusion are between 1.2 to 1 and 2 to 1.

A different type of internal crack occurs in submerged-arc welding when the width-to-depth ratio is too large. Cracks in these so-called "hat-shaped" welds are especially dangerous because radiographic inspection may not detect them. The width-to-depth ratio of any individual bead should not exceed 2:1.

Lamellar cracking or tearing is illustrated in Fig. 6-13. In (a), the shrinkage forces on the upright member are perpendicular to the direction in which the plate was rolled at the steel mill. The inclusions within the plate are strung out in the direction of rolling. If the shrinkage stress should become high enough, lamellar tear might occur by the progressive cracking from one inclusion to the next. A way to prevent this is illustrated in Fig. 6-13(b). Here, the bevel has been made in the upright plate. The weld now cuts across the inclusions, and the shrinkage forces are distributed, rather than applied to a single plane of inclusions.

Observations on Factors Contributing to Cracking

Two articles[1,2] appearing in the *Welding Journal* in 1964 summarize several of the factors confirmed by research as contributory to weld cracking:

1. The contraction forces of multiple-pass welds tend to cause separations in the base metal and they generally increase with the strength and/or hardenability of the filler metal and base metals. Therefore, softer weld metal would tend to decrease not only weld metal cracks but also heat-affected zone cracks and lamellar tearing.
2. The susceptibility to delayed cracking is proportional to the hydrogen content of the welding atmosphere.

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[1] "Weld Cracking Under Hindered Contraction: Comparison of Welding Processes," Travis, Barry, Moffat, and Adams, MIT, Welding Journal, November, 1964

[2] "Delayed Cracking in Steel Weldments," Interrante and Stout, Welding Journal, April, 1964.

3. Greater crack sensitivity is exhibited by high-chemistry base metal and by heavier plate thicknesses.
4. In general, cracking will initiate in the heat-affected zone of the base metal, except in cases where the weld metal is of higher hardness.
5. With an open-arc or even a shielded-arc manual electrode, it can be assumed that in hot humid weather the arc atmosphere will contain more hydrogen as water vapor than in cool, dry weather. Any tendency to minimize the importance of preheat, of keeping the joint hot, or possibly of postheat in hot summer months, could be at the root of cracking problems on heavy restrained joints. This would be especially true if either the weld metal or the base metal is hardenable because of alloy or carbon content.

Low heat input with interruptions in the welding cycle tends to aggravate the problem.

The welding position and its influence on bead size, heat input, number of layers, etc., has a direct influence on the cracking tendency. For example, three-o'clock groove welds are more sensitive to cracking than flat-position groove welds.

TABLE 6-3 Compositions of Carbon Steels

SAE Number	Chemical Composition Limits (%)			
	C	Mn	P, max.	S, max.
1005	0.06 max.	0.35 max.	0.040	0.050
1006	0.08 max.	0.25-0.40	0.040	0.050
1008	0.10 max.	0.30-0.50	0.040	0.050
1010	0.08-0.13	0.30-0.60	0.040	0.050
1011	0.08-0.13	0.60-0.90	0.040	0.050
1012	0.10-0.15	0.30-0.60	0.040	0.050
1013	0.11-0.16	0.50-0.80	0.040	0.050
1015	0.13-0.18	0.30-0.60	0.040	0.050
1016	0.13-0.18	0.60-0.90	0.040	0.050
1017	0.15-0.20	0.30-0.60	0.040	0.050
1018	0.15-0.20	0.60-0.90	0.040	0.050
1019	0.15-0.20	0.70-1.00	0.040	0.050
1020	0.18-0.23	0.30-0.60	0.040	0.050
1021	0.18-0.23	0.60-0.90	0.040	0.050
1022	0.18-0.23	0.70-1.00	0.040	0.050
1023	0.20-0.25	0.30-0.60	0.040	0.050
1025	0.22-0.28	0.30-0.60	0.040	0.050
1026	0.22-0.28	0.60-0.90	0.040	0.050
1029	0.25-0.31	0.60-0.90	0.040	0.050
1030	0.28-0.34	0.60-0.90	0.040	0.050
1035	0.32-0.38	0.60-0.90	0.040	0.050
1037	0.32-0.38	0.70-1.00	0.040	0.050
1038	0.35-0.42	0.60-0.90	0.040	0.050
1039	0.37-0.44	0.70-1.00	0.040	0.050
1040	0.37-0.44	0.60-0.90	0.040	0.050
1042	0.40-0.47	0.60-0.90	0.040	0.050
1043	0.40-0.47	0.70-1.00	0.040	0.050
1044	0.43-0.50	0.30-0.60	0.040	0.050
1045	0.43-0.50	0.60-0.90	0.040	0.050
1046	0.43-0.50	0.70-0.90	0.040	0.050
1049	0.46-0.53	0.60-0.90	0.040	0.050
1050	0.48-0.55	0.60-0.90	0.040	0.050
1053	0.48-0.55	0.70-1.00	0.040	0.050
1055	0.50-0.60	0.60-0.90	0.040	0.050
1060	0.55-0.65	0.60-0.90	0.040	0.050
1064	0.60-0.70	0.50-0.80	0.040	0.050
1065	0.60-0.70	0.60-0.90	0.040	0.050
1069	0.65-0.75	0.40-0.70	0.040	0.050
1070	0.65-0.75	0.60-0.90	0.040	0.050
1074	0.70-0.80	0.50-0.80	0.040	0.050
1075	0.70-0.80	0.40-0.70	0.040	0.050
1078	0.72-0.85	0.30-0.60	0.040	0.050
1080	0.75-0.88	0.60-0.90	0.040	0.050
1084	0.80-0.93	0.60-0.90	0.040	0.050
1086	0.80-0.93	0.70-1.00	0.040	0.050
1086	0.80-0.93	0.30-0.50	0.040	0.050
1090	0.85-0.98	0.60-0.90	0.040	0.050
1095	0.90-1.03	0.30-0.50	0.040	0.050

From the 1969 SAE Handbook. Some grades have wider ranges when producing steel for structural sheet and welded tubing.

STEELS AND WELDING RECOMMENDATIONS

The Carbon Steels

Classification of the carbon steels is based principally on carbon content. The groups are: low-carbon (to 0.30% carbon), medium-carbon (0.30 to 0.45%), and high-carbon (more than 0.45%). The first group is sometimes subdivided into the very-low-carbon steels (to 0.15%) and the mild steels (0.15 to 0.30%). Standard SAE compositions of carbon steels, applicable to structural shapes, plate, strip, sheet, and welded tubing are listed in Table 6-3.

Mechanical properties of hot-finished steels are influenced principally by chemical composition (particularly carbon content), but other factors — finishing temperature, section size, and the presence of residual elements — also affect properties. A 3/4-in. plate, for example, has higher tensile properties and lower elongation than a 1-1/2-in. plate of the same composition. This results from the higher rate of cooling of the 3/4-in. plate from the rolling temperature. Typical tensile properties of hot-rolled and cold-finished low-carbon steels are listed in Table 6-4.

Low-Carbon Steels

In general, steels with carbon contents to 0.30% are readily joined by all common arc-welding processes. These grades account for the greatest tonnage of steels used in welded structures. Typical applications include tanks, structural assemblies, vessels, machine bases, earth-moving and agricultural

TABLE 6-4. Typical Minimum Mechanical Properties of Carbon-Steel Bars

AISI or SAE No.	Condition*	Tensile Strength (1000 psi)	Yield Strength (1000 psi)	Elongation in 2 in. (%)
1010	HR	47	26	28
	CF	53	44	20
1015	HR	50	28	28
	CF	56	47	18
1020	HR	55	30	25
	CF	61	51	15
1025	HR	58	32	25
	CF	64	54	15
1030	HR	68	38	20
	CF	76	64	12
1035	HR	72	40	18
	CF	80	67	12
1040	HR	76	42	18
	CF	85	71	12
1045	HR	82	45	16
	CF	91	77	12
1050	HR	90	50	15
	CF	100	84	10

* HR = hot rolled; CF = cold finished.
Data from ASM Metals Handbook, 8th Ed., Vol. 1.

equipment, and general weldments.

Steels with very low carbon content — to 0.13% — are good welding steels, but they are not the best for high-speed production welding. The low carbon content and the low manganese content (to 0.30%) tend to produce internal porosity. This condition is usually corrected by modifying the welding procedure slightly — usually by using a slower speed. If the presence of some internal porosity has no detrimental effect on service requirements of the assembly, standard high-speed welding procedures can be used.

Steels with very low carbon content are more ductile and easier to form than higher-carbon steels. They are used for applications requiring considerable cold forming, such as stampings or rolled or formed shapes.

Steels with 0.15 to 0.20% carbon content have excellent weldability. They seldom require anything beyond standard welding procedures, and they can be welded with all types of mild-steel electrodes. These steels should be used for maximum production speed on assemblies or structures that require extensive welding.

Steels at the upper end of the low-carbon range — the 0.25 to 0.30% carbon grades — have very good weldability, but when one or more of the elements is on the high side of permissible limits, cracking can result, particularly in fillet welds. With slightly reduced speeds and currents, any of the standard electrodes can be used for these steels. In thicknesses to 5/16 in., standard procedures apply.

If some of the elements — particularly carbon, silicon, or sulfur — are on the high side of the limits, surface holes may form. Reducing current and speed minimizes this problem.

Although most welding applications of these steels require no preheating, heavy sections (2-in. or more) and certain joint configurations may require a preheat. Less preheating is required when low-hydrogen processes are used. In general, steels in the 0.25 to 0.30% carbon range should be welded with low-hydrogen electrodes or with a low-hydrogen process if the temperature is below 50°F.

Medium and High-Carbon Steels

Because hardenability of steel increases with carbon content, the medium and high-carbon steels serve where hardness, wear resistance, or higher strength are needed. Important uses for medium-carbon steels (to 0.45%) include wear plates, springs, and components for railroad, agricultural, and earth-moving and materials-handling equipment.

Unfortunately, the same characteristics that make these steels so suitable for use in rugged parts and structures make them more difficult and costly to weld. The medium-carbon steels can be welded successfully, however, provided proper procedures and preheat and interpass temperatures are used. Sometimes, postweld stress relief may be required.

The high-carbon steels are almost always used in a hardened condition. Typical applications are for metalworking and woodworking tools, drills, dies, and knives, and for abrasion-resistant parts such as plowshares and scraper blades. Some farm equipment is built from rerolled rail stock (0.65% C), which is welded in the as-rolled condition, using preheating, interpass heating, and postweld stress relief.

Hardness of these steels can range from dead soft in the annealed condition to Rockwell C 65 (with rapid quench treatment) for the higher-carbon grades. Although an AISI 1020 steel can be made as hard as Rc 50, hardness is very shallow. Increased carbon content increases depth of hardening and maximum attainable hardness to about Rc 65. Alloying elements increase depth of hardening but have little effect on maximum hardness possible.

It is advisable to make sample weld tests to determine cracking tendencies of steels containing 0.30% or more carbon. If such tendencies are apparent, preheating of the steel may be necessary to retard the cooling rate from the welding temperature. Required preheat temperature varies with analysis, size, and shape of the steel and with the amount of heat input from the welding process. In general, the higher the carbon or alloy content and the thicker the plate, the higher the preheat temperature needed to provide the slow cooling rate required to prevent hardening. For shop calculation, a Preheat Calculator — available from The Lincoln Electric Company at a nominal cost — is a handy tool for determining preheat requirements of various thicknesses of common analysis steels. (See Section 3.3.)

Use of low-hydrogen processes can minimize the degree of preheating necessary and, in 14-gage and thinner materials, can eliminate the need for preheating entirely. As a rule of thumb, preheat temperatures used with low-hydrogen electrodes can be 100 to 200°F lower than those needed for electrodes other than low-hydrogen.

AWS Structural Steels

The American Welding Society does not write specifications for structural steel but does recognize many steels specified by ASTM, API, and ABS as suitable for welded structures with the various arc welding processes. Table 6-6 shows a list of these steels with the mechanical property requirements and the proper filler metals for welding. Since the table does not contain the complete mechanical property or chemical requirements it is suggested the reader consult the original specification for further information.

In general, these steels have maximum limits on carbon sulfur and phosphorous. Manganese may be specified as a range or in a maximum amount. Small amounts of other alloys may be added in order to meet the mechanical property requirements. All the steels listed in Tabel 6-6 have satisfactory weldability characteristics but some may require special procedures or techniques, such as limited heat input or minimum preheat and interpass temperatures. Some structural steels are not intended for arc welding. For example, A440 is intended primarily for riveted or bolted structures, see Table 6-5.

High-Strength Low-Alloy Structural Steels

Higher mechanical properties and, usually, better corrosion resistance than the structural carbon steels are characteristics of the high-strength low-alloy (HSLA) steels. These improved properties are achieved by additions of small amounts of alloying elements. Some of the HSLA types are carbon-manganese steels; others contain different alloy additions, governed by requirements for weldability, formability, toughness, or economy. Strength of these steels is between those of structural carbon steels and the high-strength quenched-and-tempered steels.

High-strength low-alloy steels are usually used in the as-rolled condition, although some are available that require heat treatment after fabrication. These steels are produced to specific mechanical-property requirements rather than to chemical compositions. Minimum mechanical properties available in the as-rolled condition vary among the grades and, within most grades, with thickness. Ranges of properties available in this group of steels are:

1. Minimum yield point from 42,000 to 70,000 psi.
2. Minimum tensile strength from 60,000 to 85,000 psi.
3. Resistance to corrosion, classed as: equal to that of carbon steels, twice that of carbon steels, or four to six times that of carbon steels.

The HSLA steels are available in most commercial wrought forms and are used extensively in products and structures that require higher strength-to-weight ratios than the carbon structural steels offer. Typical applications are supports and panels for truck bodies, railway cars, mobile homes, and other transportation equipment; components for tractors, threshers, fertilizer spreaders, and other agricultural machinery; materials-handling and storage equipment; and buildings, bridge decks, and similar structures.

The high-strength low-alloy steels should not be confused with the high-strength quenched-and-tempered alloy steels. Both groups are sold primarily on a trade-name basis, and they frequently share the same trade-name, with different letters or numbers being used to identify each. The quenched-and-tempered steels are full-alloy steels that are heat treated at the mill to develop optimum properties. They are generally martensitic in structure, whereas the HSLA steels are mainly ferritic steels; this is the clue to the metallurgical and fabricating differences

TABLE 6-5. Specifications for High-Strength Low-Alloy Steels

Specification or Practice	Coverage
ASTM	
A-242	42,000 to 50,000-psi yield-point steels with atmospheric corrosion resistance equal to twice (with copper) or four or more times that of structural carbon steels. The more corrosion-resistant grades are used as "weathering steels."
A-374	Cold rolled sheets and strip with 45,000-psi yield point; similar in many respects to A-242.
A-375	Hot-rolled sheets and strip with 50,000-psi yield point; similar in many respects to A-242.
A-440	Intermediate manganese steels with 42,000 to 50,000-psi yield points. Copper additions provide atmospheric corrosion resistance double that of carbon steel. Good abrasion resistance, only fair weldability. Used primarily for riveted or bolted products.
A-441	Manganese-vanadium steels with 40,000 to 50,000-psi yield points. Copper additions provide atmospheric corrosion resistance double that of carbon steel. Lower manganese and carbon; therefore, improved weldability over A-440 steels.
A 572	Columbium-vanadium nitrogen grades with six yield points from 42,000 to 65,000 psi. Grades with copper additions for improved atmospheric corrosion resistance are available. Modifications high in columbium may have excellent low-temperature notch toughness when produced to fine-grain practice (by roller quenching or normalizing).
A-588	Similar in most respects to A-242 steels, except that a 50,000-psi yield-point minimum is provided up to 4 in. thick and material up to 8 in. thick and is covered in the specification. Has four times the atmospheric corrosion resistance of carbon steel.
SAE (Recommended Practice — not a specification)	
J410b	Covers all major HSLA types, with yield strengths from 42,000 to 70,000 psi. Unlike ASTM, SAE gives greater attention to formability, toughness, and weldability. However, ASTM specs give wider coverage of mill forms and larger section thicknesses.
DoD	
Mil-S-7809A (May 3, 1963)	Covers HSLA steels in bars, shapes, sheets, strip, and plates.
Mil-S-13281B (Oct. 10, 1966)	Covers carbon, alloy, and HSLA steels for welded structures.

Source: "High-Strength Low-Alloy Steels", *Machine Design*, Feb. 17, 1972.

between the two types. In the as-rolled condition, ferritic steels are composed of relatively soft, ductile constituents; martensitic steels have hard, brittle constituents that require heat treatment to produce their high-strength properties.

Strength in the HSLA steels is achieved instead by relatively small amounts of alloying elements dissolved in a ferritic structure. Carbon content rarely exceeds 0.28% and is usually between 0.15 and 0.22%. Manganese content ranges from 0.85 to 1.60%, depending on grade, and other alloy additions — chromium, nickel, silicon, phosphorus, copper, vanadium, columbium, and nitrogen — are used in amounts less than one percent. Welding, forming, and machining characteristics of most grades do not differ markedly from those of the low-carbon steels.

To be weldable, the high-strength steels must have enough ductility to avoid cracking from the rapid cooling inherent in welding processes. Weldable HSLA steels must be sufficiently low in carbon, manganese, and all "deep-hardening" elements to ensure that appreciable amounts of martensite are not formed upon rapid cooling. Superior strength is provided by solution of the alloying elements in the ferrite of the as-rolled steel. Corrosion resistance is also increased in certain of the HSLA steels by the alloying additions.

Addition of a minimum of 0.20% copper usually produces steels with about twice the atmospheric corrosion resistance of structural carbon steels. Steels with four to six times the atmospheric corrosion resistance of structural carbon steels are obtained in many ways, but, typically, with additions of nickel and/or chromium, often with more than 0.10% phosphorus. These alloys are usually used in addition to the copper.

Standard specifications or recommended practices covering the major types of HSLA steels are available from the American Society for Testing and Materials, the Society of Automotive Engineers, and the Department of Defense. These standards are summarized in Table 6-5.

Other standardizing organizations such as the American Institute of Steel Construction, The American Association of Railroads, and the Department of Transportation have established specifications or practices for the use of HSLA steels in certain industries and applications.

ASTM's specifications are oriented principally to mill form and mechanical properties; SAE's recommended practices include, in addition, information on fabrication characteristics — toughness, weldability, and formability.

ASTM Specifications

Five ASTM specifications cover the high-strength low-alloy structural steels. They are: A242, A440, A441, A572, and A588. Table 6-6 lists the

TABLE 6.6. Minimum Mechanical Properties for ASTM HSLA Steels Approved for Use by AISC Specifications for the Design, Fabrication, and Erection of Structural Steel for Buildings (1969) AWS Building Code D1.0-69 (Revised 1970)

ASTM GRADE and Descriptive Information	Mechanical Properties: Tensile Strength (ksi min.)	Yield Point (ksi min.)	Elongation in 2 in. % min	Material Shape	Thickness Group Or Grade	Chemical Requirements (Ladle) Percent: C Max.	Mn† Max.	P Max.	S Max.	Si †	Cu Min.	V Min.
A36 Structural Steel	58 to 80	36	23	Shapes		0.26	-	0.04	0.05	–	0.20*	
	58 to 80	36	23	Plate	to 3/4 incl.	0.25	–	0.04	0.05	-	0.20*	
	58 to 80	36	23	Plate	over 3/4 to 1-1/2 incl	0.25	0.80 - 1.20	0.04	0.05	-	0.20*	
	58 to 80	36	23	Plate	over 1-1/2 to 2-1/2 incl	0.26	0.80 - 1.20	0.04	0.05	0.15 - 0.30	0.20*	
	58 to 80	36	23	Plate	over 2-1/2 to 4" incl	0.27	0.85 - 1.20	0.04	0.05	0.15 - 0.30	0.20*	
	58 to 80	36	23	Plate	over 4 to 8" incl	0.29	0.85 - 1.20	0.04	0.05	0.15 - 0.30	0.20*	
	58 to 80	36	23	Bars & Bar Shapes	to 3/4" incl	0.26	-	0.04	0.05	-	0.20*	
	58 to 80	36	23	Bars & Bar Shapes	over 3/4" to 1-1/2" incl	0.27	0.60 - 0.90	0.04	0.05		0.20*	
	58 to 80	36	23	Bars & Bar Shapes	over 1-1/2" to 4" incl	0.28	0.60 - 0.90	0.04	0.05		0.20*	
A53 GRADE B Welded & Seamless Steel Pipe [illegible]	60 min.	35	**		●			**				
A242 High Strength Low Alloy Structural Steel	70 min	50	**	Plates & Bars	to 3/4" incl	0.22	1.25		0.05			
	67 min	46	**	Plates & Bars	over 3/4 to 1-1/2 incl	0.22	1.25		0.05			
(other alloying elements may be added)	63 min	42	21	Plates & Bars	over 1-1/2 to 4" incl	0.22	1.25		0.05			
(If C max ≤0.15, Mn_{max} can be raised to 1.40)	70 min	50	**	Struc. Shapes	I	0.22	1.25		0.05			
	67 min	46	**	Struc. Shapes	II	0.22	1.25		0.05			
	63 min	42	21	Struc. Shapes	III	0.22	1.25		0.05			
A375 High Strength, Low Alloy Hot Rolled Steel Sheet Strip	70 min	50	22			0.22	1.25		0.05			
When used for welding, the chemistry shall be checked for weldability based on evidence acceptable to the buyer												
A441 High Strength Low Alloy Structural Manganese Vanadium Steel	70 min	50	**	Plates & Bars	to 3/4" incl	0.22	.85 - 1.25	0.04	0.05	0.30	0.20	0.02
	67 min	46	**	Plates & Bars	over 3/4" to 1-1/2" incl	0.22	.85 - 1.25	0.04	0.05	0.30	0.20	0.02
	63 min	42	24	Plates & Bars	over 1-1/2" to 4" incl.	0.22	.85 - 1.25	0.04	0.05	0.30	0.20	0.02
	60 min	40	24	Plates & Bars	over 4" to 8" incl	0.22	.85 - 1.25	0.04	0.05	0.30	0.20	0.02
	70 min	50	**	Struc. Shapes	I	0.22	.85 - 1.25	0.04	0.05	0.30	0.20	0.02
	67 min.	46	**	Struc. Shapes	II	0.22	.85 - 1.25	0.04	0.05	0.30	0.20	0.02
	63 min	42	24	Struc. Shapes	III	0.22	.85 - 1.25	0.04	0.05	0.30	0.20	0.02
A500 Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes	45 min	33	25	Round Structural Tubing	A	0.26		0.04	0.05		0.20*	
	58 min	42	23	Round Structural Tubing	B	0.26		0.04	0.05		0.20*	
	45 min	39	25	Shaped Struc. Tub.	A	0.26		0.04	0.05		0.20*	
	58 min	46	23	Shaped Struc. Tub.	B	0.26		0.04	0.05		0.20*	
A501 Hot Formed Welded and Seamless Carbon Steel Structural Tubing	58 min	36	23			0.26		0.04	0.05		0.20*	
A529 Structural Steel (42 ksi min. yield) (1/2 in. max. thickness)	60 to 85	42	19			0.22	1.20	0.04	0.05		0.20*	
A570 GRADES D & E Hot Rolled Carbon Steel Sheets & Strip, Struc. Quality	55 min	40	**		D	0.25	0.60 - 0.90	0.04	0.04		0.20*	
	58 min	42	**		E	0.25	0.60 - 0.90	0.04	0.04		0.20*	

* When Specified ** See ASTM Standards for details † Where two figures are given this is a min-max range

TABLE 6-6. (Continued)

ASTM Grade and Descriptive Information	Material Shape	Thickness Or Group	Mechanical Properties: Tensile Strength (ksi min.)	Yield Point (ksi min.)	Elong. in 2 in. % min.	Grade	Chemical Requirements (Ladle) Percent: C Max.	Mn Max.	P Max.	S Max.	Si Max.	Ni Max.	Cr Max.	Mo Max.	Cu Max.	V Max.	Cb Max.	Ti Max.	Others
A572 High-Strength Low-Alloy, Columbium-Vanadium Steels of Structural Quality	Shapes And Plates		60 min.	42	24	42	0.21	1.35	0.04	0.05	(5)					(2)	(1)(3)		N (4)
Alloy content shall be in accordance with one of the following:			60 min.	45	22	45	0.22	1.35	0.04	0.05	(5)					(2)	(1)(3)		(4)
			65 min.	50	21	50	0.23	1.35	0.04	0.05	(5)					(2)	(1)(3)		(4)
			70 min.	55	20	55	0.25	1.35	0.04	0.05	(5)					(2)	(1)(3)		(4)
			75 min.	60	18	60	0.26	1.35	0.04	0.05	(5)					(2)	(1)(3)		(4)
			80 min.	65	17	65	0.26	1.35	0.04	0.05	(5)					(2)	(1)(3)		(4)
A588 High Strength Low-Alloy Structural Steel with 50 ksi min. Yield Point to 4 inch Thickness						A	0.10-0.19	0.90-1.25	0.04	0.05	0.15-0.30	-	0.40-0.65	-	0.25-0.40	0.02-0.10	-	-	-
	Plates And Bars	to 4" incl.	70 min.	50	21	B	0.10-0.20	0.75-1.25	0.04	0.05	0.15-0.30	0.25-0.50	0.40-0.70	-	0.20-0.40	0.01-0.10	-	-	-
	Plates And Bars	over 4" to 5" incl.	67 min.	46	21	C	0.15 Max.	0.80-1.35	0.04	0.05	0.15-0.30	0.25-0.50	0.30-0.50	-	0.20-0.50	0.01-0.10	-	-	-
	Plates And Bars	over 5" to 8" incl.	63 min.	42	21	D	0.10-0.20	0.75-1.25	0.04	0.05	0.50-0.90	-	0.50-0.75	-	0.30 Max.	-	0.04	-	Zr 0.05-0.15
	Shapes	Group 1,2,3,4	70 min.	50	19	E	0.15 Max.	1.20 Max.	0.04	0.05	0.15-0.30	0.75-1.25	-	0.10-0.25	0.50-0.80	0.05 Max.	-	-	-
	Shapes	Group 5	67 min.	46	19	F	0.10-0.20	0.50-1.00	0.04	0.05	0.30 Max.	0.40-1.10	0.30 Max.	0.10-0.20	0.30-1.00	0.01-0.10	-	-	-
						G	0.20 Max.	1.20 Max.	0.04	0.05	0.25-0.70	0.80 Max.	0.50-1.00	0.10 Max.	0.30-0.50	-		0.07	-
A514 High Yield Strength Quenched and Tempered Alloy Steel Plate Suitable for Welding	Plate	to 3/4" incl.	115 to 135	100	18	E	0.10-0.20	0.40-0.70	0.035	0.04	0.20-0.35	-	1.40-2.00	0.40-0.60	0.20-0.40			0.04-0.10	B 0.0015-.005
	Plate	over 3/4" to 2-1/2" incl.	115 to 135	100	18	F	0.10-0.20	0.60-1.00	0.035	0.04	0.15-0.35	0.70-1.00	0.40-0.65	0.40-0.60	0.15-0.50	0.03-0.08		-	B 0.002-.006
	Plate	over 2-1/2" to 4" incl.	105 to 135	90	17														

A572 alloy notes:
(1) Cb 0.005-0.05
(2) V 0.01-0.10
(3) Cb (0.05 max) + V 0.02-0.10
(4) N (with V) 0.015

(4) N 0.015 max when added as a supplement to V shall be reported, and the minimum ratio of V to N shall be 4 to 1.
(1)(3) Cb when added either singly or in combination with V unless combined with 0.15 min Si shall be restricted to plate or bar thickness of 1/2" max. and to shapes of Table A, Group 1 of Spec A6.
(5) Si 0.30 max for shapes and plates to 1-1/2" for grade 42 plates over 1-1/2" (0.15 - 0.30 max)

1. Where two figures are given this is a min-max range

mechanical properties of these steels. Specifications A374 and A375 cover similar steels in sheet and strip form.

ASTM A242 covers HSLA structural steel shapes, plates, and bars for welded, riveted, or bolted construction. Maximum carbon content of these steels is 0.24%; typical content is from 0.09 to 0.17%. Materials produced to this specification are intended primarily for structural members where light weight and durability are important.

Some producers can supply copper-bearing steels (0.20% minimum copper) with about twice the atmospheric corrosion resistance of carbon steels. Steels meeting the general requirements of ASTM A242 but modified to give four times the atmospheric corrosion resistance of structural steels are also available. These latter grades — sometimes called "weathering steels" — are used for architectural and other structural purposes where it is desirable to avoid painting for either esthetic or economic reasons.

Welding characteristics vary according to the type of steel; producers can recommend the most weldable material and offer welding advice if the conditions under which the welding will be done are known.

ASTM A440 covers high-strength intermediate-manganese copper-bearing HSLA steels used principally for riveted or bolted structures. These steels are not generally recommended for welding because of their relatively high carbon and manganese contents. ASTM A440 and its companion, A441, have the same minimum mechanical properties as A242.

ASTM A440 steels have about twice the atmospheric corrosion resistance of structural carbon steel and very good abrasion resistance. The high manganese content (typically, about 1.45%) tends to cause weld metal to air harden — a condition that may produce high stresses and cracks in the weld. If these steels must be welded, careful preheating (higher than for A441) is necessary.

ASTM A441 covers the intermediate-manganese HSLA steels that are readily weldable with proper procedures. The specification calls for additions of vanadium and a lower manganese content (1.25% maximum) than ASTM A440. Minimum mechanical properties are the same as A242 and A440 steels, except that plates and bars from 4 to 8-in. thick are covered in A441.

Atmospheric corrosion resistance of this steel is approximately twice that of structural carbon steel. Another property of ASTM A441 steel is its superior toughness at low temperatures. Only shapes, plates, and bars are covered by the specification, but weldable sheets and strip can be supplied by some producers with approximately the same minimum mechanical properties.

ASTM A572 includes six grades of high-strength low-alloy structural steels in shapes, plates, and bars. These steels offer a choice of strength levels ranging from 42,000 to 65,000-psi yields (Table 6-6). Proprietary HSLA steels of this type with 70,000 and 75,000-psi yield points are also available. Increasing care is required for welding these steels as strength level increases.

A572 steels are distinguished from other HSLA steels by their columbium, vanadium, and nitrogen content. Copper additions above a minimum of 0.20% may be specified for atmospheric corrosion resistance about double that of structural carbon steels.

A supplementary requirement is included in the specification that permits designating the specific alloying elements required in the steel. Examples are the Type 1 designation, for columbium; Type 2, for vanadium; Type 3, for columbium and vanadium; and Type 4, for vanadium and nitrogen. Specific grade designations must accompany this type of requirement.

ASTM A588 provides for a steel similar in most respects to A242 weathering steel, except that the 50,000-psi yield point is available in thicknesses to at least 4 in.

SAE Specifications

High-strength low-alloy steels are also covered in the SAE Recommended Practice J410b. This is not a standard. Rather, it is a recommended practice — a guide or memorandum from SAE to its members to help standardize their engineering practices. SAE J410b was written long before most of the HSLA steels had ASTM specifications. Its content is more general than the ASTM documents, and its intent is to guide material selection in the light of fabrication requirements. Now that ASTM has defined almost all of the HSLA steels in standard specifications, SAE J410b is seldom used as a material specification. But the SAE document is still valuable as a general guide to using the HSLA steels.

The SAE document addresses itself primarily to the specific needs of fabricators of automobiles, trucks, trailers, agricultural equipment, and aircraft. This is why SAE J410b does not cover the thick plates and heavier structural shapes. Minimum mechanical properties of commonly used steels covered by SAE J410b are listed in Table 6-7.

TABLE 6-7. Minimum Mechanical Properties for SAE J410b HSLA Steels

Grade, Form, and Thickness	Tensile Strength (1000 psi)	Yield Strength 0.2% Offset (1000 psi)	Elongation (%)	
			2 in.	8 in.
945 A, C				
Sheet, strip	60	45	22	...
Plate, bar				
To 1/2 in.	65	45	22	18
1/2 to 1-1/2 in.	62	42	24	19
1-1/2 to 3 in.	62	40	24	19
950 A, B, C, D				
Sheet, strip	70	50	22	...
Plate, bar				
To 1/2 in.	70	50	22	18
1/2 to 1-1/2 in.	67	45	24	19
1-1/2 in. to 3 in.	63	42	24	19
945X*	60	45	22	18
950X*	65	50	22	18
955X	70	55		
960X	75	60		
965X	80	65		
970X	85	70		

* To 3/8 in. thick.

For mechanical-property data on materials thicker than those listed in the table, suppliers should be consulted. SAE J410b high-strength low-alloy steels may be specified as annealed, normalized, or otherwise specially prepared for forming. When this is done, mechanical properties are agreed upon between supplier and purchaser.

Each grade has chemical composition limits to control welding characteristics in a manner similar to ASTM designations. Table 6-8 lists relative formability, weldability, and toughness of the J410b steels.

TABLE 6-8. Fabrication Characteristics of SAE J410b Steels

Formability	Weldability	Toughness
945A	945A	945A
950A	950A	950A
945C, 945X	950D	950B
950B, 950X	945X	950D
950D	950B, 950X	945X, 950X
950C	945C,	945C, 950C
	950C	

Alloys are listed in order of decreasing excellence; most formable, most weldable, and toughest alloys at the top.

Source: *Machine Design*, Metals Reference Issue, Dec. 14, 1967.

Grade 945A has excellent arc and resistance-welding characteristics and the best formability, weldability, and low-temperature notch toughness. It is available in sheets, strip, and light plate.

Grade 945C is a carbon-manganese steel with satisfactory arc-welding properties if proper procedures are used to prevent hardening of the weld metal. Moderate preheat is usually required, especially for thick sections. It is similar to Grade 950C, but has lower carbon and manganese content to improve arc-welding characteristics, formability, and low-temperature notch toughness, at some sacrifice in strength.

Grade 945X is a columbium or vanadium-treated carbon-manganese steel similar to 945C except for improved toughness and weldability.

Grade 950A has good weldability, low-temperature notch toughness, and formability. It is normally available only in sheet, strip, and light plate.

Grade 950B has satisfactory arc-welding properties and fairly good low-temperature notch toughness and formability.

Grade 950C is a carbon-manganese steel that can be arc welded if the cooling rate is controlled, but is unsuitable for resistance welding. Formability and toughness are fair.

Grade 950D has good weldability and fairly good formability. Its phosphorus content reduces its low-temperature properties.

Grade 950X is a columbium or vanadium-treated carbon-manganese steel similar to 950C except for somewhat improved welding and forming properties.

Several other grades are also covered by SAE J410b — higher-strength steels that have reduced formability and weldability.

Modifications of standard SAE-grade designations are also available. For example, fully killed steels made to fine-grain practice are indicated by the suffix "K." Thus, 945AK is a fully killed, fine-grain, HSLA steel with maximum ladle analysis of 0.15% carbon and a yield strength of about 45,000 psi. All grades made to K practice may not be available from all suppliers. This fine-grain practice is usually specified when low-temperature notch toughness is important.

Steels designated by the suffix "X" contain strengthening elements, such as columbium or vanadium (with or without nitrogen) added singly or in combination. These are usually made semi-killed. However, killed steel may be specified by indicating both suffixes, such as SAE 950XK.

Available HSLA-steel grades often have characteristics in excess of the specification minimums. Literature from producer companies contains information on physical and mechanical property ranges and suggested fabricating and welding practices.

High-Yield Strength Quenched-and-Tempered Alloy Steels

The high-yield-strength quenched-and-tempered construction steels are full-alloy steels that are treated at the steel mill to develop optimum properties. Unlike conventional alloy steels, these grades do not require additional heat treatment by the fabricator except, in some cases, for a stress relief.

These steels are generally low-carbon grades (upper carbon limit of about 0.20%) that have minimum yield strengths from 80,000 to 125,000 psi.

Some high-yield-strength grades are also available in abrasion-resistant modifications (AR steels), produced to a high hardness. Although these steels can have yield strengths to 173,000 psi, hardness (up to 400 Bhn) rather than strength is their key characteristic.

The high-yield-strength quenched-and-tempered alloy steels are used in such widely varying applications as hoist and crane components; end, side, and bottom plates for ore and waste-haulage cars, hopper cars, and gondolas; pressure hulls for submarines; and components for dust-collecting equipment. The AR (abrasion-resistant) modifications are used in applications requiring maximum resistance to abrasive materials — in chutes, hoppers, and dump-truck beds, for example. In such uses, strength properties are secondary and are not usually specified.

Good toughness can be combined with abrasion resistance in those steels, for use in buckets, cutter bars, scraper blades, and impact plates. However, the most abrasion-resistant grades sacrifice impact strength to gain maximum wear resistance.

HY Steels

An important group of high-yield-strength quenched-and-tempered steels is the HY steels. The most common and most available of these is HY80, which has a minimum yield strength of 80,000 psi. Higher-strength grades are HY100, HY130, HY150, and HY180. Availability of HY steels with yield strengths above 100,000 psi was limited at the time of publication, but considerable development work was being done on these materials and availability was increasing.

HY80 is commonly available in plate form. However, it can also be obtained in beams, channels, angles, and tubing. Strength and toughness of HY80 steel and its ability to be welded (under carefully controlled conditions) qualify it for use in critical applications such as pressure hulls for submarines and deep-submergence research and rescue vessels. The higher-strength HY steels will probably also qualify for the same types of applications after sufficient testing has been done to determine their reliability in welded structures.

Mechanical properties of these steels are influenced by section size. Carbon content is the principal factor that determines maximum attainable strength. Most alloying elements make a small contribution to strength, but their dominant effect is on hardenability — which determines the maximum thickness or depth of steel that can be fully hardened on quenching.

HY80 is normally supplied to the toughness requirements of MIL-S-16216. In plate 1/2 to 1-1/2-in. thick, 50 ft-lb of impact energy absorption is required at minus 120°F with a longitudinal Charpy V-notch specimen.

A typical value for the ductile-to-brittle transition temperature of a 100,000-psi steel in 1/2-in. plate is minus 180°F, as determined with both longitudinal and transverse Charpy V-notch specimens.

Many of the high-yield-strength steels are available in three or four strength or hardness levels. The different levels are achieved by variations in carbon and alloy content, tempering temperature, and tempering time.

In general, the 100,000-psi steels have fatigue strengths in the 50,000 to 70,000-psi range in rotating-beam tests. Higher-strength grades have higher endurance limits — about 60% of their tensile strength.

The compressive yield strength of 100,000-psi steels is usually about the same as tensile yield strength. Shear strength generally ranges from about 85 to 100% of the tensile yield strength.

ASTM Specifications

Two plate specifications, ASTM A514 for welded structures and A517 for boilers and other pressure vessels, allow for the effect of section size on yield strength, tensile strength, and ductility. ASTM A514 requires a minimum yield strength of 100,000 psi for material up to 2-1/2-in. thick, and 90,000 psi for material from 2-1/2 to 4 in. thick. ASTM A517 requires uniform yield strengths of 100,000 psi for all material up to 3/4-in. thick. Representative trade names of the A514 and A517 steels are given in Table 6-9.

TABLE 6-9. Representative ASTM A514/517 Steels

Producer	Trade Name
Armco Steel Corp.	SSS-100 SSS-100A SSS-100B
Bethlehem Steel Corp.	RQ-100A, RQ-100 RQ-100B
Great Lakes Steel Corp. and Phoenix Steel Corp.*	N-A-XTRA 100 N-A-XTRA 110
Jones & Laughlin Steel Corp.	Jalloy-S-100 Jalloy-S-110
United States Steel Corp. and Lukens Steel Corp.*	T-1 T-1 Type A T-1 Type B

* Licensee

Weldability

Most high-yield-strength quenched-and-tempered alloy steels can be welded without preheat or postheat. If suppliers' recommendations are followed for controlling welding procedures, 100% joint efficiency can be expected in the as-welded condition for the 90,000 and 100,000-psi yield-strength grades.

If the heat-affected zone cools too slowly, the beneficial effects of the original heat treatment (particularly notch toughness) are destroyed. This can be caused by excessive preheat temperature, interpass temperature, or heat input. On the other hand, if the heat-affected zone cools too rapidly, it can become hard and brittle and may crack. This is caused by insufficient preheat or interpass temperature or insufficient heat input during welding. Producers' recommendations should be followed closely.

The quenched-and-tempered steels can be welded by the shielded metal-arc, submerged-arc, and gas-shielded-arc processes. Weld cooling rates for these processes are relatively rapid, and mechanical properties of the heat-affected zones approach those of the steel in the quenched condition. Reheat-treatment, such as quenching and tempering after welding, is not recommended.

Because of the desirability of relatively rapid cooling after welding, thin sections of these materials can usually be welded without preheating. When preheating is required, both maximum and minimum temperatures are important. If the sections to be welded are warm as a result of preheating and heat input from previous welding passes, it may be

TABLE 6-10. Composition of ASTM A-203-69 Nickel-Steel Plate for Pressure Vessels

Element and Plate Thickness	Composition (%)			
	Grade			
	A*	B*	D†	E†
Carbon, max				
To 2 in.	0.17	0.21	0.17	0.20
2 to 4 in.	0.20	0.24	0.20	0.23
4 to 6 in.	0.23	0.25	...	...
Manganese, max				
To 2 in.	0.70	0.70	0.70	0.70
2 to 4 in.	0.80	0.80	0.80	0.80
4 to 6 in.	0.80	0.80	...	...
Phosphorus, max	0.035	0.035	0.035	0.035
Sulfur, max	0.04	0.04	0.04	0.04
Silicon (ladle analysis)	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30
Nickel (ladle analysis)	2.10-2.50	2.10-2.50	3.25-3.75	3.25-3.75

* Covers plate to 6-in. thick.
† Covers plate to 4-in. thick.

necessary to reduce current or increase arc travel speed for subsequent passes, or to wait until the metal cools somewhat. Interpass temperature is just as important as preheat temperature and should be controlled with the same care.

In the ASTM specifications A514 and A517 there are several grades of quenched and tempered constructional steels listed. Welding procedures for all of these steels are similar but no one procedure is right for all grades. Welding procedures are available from the steel manufacturers. When in doubt, consult the steel manufacturer.

The following is a general shielded metal-arc procedure for one of the popular grades of quenched and tempered constructional steels and can be used as a *guide* for all grades or other welding processes.

Use only low hydrogen type electrodes and usually the electrode specified for A514 and A517 steels is E11018. Under some conditions a lower tensile strength electrode may be used and this will be discussed later. Make sure electrodes are dry. Under normal conditions of humidity electrodes should be returned to the drying ovens after an exposure of four hours maximum. If the humidity is high, reduce the exposure time. Electrodes are shipped in hermetically sealed containers and the contents of any damaged container should be redried before using. See Table 6-14 for drying temperatures.

Clean the joint thoroughly. Remove all rust and scale preferably by grinding. If the base metal has been exposed to moisture, preheat to drive off the moisture. On thin sections, allow the plate to cool, if necessary, before starting to weld.

The amount of preheat and the amount of welding heat put into the weld must be kept within definite boundaries during the actual welding. Usually preheating is not necessary or desirable on thin sections but in order to avoid cracks preheating is necessary if:

The joints are highly restrained.

The structure is very rigid.

The weld joint is on thick sections.

Whether or not the base metal is preheated, it is necessary to approximate the heat input before starting to weld. The heat input in watt-seconds (joules) per linear inch of weld is

$$\text{Heat input} = \frac{I \times E \times 60}{V}$$

where I is the arc amperes, E is the arc volts, and V is the welding speed in in./min. Calculation by this formula is only approximate because the heat losses can be large. Also, there are many variables that affect the heat distribution and the maximum temperature of the base metal at the joint but the formula is sufficiently accurate to predict the maximum allowable heat input for a given set of conditions.

In industry, the term "heat unit" is used and is equal to the watt-seconds per linear inch of weld divided by 1000.*

*A calculator is available from the United States Steel Corporation for quickly determining heat units. Also available are tables for maximum heat units when welding T-1, T-1 Type A, and T-1 Type B

Maximum suggested heat units input for USS T-1 steel per linear inch of weld is shown in the table below.

Suggested Maximum Heat Units†

Preheat and Interpass Temperature	Plate Thickness							
	3/16"	1/4"	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"
70°F	27	36	70	121	any	any	any	any
200°F	21	29	56	99	173	any	any	any
300°F	17	24	47	82	126	175	any	any
350°F	15	21.6	43.5	73.5	109.5	161	any	any
400°F	13	19	40	65	93	127	165	any

† From the "*Welding Heat Input Calculator*" by the United States Steel Corporation.

Also see Section 3-3.

Before making a production weld it is recommended to set up a tentative procedure and make a test weld. The tentative procedure includes the preheat, if any, interpass temperature, welding current, voltage, and welding speed. It is important to keep the welding current, speed and interpass temperature under close control.

The following are some general rules to follow to promote good weld quality.

Always use stringer beads, never wide weave beads.

Clean thoroughly between passes.

Use the same precautions to prevent cracking as discussed earlier in this section.

Back gouge with arc gouging and remove the scale by grinding. Do not use oxyacetylene to back gouge.

Usually the electrodes used are the E11018 type but lower strength electrodes may be specified where the stress does not require the high yield strength of E11018. A good example is the lower stress in the web to flange fillet welds. However, if lower strength electrodes are used the same limitations apply as to heat input and interpass temperature.

Low-Alloy Steels

Small amounts of alloying elements such as nickel, chromium, and molybdenum can be added to steels to increase strength, hardness, or toughness, or to improve resistance to heat, corrosion, or other environmental factors. These improvements are sometimes gained with little effect on weldability or other fabricability characteristics. Generally, however, welding of low-alloy steels requires more careful control of procedures and selection of electrodes than welding of the carbon steels.

Nickel Steels

A low nickel addition (2 to 5%) greatly increases strength and hardenability and improves the corrosion resistance of a steel without a proportional reduction in ductility or a significant effect on weldability. The compositions of various thicknesses of nickel-steel plate (ASTM A-203), used principally for pressure vessels, are listed in Table 6-10.

Straight nickel steels are used mainly for low-temperature pressure vessels. The nickel content significantly improves toughness and impact strength at subzero temperatures. Nickel is also very effective in improving the hardenability of steels; heat treatment is easy because nickel lowers the critical cooling rate necessary to produce hardening on quenching.

A nickel steel containing 0.24% carbon and 2.7% nickel can have a tensile strength (normalized and drawn) of over 85,000 psi; an unalloyed steel would require a carbon content of over 0.45% to be that strong. Notch toughness of a 3-1/2% nickel steel, with a tensile strength of 70,000 to 85,000 psi, would be 15 ft-lb at minus 150°F (Charpy keyhole test), whereas a carbon steel of that strength would have a notch toughness of 15 ft-lb down to only minus 50°F.

Nickel increases hardenability for a given carbon content. For best weldability and minimum cracking tendency, carbon content should, of course, be low — no more than 0.18% if extensive welding is to be done without preheat.

For specific procedures see page 6-2.54.

Chromium Steels

In the low-alloy steels, chromium increases tensile strength, hardenability, and, to some extent, atmospheric corrosion resistance. Chromium steels with less than 0.18% carbon are readily weldable, using proper precautions against cracking. The combination of chromium and higher carbon increases hardenability and requires preheating and sometimes postheating to prevent brittle weld deposits. Production welding is not recommended for chromium steels containing more than 0.30% carbon.

Nickel-Chromium Steels

The nickel-chromium steels of the AISI series are no longer standard alloys but occasionally ther is a need to weld these alloys, especially in maintenance work.

The addition of chromium is intended to increase hardenability and response to heat treatment for a given carbon content over that of the straight nickel low alloy steels. Also a small amount of several alloying elements judiciously chosen may give a greater range of hardenability plus toughness than a larger or more costly amount of a single alloying element.

Chromium is a potent hardening agent and it is necessary to keep the carbon content low for weldability. Thin sections of the lowest carbon content type can usually be welded without preheat but the higher carbon grades require preheat and subsequent stress relief or annealing.

The lower carbon grades of the nickel-chromium steels can be welded with electrodes of the EXX15-16-18 classes and in the as welded condition the weld properties will match the base metal. However, if the weldment must be heat treated after welding, special low-hydrogen type electrodes are required. These electrodes must deposit weld metal that will respond to the same heat treatment as the base metal and match base metal properties.

The higher carbon alloys (above .40%) are not readily welded but, if necessary, a weld can usually be made with stainless E309 (second choice E310) electrodes. The weld will usually be tough and ductile but the fusion zone may be brittle. The fact that the weld is ductile allows it to give a little without putting too much bending in the brittle zone. Preheat is advised. See Section 3-3.

Molybdenum Steels

Molybdenum increases the hardenability and high-temperature strength of low-alloy steels. The low-alloy molybdenum steels are of three general types: carbon-molybdenum (AISI 4000 series), chromium-molybdenum (4100 series), and nickel-molybdenum (4300, 4600, 4700, and 4800 series).

A common use of carbon-moly and chrome-moly steels is in high-pressure piping used at high temperatures. These steels are usually purchased to an ASTM specification. Another typical use of the chrome-moly alloys — usually in the form of tubing — is in highly stressed aircraft parts. Weldability of these thin-section members is good because of the low carbon content. Low-carbon grades of these steels (below 0.18%) can usually be welded without preheat. The higher-carbon nickel and chromium grades of molybdenum steels are air-hardening.

The low carbon grades (below .18%) of carbon-moly steel can be welded much the same as mild steel. E7010-A1, E7018, and E7027-A1 electrodes will give tensile strengths in the same range as plate strength in the as-welded condition. The above electrodes with .5% moly will come close to approximating plate properties and analysis where subsequent heat treatment is required. (See Preheat Table for steels above .18% carbon.)

When carbon content of the carbon-moly alloys is low (approximately .15%), these steels are readily weldable. In pressure vessels, this low carbon content is usually used, but in piping the carbon may be somewhat higher. Where carbon is above .18% preheating is generally required.

Welding procedure is essentially the same as for mild steel. In the case of piping, a back up ring is recommended generally to keep the inside of the pipe clean. The ring if of proper design causes only slight obstruction which is not objectionable, in most cases.

Where backing ring is not used, an experienced weldor can put in a first pass with a small reinforcement in the inside. It is important that this first pass completely penetrate the joint so that no notch is left at the root of the joint.

Stress relieving is generally specified when the thickness of the metal is greater than 3/8". Temperature of 1200° — 1250°F is used with usual procedure as to time of heating (one hour per inch of thickness) and length of pipe heated (6 times thickness on each side of weld).

The cooling rate is from 200° — 250°F per hour down to 150° — 200° F in which case cooling may be done in still air.

For the welding of the steels mentioned herein the use of E7010-A1 electrode is recommended for ease of welding in out-of-position work. The preheat and post heat treatment above is also required when E7010-A1 electrodes are used. Where the work can be positioned for downhand welding or where large welds are required in any position, the low hydrogen electrodes can be used to advantage as they will reduce the preheat temperatures required.

In applications where tensile strength of weld need not be as high as the base metal but where other physical characteristics of the weld should be comparable to the base metal, the regular type of electrode, as used for welding mild steel, can be employed with very satisfactory results. For joining work of this type, E6010 electrodes are recommended.

On light chrome-moly tubing, E6013 electrodes designed especially for aircraft work are often used. These mild steel electrodes usually pick up enough alloy from the base metal to give the required tensile strength in the as-welded condition. When welded on the AISI 4130, their normal 70,000 to 80,000 psi tensile strength is increased by pick-up of alloy and carbon to a satisfactory approximation of the physical properties of AISI 4130. The additional thickness of weld due to the usual build-up on light gauge work makes the welded joint stronger than the parent metal.

On the higher carbon and alloy grades where heat treated welds with properties similar to plate properties are necessary, special electrodes can be used that will deposit the proper analysis. A low hydrogen type electrode is used to reduce the tendency for cracking that is quite prevalent on these steels. Preheat and post heat treatment usually will be required.

On the grades over .40% carbon where production welding is not recommended, it is possible to make a weld with E309 type stainless electrode or E310 as a second choice. The weld will be fairly ductile if the proper low penetrating procedure is used; however, the fusion zone may be very brittle depending upon the air hardenability of the alloy. Preheating and slow cooling will tend to reduce this hardness in the fusion zone.

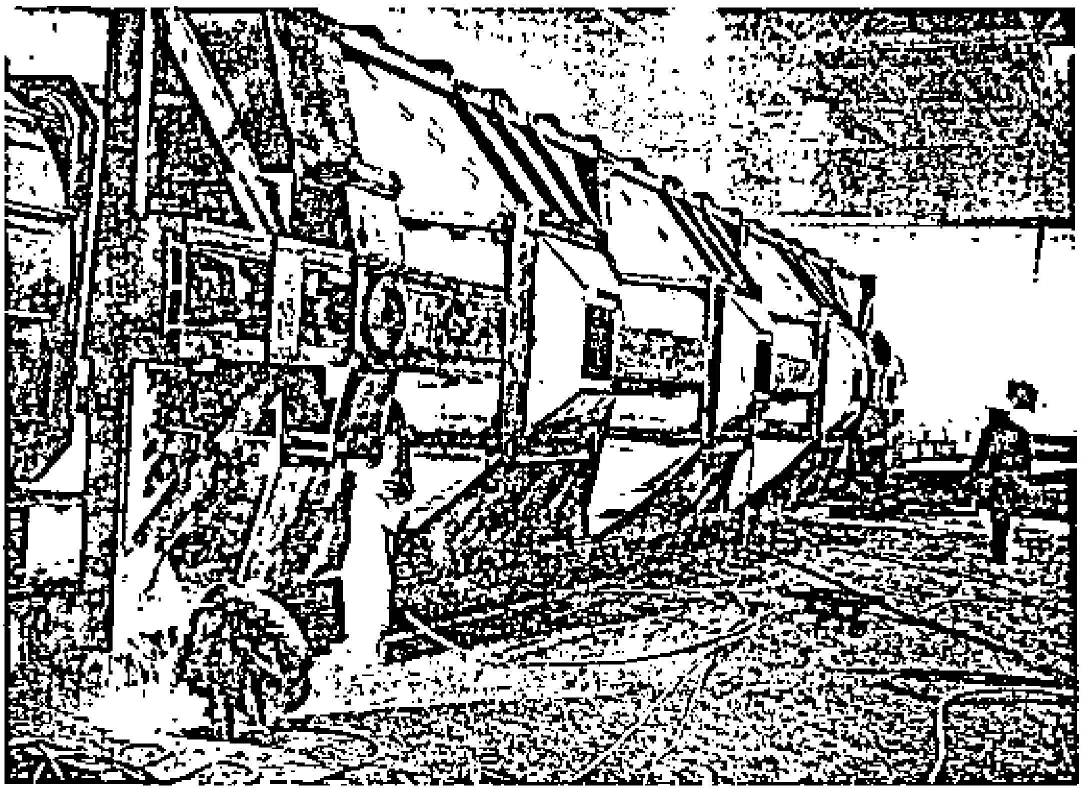
Where molybdenum is added to base metals to increase the resistance to creep at elevated temperatures, the electrode deposit must have a similar amount of molybdenum.

The following table gives the approximate preheat and interpass temperatures for AISI alloy steel bars when welded with low-hydrogen type electrodes.

Approximate Preheat and Interpass Temperature for AISI Alloy Steel Bars*

AISI Steel	Preheat and Interpass Temperature °F – section thickness, in.		
	To 1/2	1/2 – 1	1 – 2
1330	350 – 450	400 – 500	450 – 550
1340	400 – 600	500 – 600	600 – 700
4023	100 min.	200 – 300	250 – 350
4028	200 – 300	250 – 350	400 – 500
4047	400 – 500	450 – 550	500 – 600
4118	200 – 300	350 – 450	400 – 500
4130	300 – 400	400 – 500	450 – 550
4140	400 – 500	600 – 700	600 – 700
4150	600 – 700	600 – 700	600 – 700
4320	200 – 300	350 – 450	400 – 500
4340	600 – 700	600 – 700	600 – 700
4620	100 min.	200 – 300	250 – 350
4640	350 – 450	400 – 500	450 – 550
5120	100 min	200 – 300	250 – 350
5145	400 – 500	450 – 550	600 – 600
8620	100 min	200 – 300	250 – 350
8630	200 – 300	250 – 350	400 – 500
8640	350 – 450	400 – 500	450 – 550

* From ASM Metal Handbook Volume 6, Eighth Edition.



This hopper car has a carbon steel frame and stainless steel hoppers. Weldors are working on the frame.

Welding Carbon and Low-Alloy Steels with the Shielded Metal-Arc Process

Most welding on steel is done manually with shielded metal-arc (stick) electrodes. As in any manual process, the skill and dexterity of the operator are important for quality work; but equally important is selection of the correct type of electrode.

CONSIDERATIONS IN ELECTRODE SELECTION

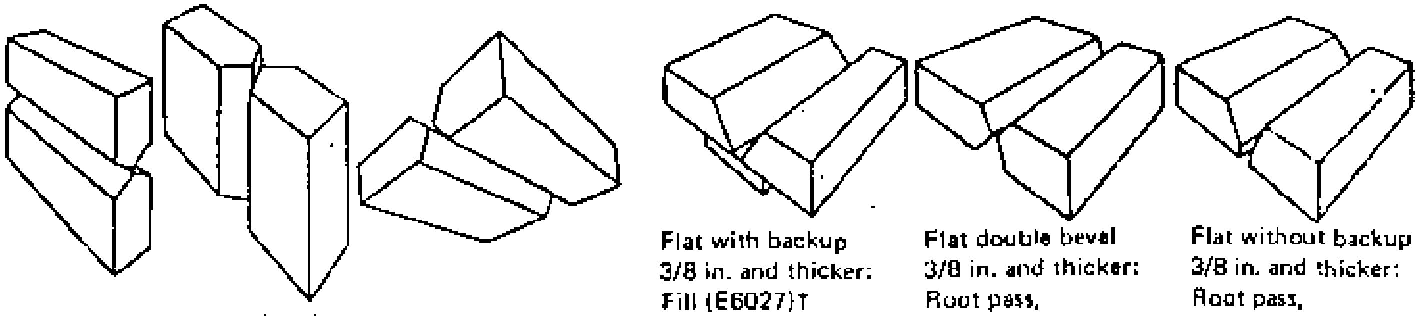
Choice of electrode is straightforward when welding high-strength or corrosion-resistant steels. Here, choice is generally limited to one or two electrodes designed specifically to give the correct chemical composition in the weld metal. But most arc welding involves the carbon and low-alloy steels for which many different types of electrodes provide satisfactory chemical compositions in the weld metal. From the many possibilities, the object is to pick an electrode that gives the desired quality of weld at the lowest welding cost. Usually, this means the electrode that allows the highest welding speed with the particular joint. To meet this objective, electrodes are selected according to the design and positioning of the joint.

Electrodes compounded to melt rapidly are called "fast-fill" electrodes, and those compounded to solidify rapidly are called "fast-freeze" electrodes. Some joints and welding positions require a compromise between the fast-fill and fast-freeze characteristics, and electrodes compounded to meet this need are called "fill-freeze" electrodes. There are also electrodes which are classified as "fast follow."

The fill-freeze-follow terminology used to classify types of electrodes is also used to designate types of joints. Overhead or vertical joints that normally require fast-freeze electrodes are thus termed "freeze" joints, while flat joints and some horizontal joints, where rapid deposition is important, are called "fill" joints. Some joints, especially those in sheet metal, require an electrode that permits rapid electrode travel with minimum skips, and are thus called "follow" joints. The fill-freeze electrodes usually are best suited for follow joints, and thus, fill-freeze electrodes are called fast-follow electrodes when the reference is to joints requiring fast electrode travel.

Although the terms fill, freeze, and fill-freeze, are straightforward as applied to electrodes, use of these terms to describe types of joints is not so clear-cut. For example, some overhead "freeze" joints require a fill-freeze, rather than fast-freeze, electrode. By the same token, a "follow" joint in sheet metal may require a fast-freeze, rather than a fill-freeze, electrode. The use of these terms to identify types of joints, and the types of electrodes

BUTT WELDS



Horizontal / Vertical
Plate 3/16 to 5/8 in.
Freeze (E6010, E6011)

Overhead
Plate over 5/8 in.
Fill-freeze (E7018)

Flat with backup
3/8 in. and thicker:
Fill (E6027)†

Flat double bevel
3/8 in. and thicker:
Root pass,
Fill-freeze (E7018);
All other passes,
Fill (E6027)†

Flat without backup
3/8 in. and thicker:
Root pass,
Fill-freeze (E7018);
All other passes,
Fill (E6027)†

†E7028 may be substituted

Fig. 6-14. Guide to selection of electrodes for butt welds recommended for these joints, are explained in Fig. 6-14, 6-15, and 6-16, which show butt welds, fillet welds, and sheet-metal welds, respectively.

AWS A5.1-69 is a complete specification for mild-steel electrodes for shielded metal-arc welding (see Section 4.1). Typical mechanical properties of mild-steel deposited weld metal are given in Table 6-11.

A combination of letters and numbers used by the American Welding Society to identify the various classes of electrodes is given in Table 4-1. For a more complete description of this system see Section 4.1. Typical current ranges for all AWS A5.1 electrodes is given in Table 6-12. A guide to the application of electrodes for steels of specific ASTM designations is presented in Table 6-13.

TABLE 6-11. Typical Mechanical Properties of Mild-Steel Deposited Weld Metal

Electrode Classification	Condition							
	As-Welded				Stress-Relieved at 1150° F			
	Tensile Strength (psi)	Yield Strength (psi)	Elong. in 2 in. (%)	Impact* (ft-lb)	Tensile Strength (psi)	Yield Strength (psi)	Elong. in 2 in. (%)	Impact* (ft-lb)
E6010	69,000	60,000	28	55 (1)	65,000	51,000	32	75
E6011	70,000	63,000	25	50 (1)	65,000	51,000	30	90
E6012	72,000	64,000	21	43	71,000	62,000	23	47
E6013	74,000	62,000	24	55	74,000	58,000	28	
E6020	67,000	57,000	27	50				
E6027	68,000	58,000	28	40 (1)	66,000	57,000	30	80
E7014	73,000	67,000	24	55	73,000	65,000	26	48
E7015	75,000	68,000	27	90				
E7016	75,000	68,000	27	90	71,000	60,000	32	120
E7018	74,000	65,000	29	80 (1)	72,000	58,000	31	120
E7024	86,000	78,000	23	38	80,000	73,000	27	38
E7028	85,000	78,000	26	26 (2)	81,000	73,000	26	85

* Charpy V-notch at 70°F except where noted.
(1) Charpy V-notch at −20°F.
(2) Charpy V-notch at 0°F.

TABLE 6-12. Typical Current Ranges for Electrodes

Electrode Diameter (in.)	Current Range (amp)								
	Electrode Type								
	E6010, E6011 DC+	E6012	E6013	E6020	E6027	E7014	E7015, E7016	E7018	E7024, E7028
1/16	–	20 – 40	20 – 40	–	–	–	–	–	–
5/64	–	25 – 60	25 – 60	–	–	–	–	–	–
3/32	40 – 80	35 – 85	45 – 90	–	–	80 – 125	65 – 110	70 – 100	100 – 145*
1/8	75 – 125	80 – 140	80 – 130	100 – 150	125 – 185	110 – 160	100 – 150	115 – 165	140 – 190
5/32	110 – 170	110 – 190	105 – 180	130 – 190	160 – 240	150 – 210	140 – 200	150 – 220	180 – 250
3/16	140 – 215	140 – 240	150 – 230	175 – 250	210 – 300	200 – 275	180 – 255	200 – 275	230 – 305
7/32	170 – 250	200 – 320	210 – 300	225 – 310	250 – 350	260 – 340	240 – 320	260 – 340	275 – 365
1/4	210 – 320	250 – 400	250 – 350	275 – 375	300 – 420	330 – 415	300 – 390	315 – 400	335 – 430
5/16	275 – 425	300 – 500	320 – 430	340 – 450	375 – 475	390 – 500	375 – 475	375 – 470	400 – 525*

*These values do not apply to the E7028 classification.

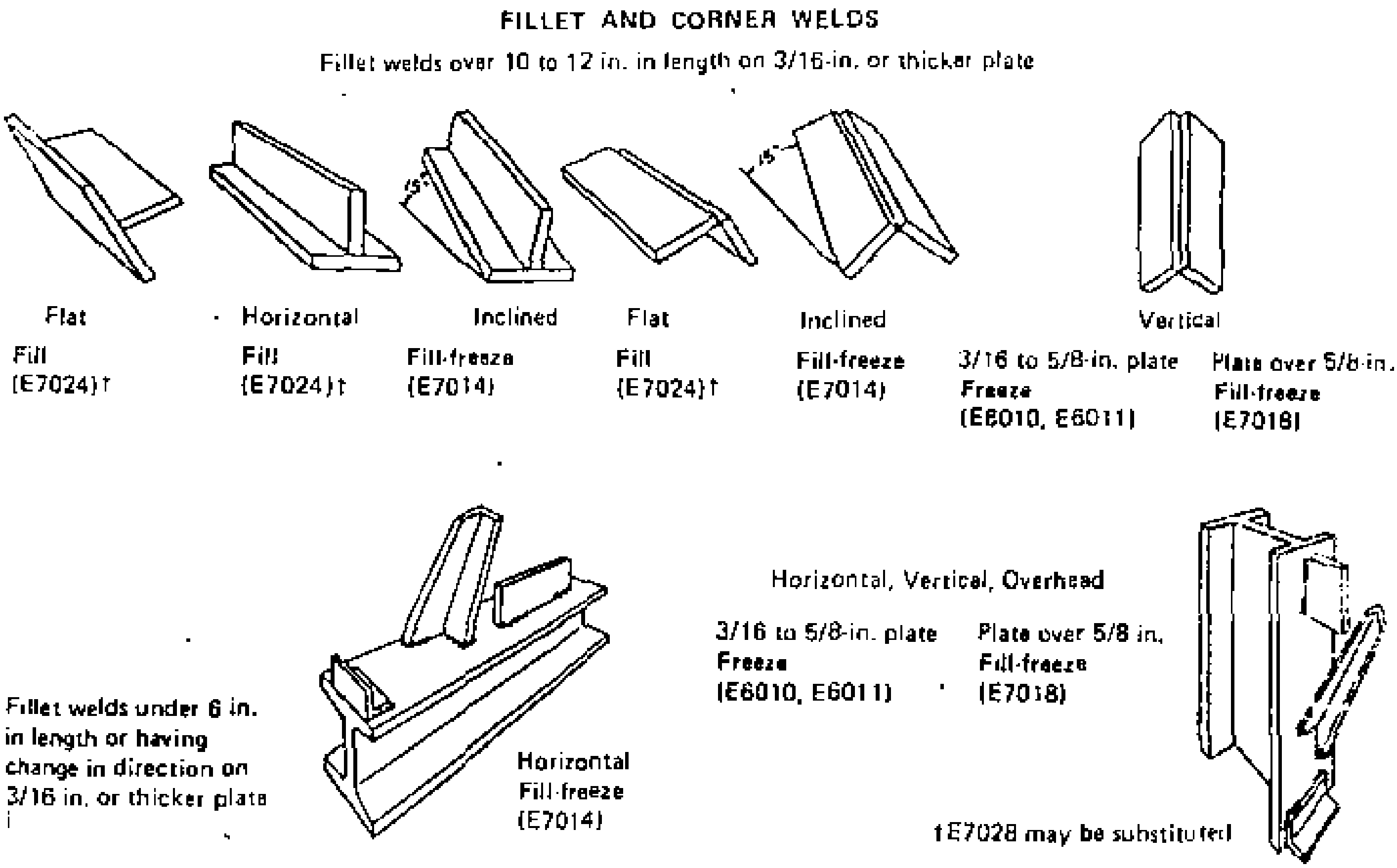


Fig. 6-15. Guide to selection of electrodes for fillet and corner welds

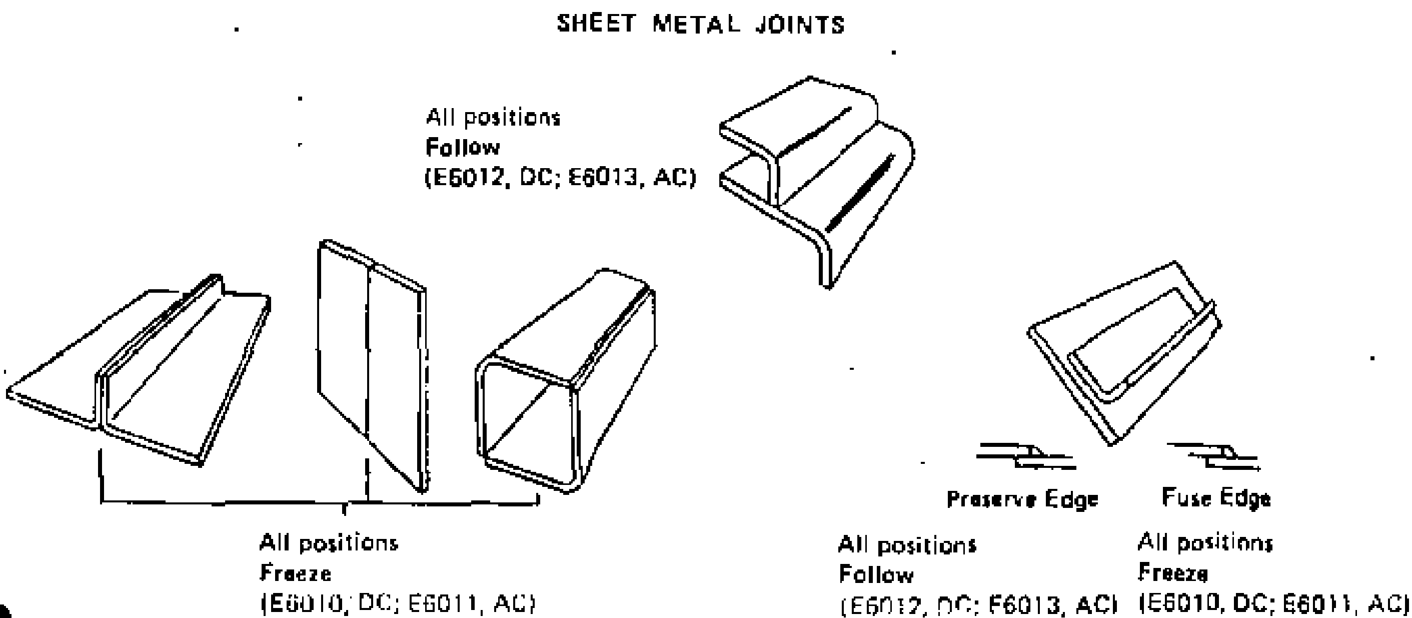


Fig. 6-16. Guide to selection of electrodes for sheet-metal welds

TABLE 6-13. Recommended Electrodes for Carbon and Low Alloy ASTM Steels (See Note 10)

ASTM Specification	Description	Grades	Recommended Electrodes
	Steel Plates, Sheets, Forgings, Shapes, and Castings		
A36-74	Structural 36,000 psi Min. YS		Note 1
A113-70a	Railway rolling stock	All	Note 1
A131-74	Structural for ships	A, B, C, CS, D & E	Note 1
		AH, DH & EH	E7018
A148-73	Steel castings for structural use	80-40 & 50	E8018-C3
		90-60	E9018-G
		105-85 & 120-95	E11018-M
A202-74a	Boiler & pressure vessel	A & B	E9018-G
A203-74a	Pressure vessel	A & B	E8018-C1
		D & E	E8018-C2
A204-74a	Boiler & pressure vessel	A & B	E7010-A1 or E7018-A1
		C	E8018-B2
A205-74a	Boiler & pressure vessel	A & B	E8018-C3
A225-74a	Boiler & pressure vessel	A & B	E8018-C3
A236-74	Forgings, railway	A & B	E7018 or E7028
		C, D & E	E8018-C3
		F & G	E9018-G
		H	E11018-M
A238-71	Forgings, railway	A	E8018-C3
		B	E9018-G
		C, D & E	E11018-M
A242-74	High strength structural	All	E7018 or E7028, Note 3
A266-69	Drum forgings	1	Note 1
		2	E7018
		3	E8018-C3
A283-74	Structural plates	All	Note 1
A284-70a	Carbon-silicon plates	All	Note 1
A285-74a	Flange & firebox plate	All	Note 1
A299-74a	Boiler plate	All	E8018-C3
A302-74a	Boiler & pressure vessel	All	E8018-C3
A328-70	Steel piling	All	E7018 or E7028
A336-70a	Alloy forgings	F1	E7018-A1
		F12	E8018-B2
		Other grades	Note 9
A352-74a	Low-temperature castings	LCA, LCB & LCC	E7018
		LC1	E7018-A1
		LC2	E8018-C1
		LC3	E8018-C2
A356-74	Steam-turbine castings	5	E8018-B1
		6	E8018-B2
		8 & 10	E9018-B3
A361-71	Galvanized sheets		Notes 1 & 8
A366-72	Carbon steel sheets		Note 1
A372-74	Pressure vessel forgings	Class I	E7018 or E7028
		Class II	E8018-C3
		Class III	E9018-G
		Class IV	E11018-M
A387-74a	Cr-Mo boiler plate	A, B & C	E8018-B2
		D	E9018-B3
A389-74a	High-temperature castings	C23	E8018-B2
		C24	E9018-B3
A410-72	Pressure vessel plate		E8018-C2

Continued

TABLE 6-13. Recommended Electrodes for Carbon and Low Alloy ASTM Steels, Cont'd. (See Note 10)

ASTM Specification	Description	Grades	Recommended Electrodes
		Steel Plates, Sheets, Forgings, Shapes, and Castings	
A414-72	Flange & firebox sheet	A, B, C & D	Note 1
		E & F	E7018 or E7028
		G	E8018-C3
A424-73	Sheet for porcelain enameling		E7018
A441-74	High-strength structural	All	E7018 or E7028
			Note 3
A442-74	Fine grain plate	All	E7018 or E7028
A444-71	Galvanized steel sheet	A, B & C	Note 1 & 8
A446-72		D & F	E7010-A1
A455-74C	C-Mn pressure vessel plate	All	E8018-C3
A486-74	Highway bridge castings	70	E7018 or E7028
		90	E9018-G
A487-71a	Castings for pressure service	8N, 9N	E8018-B3
		A, AN, AQ, B, N, C & CN	Note 1
		BQ & CQ	E8018 C3
A514-74a	Quenched & tempered plate	All	E11018 M
			Note 4
A515-74b	High-temperature boiler plate	All	E7018 or E7028
A516-74a	Low-temperature pressure —	55 & 60	E7018 or E7028
	vessel plate	65 & 70	E7018 or E8018-C3
A517-74a	Quenched & tempered plate	All	E11018-M
			Note 4
A526-71	Galvanized sheets		Notes 1 & 8
A528-71			
A529-72	Structural, 42,000 psi Min. YS		Note 1
A533-74	Quenched & tempered plate	Class 1	E8018-C3
		Class 2 & 3	E11018-M
A537-74	Pressure-vessels and structures	Class 1	E7018 or E7028
		Class 2	E8018-C3
A541-73	Pressure vessel forging	Class 1	E7018 or E7028
		Class 2, 3 & 4	E8018 C3
		Class 5	E8018-B2
		Class 6	E9018-B3
A543-74	Quenched & tempered plate	1, 2 & 3	E11018-M
			Note 4
A570-72	Structural sheet & strip	All	Note 1
A572-74b	Structural plate	42 & 45	Note 1
		50 & 55	E7018 or E7028
		60 & 65	E8018-C3
E573-74	Structural plate	65 & 70	E7018 or E7028
E588-74a	High-strength structural	All	E7018 or E7028
			Note 3
E606-71	High-strength sheet	All	Note 1
E607-70	High-strength low-alloy sheet	45, 50 & 55	Note 1
		60 & 65	E8018 C3
		70	E9018-G
E611-72	Cold rolled sheet	A, B, C & D	Note 1
A615-74a	Reinforcement bars	40	Note 1
		60	E9018 G
		75	E11018 M
A616-72	Reinforcement bars	50	E8018-C3
		60	E9018-G
A617-74	Reinforcement bars	40	Note 1
		60	E9018 G
A706-74	Reinforcement bars	60	E9018-G

Continued

TABLE 6-13. Recommended Electrodes for Carbon and Low Alloy ASTM Steels, Cont'd. (See Note 10)

ASTM Specification	Description	Grades	Recommended Electrodes
		Steel Pipe, Tubes, and Fittings	
A53-73 A106-74 A120-73 A135-73d A139-74 A179-73 A192-73 A211-73 A214-71 A226-73 A252-74 A523-73 A587-73 A589-73	Mild-steel pipe	All	Notes 1 and 2
A105-73	High-temperature fittings	I & II	E7018
A106 74	High-temperature pipe	A, B, C	E7018
A155 74	High-temperature pipe	C45, C50, C55	Note 1
		KC & KCF-55, 60	E7018 or E7028
		KC & KCF-65	E7018 or E7028
		CM65, 70	E7010-A1 or E7018-A1
		CM75	E8018-B2
		CMS75 & CMSH70	E8018-C3
		1/2, 1, & 1-1/4, Cr	E8018-B2
		2-1/4 Cr	E9018-B3
E161-72	Still tubes	Low-carbon	Note 1
		T1	E7010-A1 or E7018-A1
E178-73 & E179-73	Boiler tubes & Condenser tubes	All	Note 1
A181-68	General service fittings	I & II	E7018 or E7010-A1
A182-74	High-temperature fittings	F1	E7010-A1, E7018-A1
		F2, F11, F12	E8018-B2, Note 9
A199-73	Heat-exchanger & condenser tubes	T11	E8018-B2, Note 9
A200-72	Refinery still tubes	T11	E8018-B2, Note 9
A209 73	Carbon-moly boiler tubes	T1, T1a & T1b	E7010-A1, E7018-A1
A210-73	Carbon-steel boiler tubes	A1	Note 1 or E7010-A1
		C	E7010-A1
A213-74b	Boiler tubes	T2, T11, T12, & T17	E8018-B2
A214-74b	Condenser tubes	All	Note 1
A216-74b	High-temperature cast fittings	WCA, WCB, WCC	E7018 or E7018-A1
A217-74c	High-temperature cast fittings	WC1	E7010-A1
		WC4	E8018-C3
		WC6	E8018-B2
A234-74	Wrought welding fittings	WPA, WPB & WPC	Note 1
		WP1	E7010-A1, Note 2
		WP11	E8018-B2
A250-73	Carbon-moly boiler tubes	T1, T1a, T1b	E7010-A1, Note 2
A333-74 & A334-74	Low-temperature pipe	1 & 6	E7018 or E8018-C3
		3	E8018-C2
		7	E8018-C1
A335-74a	High-temperature pipe	P1	E7010-A1, Note 2
		P2, P11 & P12	E8018-B2
		Others	Note 9
A350-74	Low temperature fittings	LF1 & LF2	E8018-C1
		LF3	E8018-C2
		LF5	E8018-C3
A369 73a	High-temperature pipe		See A335 & A182

Continued

TABLE 6-13. Recommended Electrodes for Carbon and Low Alloy ASTM Steels, Cont'd. (See Note 10)

ASTM Specification	Description	Grades	Recommended Electrodes
	Steel Pipe, Tubes, and Fittings (continued)		
A381-73	High-pressure pipe	Y35, Y42 & Y46	Notes 1 & 2
		Y52 & Y56	Note 5
		Y60 & Y65	Note 5 or E8018-C3
A405-70	High-temperature pipe	P24	E8018-B2
A420-73	Low-temperature pipe	See A203, A333, A334, A350	
A423-73	Low-alloy tube	1 & 2	E8018-C3 or E7018
A426-74	High-temperature cast pipe		See A335
A498-73	Condenser tubes	See A199, A179, A213, A214, & A334	
A500-74a	Structural tubing	A, B & C	E7018 & Note 1
A501-74	Structural tubing		E7018 & Note 1
A524-72a	Process piping	1 & 2	E7010-A1 or E7018
A556-73 &	Feed water heater tubes	A2 & B2	E7018, Note 1
A557-73		C2	E7018
A618-74	Structural tubing	I II & III	E7018

Note 1. Unless restricted by specifications; use any E60XX or E70XX electrode for steel grades with 60,000 psi or less tensile strength. for steel grades with 60,000 to 70,000 psi tensile strength use E70XX electrodes

Note 2. Use E7010-G, specially designed for field-welding pipe.

Note 3. Use E8018-C1 or E8010-B2 for best color match on unpainted steels with enhanced atmospheric corrosion resistance. Consult the steel supplier

Note 4. E7018 or E8018-C3 are frequently used for fillet welds

Note 5 Use special electrode designed for field welding 5LX pipe, Grades X42 thru X65

Note 6. Do not use E8018 B2 for low-temperature applications

Note 7. E7018, E7028 for fillets, or E8018 C3 for general purpose welding, can be used on these steels. If the weldment is to be precipitation-hardened or high weld strength is required, use E8018 B2.

Note 8. Usually E6010 is the most satisfactory electrode for galvanized sheet.

Note 9. Electrode recommendations for other alloy steels may be found in Sections 6.1 and 7.2

Note 10. These recommendations are based on matching the tensile properties of the weld deposit and the plate, and also the chemical properties of the weld deposit and the plate where chemistry is important. Since it is impossible to foresee all the conditions of every application, other electrodes than those recommended here may also be satisfactory and should be tested before the weldment is started

FAST-FREEZE ELECTRODES

Fast-freeze electrodes are compounded to deposit weld metal that solidifies rapidly after being melted by the arc, and are thus intended specifically for welding in the vertical and overhead positions. Although deposition rates are not as high as with other types of electrodes, the fast-freeze type can also be used for flat welding and is, thus, considered an "all-purpose" electrode that can be used for any weld in mild steel. However, welds made with fast-freeze electrodes are slow and require a high degree of operator skill. Therefore, wherever possible, work should be positioned for downhand welding, which permits the use of fast-fill electrodes.

Fast-freeze electrodes provide deep penetration and maximum admixture. The weld bead is flat with distinct ripples. Slag formation is light, and the arc is easy to control.

Applications for fast-freeze electrodes are:

- General-purpose fabrication and maintenance welding.
- Vertical-up and overhead plate welds requiring X-ray quality.
- Pipe welding, including cross-country, in-plant, and noncritical small-diameter piping.
- Welds to be made on galvanized, plated, painted, or unclean surfaces.
- Joints requiring deep penetration, such as square-edge butt welds.
- Sheet-metal welds, including edge, corner, and butt welds.

Electrode Characteristics

E6010: This is the basic fast-freeze electrode for general-purpose DC welding. Light slag and good wash-in permit excellent control of the arc. The E6010 electrode is particularly valuable for critical out-of-position applications, such, as with pipe welding.

E6011: A general fast-freeze electrode for use with industrial AC welders, E6011 is also the preferred electrode for sheet-metal edge, corner, and butt welds with DCSP. The electrode is also used for vertical-down welding, and for applications requiring exceptionally low silicon deposit. Special grades are available for general-purpose shop use with small, low open-circuit voltage AC welders (not suitable for X-ray quality). E6011 is also available in a special grade producing little slag, that is designed especially for tack welding.

E7010-A1: This fast-freeze electrode is designed for welding high-strength pipe, such as X52 or X56, and for other out-of-position welding where high strength or control of alloy in the weld are important. It produces a 70,000-psi deposit containing 0.5% molybdenum. Operation is similar to E6010.

E7010-G: This electrode is similar to E7010-A1, but is designed specifically to avoid any surface-hole tendency in fill and cover-pass welds on high-strength pipe. Special grades are available for welding all passes on X60 and X65 high-strength line pipe.

Welding Techniques

Current and Polarity: Unless otherwise specified, use DCRP with Exx10, and use AC with Exx11. Exx11 electrodes can be used on DCRP with a current about 10% below normal AC values. Always adjust current for proper arc action and control of the weld puddle.

Flat Welding: Hold an arc of 1/8 in. or less, or touch the work lightly with the electrode tip. Move fast enough to stay ahead of the molten pool. Use currents in the middle and high portion of the range.

Vertical Welding: Use an electrode of 3/16 in. or smaller. Vertical-down techniques are used by pipeliners and for single-pass welds on thin steel. Vertical-up is used for most plate welding. Make the first vertical-up pass with either a whipping technique for fillet welds, or with a circular motion for V-butt joints (Fig. 6-17). Apply succeeding passes with a weave, pausing slightly at the edges to insure penetration and proper wash-in. Use currents in the low portion of the range.

Overhead and Horizontal Butt Welds: Use an electrode of 3/16 in. or smaller. These welds (Fig. 6-18) are best made with a series of stringer beads,

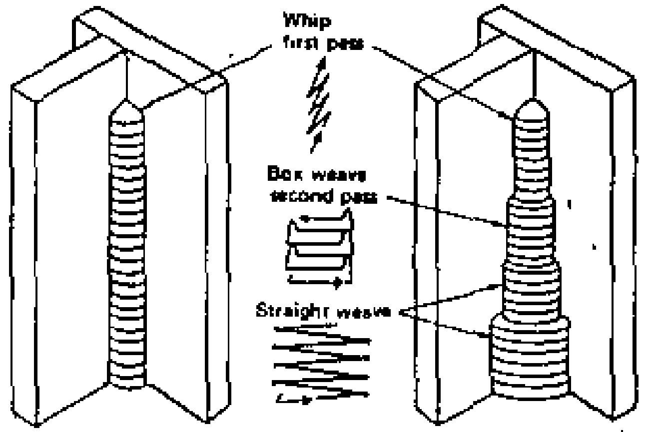


Fig. 6-17. Technique for vertical welding with fast-freeze electrodes

using a technique similar to those described for first-pass vertical-up welds.

Sheet-Metal Edge and Butt Welds: Use DCSP. Hold an arc of 3/16 in. or more. Move as fast as possible while maintaining good fusion. Position the work 45° downhill for fastest welding. Use currents in the middle range.

FAST-FILL ELECTRODES

Fast-fill electrodes are compounded to deposit metal rapidly in the heat of the arc and are, thus, well suited to high-speed welding on horizontal surfaces. The weld metal solidifies somewhat slowly; therefore this type of electrode is not well suited for out-of-position welds. However, a slight downhill positioning is permissible. Joints normally considered fast-fill include butt, fillet, lap, and corner welds in plate 3/16 in. or thicker. These joints are capable of holding a large molten pool of weld metal as it freezes.

Arc penetration is shallow with minimum admixture. The bead is smooth, free of ripples, and flat or slightly convex. Spatter is negligible. Slag formation is heavy, and the slag peels off readily.

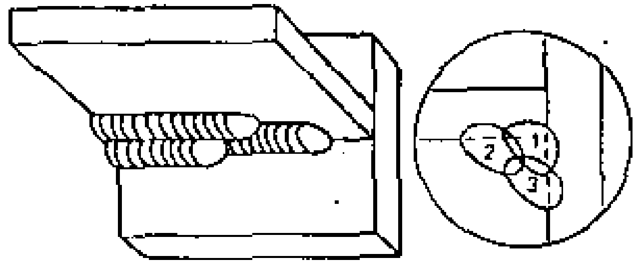


Fig. 6-18. Technique for overhead and horizontal butt welds with fast-freeze electrodes. These welds are best made with a series of stringer beads.

Applications for fast-fill electrodes are:

- Production welds on plate having a thickness of 3/16 in. or more.
- Flat and horizontal fillets, laps, and deep-groove butt welds.
- Welds on medium-carbon crack-sensitive steel when low-hydrogen electrodes are not available. (Preheat may be required.)

The coverings of fast-fill electrodes contain approximately 50% iron powder. This powder increases deposition rate by helping to contain the arc heat at the electrode, by melting to add to deposited weld metal, and by permitting currents higher than those permitted by other types of coverings. The thick, iron-bearing covering also facilitates use of the drag technique in welding.

Electrode Characteristics

E7024: This is a general-purpose fast-fill electrode. Special grades provide exceptionally high deposition rates and particularly good operating characteristics.

E6027: Used principally for flat deep-groove joints and for flat and horizontal fillets, the electrode has excellent wash-in characteristics. A friable slag permits easy slag removal in deep grooves. This electrode is sometimes used as an alternative to E7024 when X-ray quality or high notch toughness are required.

E7020-A1: The electrode is used in place of E6027 when a 70,000-psi strength or 0.5% molybdenum deposit is required.

Welding Techniques

Polarity: Use AC for highest speeds and best operating characteristics. DCRP can be used, but this type of current promotes arc blow and complicates control of the molten puddle.

Flat Welding: Use a drag technique; tip the electrode 10 to 30° in the direction of travel and make stringer beads. Weld with the electrode tip lightly dragging on the work so that molten metal is forced out from under the tip, thereby promoting penetration. The resulting smooth weld is similar in appearance to an automatic weld. Travel rapidly, but not too fast for good slag coverage. Stay about 1/4 to 3/8 in. ahead of the molten slag, as illustrated in Figure 6-19. If travel speed is too slow, a small ball of molten slag may form and roll ahead of the arc, causing spatter, poor penetration, and erratic bead shape. Optimum current usually is 5 to 10 amp above the center of the range for a given electrode.

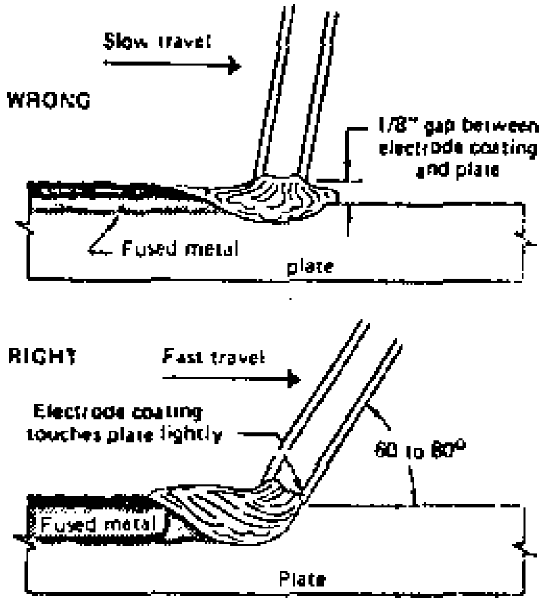


Fig. 6-19. Technique for flat welds with fast fill electrodes. An incorrect technique is included for comparison.

Do not exceed the center of the range if the weld is to be of X-ray quality.

Horizontal Fillets and Laps: Point the electrode into the joint at an angle of 45° from horizontal and use the "flat" technique described above. The tip of the electrode must touch both horizontal and vertical members of the joint. If the 45° angle between plates is not maintained, the fillet legs will be of different sizes. When two passes are needed, deposit the first bead mostly on the bottom plate. To weld the second pass hold the electrode at about 45°, fusing into the vertical plate and the first bead. Make multiple-pass horizontal fillets as shown in Figure 6-20. Put the first bead in the corner with fairly high current, disregarding undercut. Deposit the second bead on the horizontal plate, fusing into the first bead. Hold the electrode angle needed to deposit the filler beads as shown, putting the final bead against the vertical plate.

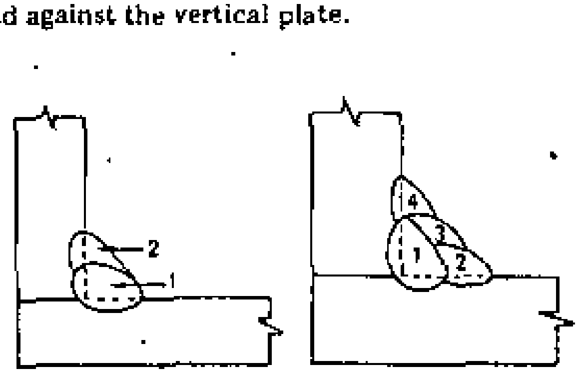


Fig. 6-20. Technique for multi-pass horizontal fillet welds with fast-fill electrodes. Beads should be deposited in the order indicated.

Deep-Groove Butt Welds: To hold the large pool of molten weld metal produced by fast-fill electrodes, either a backup plate, or a stringer bead made with a deeper-penetrating fast-freeze electrode is required. Deposit fast-fill beads with a stringer technique until a slight weave is required to obtain fusion of both plates. Split-weave welds are better than a wide weave near the top of deep grooves. When welding the second last pass, leave enough room so that the last pass will not exceed a 1/16-in. buildup. A slight undercut on all but the last pass creates no problems, because it is burned out with each succeeding pass.

FILL-FREEZE ELECTRODES

Fill-freeze electrodes are compounded to provide a compromise between fast-freeze and fast-fill characteristics, and thus provide medium deposition rates and medium penetration. Since they permit welding at relatively high speed with minimal skip, misses, and undercut, and with minimum slag entrapment, fill-freeze electrodes are also referred to as fast-follow electrodes. The electrode's characteristics are particularly suited to the welding of sheet metal, and fill-freeze electrodes are, thus, often called "sheet-metal" electrodes. Bead appearance with this group of electrodes varies from smooth and ripple-free to wavy with distinct ripples. The fill-freeze electrodes can be used in all welding positions, but are most widely used in the level or downhill positions.

Applications for fill-freeze electrodes include:

- Downhill fillet and lap welds.
- Irregular or short welds that change direction or position.
- Sheet-metal lap and fillet welds.
- Fast-fill joints having poor fitup.
- General-purpose welding in all positions.

Fast-freeze electrodes, particularly E6010 and E6011, are sometimes used for sheet-metal welding when fast-follow electrodes are not available, or when the operator prefers faster solidification. Techniques for sheet-metal welding with these electrodes are discussed in the portion of this section dealing with fast-freeze electrodes.

Electrode Characteristics

E6012: The basic fill-freeze electrode for general-purpose and production welding, this electrode provides a more forceful arc than other electrodes in the group. Special types are available for improved arc stability, minimum spatter, and easier slag removal. Some types contain iron powder in the coatings for greater mileage, better AC operation, and a smoother, quieter arc. These types are excellent for low-current applications, such as sheet-metal welding.

E6013: This electrode is used in place of E6012 for sheet-metal welding where appearance and ease of operation are more important than speed. AC operation is excellent. It is recommended for general-purpose welding with small AC transformer welding machines having low open-circuit voltage.

E7014: The electrode has highest iron-powder content in the group, and thus provides highest deposition (or maximum fast-fill capability) among the fill-freeze electrodes. It has exceptionally good operating characteristics and is often preferred by welders. It is frequently used for production welding on short, irregular, or downhill fast-fill types of joints.

Welding Techniques on Steel Plate

Polarity: Use DCSP for best performance on all applications except when arc blow is a problem. To control arc blow, use AC.

Downhand and Downhill: Use stringer beads for the first pass except when poor fitup requires a slight weave. Use either stringer or weave beads for succeeding passes. Touch the tip of the electrode to the work or hold an arc length of 1/8 in. or less. Move as fast as possible consistent with desired bead size. Use currents in the middle to higher portion of the range.

Electrode Size: Use electrodes of 3/16-in. or smaller diameter for vertical and overhead welding.

Vertical-Down: Use stringer beads or a slight weave. A drag technique must be used with some E6012 electrodes. Make small beads. Point the electrode upward so that arc force pushes molten metal back up the joint. Move fast enough to stay ahead of the molten pool. Use currents in the higher portion of the range.

Vertical-Up: Use a triangular weave. Weld a shelf at the bottom of the joint and add layer upon layer. Do not whip or take the electrode out of the molten pool. Point the electrode slightly upward so that arc force helps control the puddle. Travel slow enough to maintain the shelf without spilling. Use currents in the lower portion of the range.

Overhead: Make stringer beads using a whipping technique with a slight circular motion in the crater. Do not weave. Travel fast enough to avoid spilling. Use currents in the lower portion of the range.

Welding Techniques with Sheet Metal

The ability to adjust current while welding sheet steel is valuable, particularly when fitup or material thickness varies. Motor-generator welders equipped with foot-operated remote current controls are useful for this purpose.

Generally, use the highest current that does not cause burnthrough, does not undercut, or does not melt the edges of lap, corner, or edge welds. For fast welding, the operator must stay precisely on the joint and must travel at a uniform speed. Welding on sheet metal, thus, requires more than average skill, and a good weldor may need a few days of practice when first attempting this type of weld.

For maximum welding speed, minimum distortion, or for welding in the flat position, joints generally should be positioned 45° to 75° downhill. Use copper backup strips where possible to decrease the danger of burnthrough. The procedures tables in this handbook assume tight fitup and adequate clamping or tacking. Where poor fitup is encountered:

1. Reduce current.
2. Tilt the electrode into the direction of travel more than normally.
3. With fast-freeze electrodes use a small, quick weave technique to bridge the gap.

Deposit the entire weld in one pass using stringer beads or a slight weave. Drag the electrode on the joint and stay ahead of the molten pool. Tip the electrode well into the direction of travel so the arc force pushes the weld metal back into the joint. Use currents in the high portion of the range.

LOW-HYDROGEN ELECTRODES

Conventional welding electrodes may not be suitable where X-ray quality is required, where the base metal has a tendency to crack, where thick sections are to be welded, or where the base metal has an alloy content higher than that of mild steel. In these applications, a low-hydrogen electrode may be required.

Low-hydrogen electrodes are available with either fast-fill or fill-freeze characteristics. They are compounded to produce dense welds of X-ray quality with excellent notch toughness and high ductility. Low-hydrogen electrodes reduce the danger of underbead and microcracking on thick weldments and on high-carbon and low-alloy steels. Preheat requirements are less than for other electrodes.

Low-hydrogen electrodes are shipped in hermetically sealed containers, which normally can be stored indefinitely without danger of moisture pickup. But once the container is opened, the electrodes should be used promptly or stored in a heated cabinet. Details on electrode storage and on redrying moisture-contaminated electrodes are presented later in this section.

Applications for low-hydrogen electrodes include:

- X-ray-quality welds or welds requiring high mechanical properties.
- Crack-resistant welds in medium-carbon to high-carbon steels; welds that resist hot-short cracking in phosphorus steels; and welds that minimize porosity in sulfur-bearing steels.
- Welds in thick sections or in restrained joints in mild and alloy steels where shrinkage stresses might promote weld cracking.
- Welds in alloy steel requiring a strength of 70,000 psi or more.
- Multiple-pass, vertical, and overhead welds in mild steel.

Electrode Characteristics

E7018: This electrode has fill-freeze characteristics and is suitable for all-position operation. Iron powder in the electrode coating promotes rapid deposition. Moderately heavy slag is easy to remove. (Weld metal freezes rapidly even though slag remains somewhat fluid.) Beads are flat or slightly convex and have distinct ripples, with little spatter.

E7028: The electrode has fast-fill characteristics applicable to high-production welds where low-hydrogen quality is required. It performs best on flat fillets and deep-groove joints, but is also suitable for horizontal fillet and lap welds. Excellent restriking qualities permit efficient skip and tack welding.

Welding Techniques

Techniques for E7028 are the same as those described for conventional fast-fill electrodes. However, special care should be taken to clean the slag from every bead on multiple-pass welds to avoid slag inclusions that would appear on X-ray inspection. The ensuing discussion pertains to the techniques recommended for E7018 electrodes.

Polarity: Use DCRP whenever possible if the electrode size is 5/32-in. or less. For larger electrodes, use AC for best operating characteristics (but DCRP can also be used).

Downhand: Use low current on the first pass, or whenever it is desirable to reduce admixture with a base metal of poor weldability. On succeeding passes, use currents that provide best operating characteristics. Drag the electrode lightly or hold an arc of 1/8-in. or less. Do not use a long arc at any time, since E7018 electrodes rely principally on molten slag for shielding. Stringer beads or small weave passes are preferred to wide weave passes. When starting a new electrode, strike the arc ahead of the crater, move back into the crater, and then proceed in the normal direction. On AC, use currents about 10% higher than those used with DC. Govern travel speed by the desired bead size.

Vertical: Weld vertical-up with electrode sizes of 5/32-in. or less. Use a triangular weave for heavy single-pass welds. For multipass welds, first deposit a stringer bead by using a slight weave. Deposit additional layers with a side-to-side weave, hesitating at the sides long enough to fuse out any small slag pockets and to minimize undercut. Do not use a whip technique or take the electrode out of the molten pool. Travel slowly enough to maintain the shelf without causing metal to spill. Use currents in the lower portion of the range.

Overhead: Use electrodes of 5/32-in. or smaller. Deposit stringer beads by using a slight circular motion in the crater. Maintain a short arc. Motions should be slow and deliberate. Move fast enough to avoid spilling weld metal, but do not be alarmed if some slag spills. Use currents in the lower portion of the range.

TABLE 6-14. Procedures for Drying Low-Hydrogen Electrodes

	Drying Temperatures	
Nature of Moisture Pickup	E7018-28	E8018-X, E9018-X, E11018-X
Electrodes exposed to air for less than one week; no direct contact with water. Welds not subject to X-ray inspection.	300°F	300°F
Electrodes exposed to air for less than one week; no direct contact with water. Welds subject to X-ray inspection.	700°F	750°F
Electrodes have come in direct contact with water, or have been exposed to extremely humid conditions as indicated by core wire rusting at the holder end. Before redrying at 700 — 750F, predry electrodes in this condition at 180°F for 1 to 2 hours. This minimizes the tendency for coating cracks or oxidation of the alloys in the coating	700°F	750°F

Note: One hour at the listed temperatures is satisfactory. Do not dry electrodes at higher temperatures or for more than 8 hours. Several hours at lower temperature are not equivalent to using the specified temperatures. Remove the electrodes from the can and spread them out in the furnace. Each electrode must reach the drying temperature. (Cardboard can liners char at about 350°F.)

Redrying Low-Hydrogen Electrodes

Low-hydrogen electrodes must be dry if they are to perform properly. Electrodes in unopened,

TABLE 6-15. Characteristics of Mild-Steel Covered Electrodes*

AWS-ASTM Electrode Classification	Welding Category	General Characteristics
60,000-psi Minimum Tensile Strength		
E6010	Freeze†	Molten weld metal freezes quickly; suitable for welding in all positions with DC reverse-polarity power; has a low-deposition rate and deeply penetrating arc; can be used to weld all types of joints.
E6011	Freeze†	Similar to E6010, except can be used with AC as well as DC power.
E6012	Follow	Faster travel speed and smaller welds than E6010; AC or DC, straight-polarity power; penetration less than E6010. Primary use is for single-pass welding of thin-gage sheet metal in flat, horizontal, and vertical-down positions.
E6013	Follow	Similar to E6012, except can be used with DC (either polarity) or AC power.
E6027	Fill	Deposition rate high since covering contains about 50% iron powder; primary use is for multipass, deep-groove, and fillet welding in the flat position or horizontal fillets, using DC (either polarity) or AC power.
70,000-psi Minimum Tensile Strength		
E7014	Fill-freeze	Higher deposition rate than E6010; usable with DC (either polarity) or AC power; primary use is for inclined and short, horizontal fillet welds.
E7018	Fill-freeze	Suitable for welding low and medium-carbon steels (0.55% C max) in all positions and types of joints. Weld-metal quality and mechanical properties highest of all mild-steel electrodes; usable with DC reverse polarity or AC power.
E7024	Fill	Higher deposition rate than E7014; suitable for flat-position welding and horizontal fillets.
E7028	Fill	Similar to type E7018; used for welding horizontal and flat fillets and grooved butt fillet welds in flat position.

* E6020, E7015, and E7016 are not included because of their limited usage. Only electrodes up to 3/16 in. diameter can be used in all welding positions (flat, horizontal, vertical, and overhead).

† When used for welding sheet metal, these electrodes have follow-freeze characteristics.

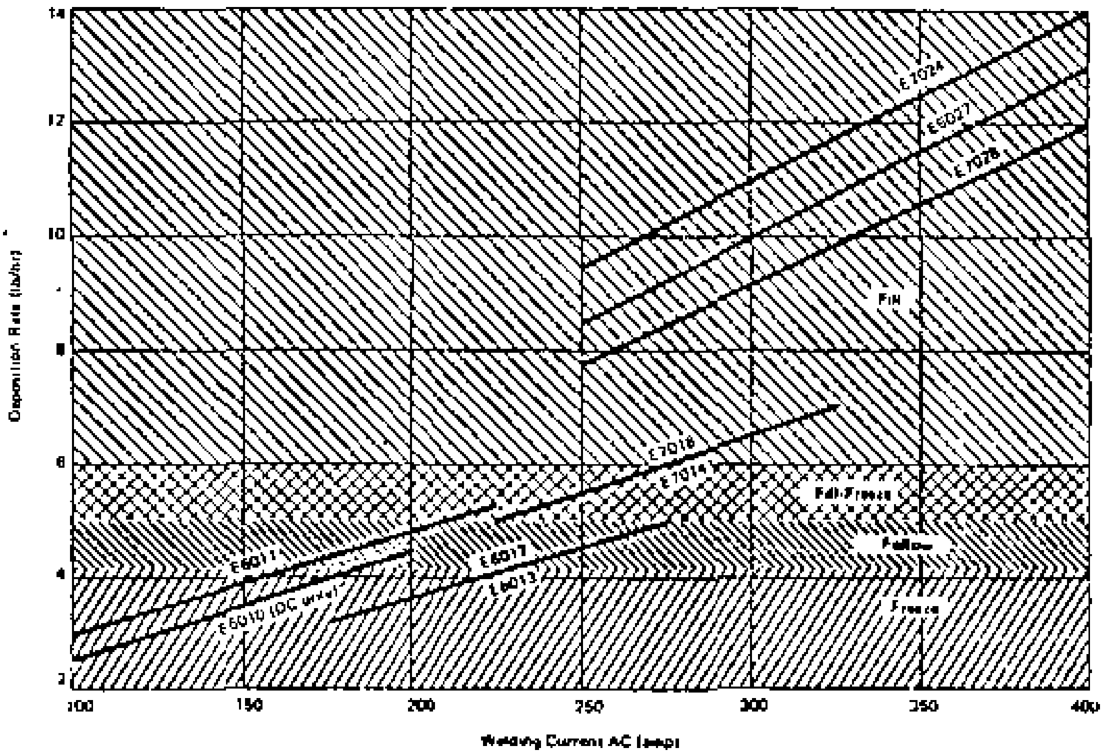


Fig. 6-21. Deposition rates for various mild steel electrodes

hermetically sealed containers remain dry indefinitely in good storage conditions. Opened cans should be stored in a cabinet at 250 to 300°F. Supplying weldors with electrodes twice a shift — at the start of the shift and at lunch, for example — minimizes the danger of moisture pickup. Return electrodes to the heated cabinet for overnight storage.

When containers are punctured or opened so that the electrode is exposed to the air for a few days, or when containers are stored under unusually wet conditions, low-hydrogen electrodes pick up moisture. The moisture, depending upon the amount absorbed, impairs weld quality in the following ways:

1. A small amount of moisture may cause internal porosity. Detection of this porosity requires X-ray inspection or destructive testing. If the base metal has high hardenability, even a small amount of moisture can contribute to underbead cracking.
2. A high amount of moisture causes visible external porosity in addition to internal porosity.
3. Severe moisture pickup can cause weld cracks or underbead cracking in addition to severe porosity.

Redrying completely restores ability to deposit quality welds. The proper redrying temperature depends upon the type of electrode and its condition. Drying procedures are listed in Table 6-14.

SUMMARY OF ELECTRODES FOR MILD STEEL

In the AWS specification A5.1-69 there are 12 different classifications of electrodes for welding mild steel. Each classification has different operating characteristics, and a summary of these characteristics is given in Table 6-15. The deposition rates for the electrodes in Table 6-15 are shown in Fig. 6-21.

ALLOY-STEEL ELECTRODES

Alloy content of the weld deposit is not critically important in the welding of common grades of steel. As discussed in the immediately preceding portions of this section, electrode selection for these

TABLE 6-16. Typical Mechanical Properties of AWS A5.5-69 Weld Metal

	E7010-A1	E8018-B2	E8018-C3	E8018-C1	E11018-M
As-Welded					
Tensile Strength (psi)	75,000	107,000	86,000	87,000	112,000
Yield Strength (psi)	68,000	90,000	78,000	74,000	102,000
Elongation (% in 2 in.)	24	21	25	22	21
Charpy V Notch (ft-lb)	68 at 70°F	65 at 70°F	48 at −20°F	61 at −75°F	35 at −60°F
Stress Relieved 1150°F					
Tensile Strength (psi)	72,000	93,000 83,000*	81,000	84,000	112,000+
Yield Strength (psi)	60,000	81,000 70,000*	70,000	71,000	96,000+
Elongation (% of 2 in.)	29	20 22*	26	24	22+
Charpy V Notch (ft-lb)	68 at 70°F	65 at 70°F 65 at 70°F*	88 at −20°F	40 at −75°F	35 at −60°F+

* Stress relieved at 1275°F
\+ Stress relieved at 1025°F

steels is based largely on whether maximum deposition rates or rapid freeze characteristics are preferred. But for alloy steels — chosen specifically for their high mechanical properties, superior corrosion resistance, or ability to withstand high temperatures — the electrode must be carefully selected so that it provides the specific chemical composition needed to maintain the desired properties of the base metal in the weld deposit.

There are many types of electrodes available for welding low-alloy steels. These types are described completely in AWS A5.5, and a brief summary of

TABLE 6-17. Recommended Electrodes for Trade-Name Steels
(See Note 10, Table 6-13)

Steel Producer	Steel Trade Name	Recommended Electrodes
Alan Wood Steel Company	AW-X 42, 45; V45	Note 1
	V50, 55; AW-X 50, 55; AW Ten; AW Dynalloy 50; AW 441, 440; Cor Ten A, B	E7018 or E7028
	V60, 65; Cor Ten C	E8018-C3
Armco Steel Corporation	C 42, 45	Note 1
	C 50, 55; Armco LTM; High Strength B, D	E7018 or E7028
	C 60, 65; High Strength A; V 60, 65	E8018-C3
	Lo-Temp; Super Lo Temp; Armco LTM, VNT	E8018-C1
	C 70	E8018-B2
	SSS 100, 100A, 100B; HY80, HY100; OTC	E11018-M
Bethlehem Steel Corporation	V42, 45, 50, 55; RQC 60N; Mn-V A441; Mayari R, R 50 Med. Mn	E7018 or E7028
	V60, 65; Mayari R 60	E8018-C3
	RQC 60 Q & T	E8018-C1
	RQC 80, 90; RQ 100, 100A, 100B	E11018-M
Inland Steel Company	INX 42, 45	Note 1
	INX 50, 55; Cor Ten A, B; Hi-Man; Tri Steel	Note 3 E7018 or E7028
	INX 60, 65; Cor Ten C; Hi-Steel	E8018-C3
	INX 70	E8018-B2
Jones & Laughlin Steel Corporation	JLX 42, 50	Note 1
	JLX 50, 55; 50CC, 55CC; Armor I, 3R, 35; Con-Tens; Ni-Cu-Ti	E7018 or E7028
	JLX 60, 65, 60CC, 65CC	E8018-C3
	JLX 70, 70CC	E8018-B2
	Jalloy S-90, 100; VAN 80	E11018-M
Kaiser Steel Corporation	Kaiser 42CV, 45CV	Note 1
	Kaiser 50CV, 55CV; Kaiser 45/G, 50CR, 50MW, 50MV	E7018 or E7028
	Kaiser 60Sp, 60CV	E8018-C3
	Kaiser 70MB	E8018-B2
Lukens Steel Company	Lukens 45, 50; LT-75N; Lukens A440, A441; Cor Ten A	E7018 or E7028
	Lukens 55, 60	E8018-C3
	Lukens LT 75QT	E8018-B2
	Lukens T1, T1A, T1B, LT-75HS	E11018-M
National Steel Corporation	GLX 45W	Note 1
	GLX 50W, 55W; GLS-441; NAX Fine Grain; NAX Hi-Mang; NAX High Tensile	E7018 or E7028
	GLX-60W, 65W	E8018-C3
	GLX 70W	E8018-B2
	N A XTRA 80, 90, 100	E11018-M
Republic Steel Corporation	35, X42W, X45W	Note 1
	X50W, X55W, A441, Cor Ten A; NAX High Tensile	E7018 or E7028
	Republic 50, 60, 65; X60W, X65W	E8018-C3
	Republic 70; X70W	E8018-B2
	Republic 80	E11018-M
United States Steel Corporation	Ex-Ten 42, 45	Note 1
	Ex-Ten 50, 55; Cor Ten A, B; Tri Ten; Pat Ten; Man-Ten (A440)	E7018 or E7028
	Cor Ten C; Man Ten; Ex-Ten 60, 65	E8018-C3
	Cor-Ten; Char-Pac	E8018-C1
	Ex-Ten 70	E8018-B2
	T-1, T-1A, T-1B	E11018-M
Youngstown Sheet & Tube Company	YSW-42, 45	Note 1
	YSW 50, 55; YS Ten; YSW A441	E7018 or E7028
	YSW 60, 65; Yo Man; Yoloy HS, HSP	E8018-C3 Note 2
	Yoloy S	E8018-C1
	YSW 70	E8018-B2

For other notes see Table 6-13

typical electrode characteristics and applications is presented in the following paragraphs. The chemical requirements of deposited weld metal are given in Table 4-7. Typical mechanical properties of some of the weld deposits are given in Table 6-16. A guide to the selection of electrodes for welding steels of specific trade names is presented in Table 6-17.

Except for electrodes for welding high-strength line pipe (see Section 13.3), most electrodes for welding low-alloy steel have low-hydrogen, fill-freeze characteristics similar to those of E7018 and are suitable for all-position fabrication and repair welding. Even though these electrodes are suitable for all-position welding, their operating characteristics are quite different from those of fast-freeze electrodes for the common steels. Weld metal from alloy-steel electrodes freezes rapidly even though the slag remains relatively fluid. Deposition rate is high, partially because the coverings contain iron powder.

Beads are flat or slightly convex and have distinct ripples with little spatter. The moderately heavy slag is easy to remove.

Some of the commonly used low-alloy high-strength electrodes include:

E8018-B2: This electrode produces a 1.25%-chromium, 0.5%-molybdenum deposit, commonly required for high-temperature, high-pressure piping. It usually meets requirements of E9018-G for some high-strength (90,000 psi tensile) steels.

E8018-C3: The electrode conforms to MIL 8018-C3 and produces a weld having a tensile strength of 80,000 psi, suitable for general-purpose welding on many high-strength alloys. This type also provides a 1%-nickel deposit for welding alloys that are to be used at low temperatures and which require good notch toughness down to -60°F. The electrode is also used for fillet welds on high-strength (110,000 psi tensile) quenched-and-tempered steels, such as ASTM A514 and A517.

E8018-C1: The type produces a 2.25%-nickel deposit with notch toughness of 50 ft-lb at -75°F and is, thus, commonly required for welding low-temperature alloys. Such alloys are frequently used to fabricate storage, piping, and transportation equipment for liquid ammonia, propane, and other gases. This group of electrodes is also recommended for the best color match on unpainted corrosion-resistant ASTM A242 steels. (Cor-Ten, Mayari-R, and others).

E11018-M: The electrode conforms to MIL-11018-M and produces a 110,000-psi tensile strength needed for full-strength welds on quenched-and-tempered steels, ASTM A514 and A517 (T-1, SSS-100, HY-80, and others)

GENERAL CONSIDERATIONS IN WELDING

Joint Positions

As noted earlier in this section, joint position is often the primary factor in electrode selection and is therefore largely responsible for the speed and cost of welding. Where possible, work should be positioned flat for fastest welding speed.

Sheet-Metal Welds: In sheet steel from 10 to 18 gage, welds are usually larger than needed for joint strength. Thus, the primary objective is to avoid burnthrough while welding at fast travel speeds with minimum skips and misses. Fastest speeds are obtained with the work positioned 45 to 75° downhill. Refer to the prior portion of this section on fill-freeze electrodes.

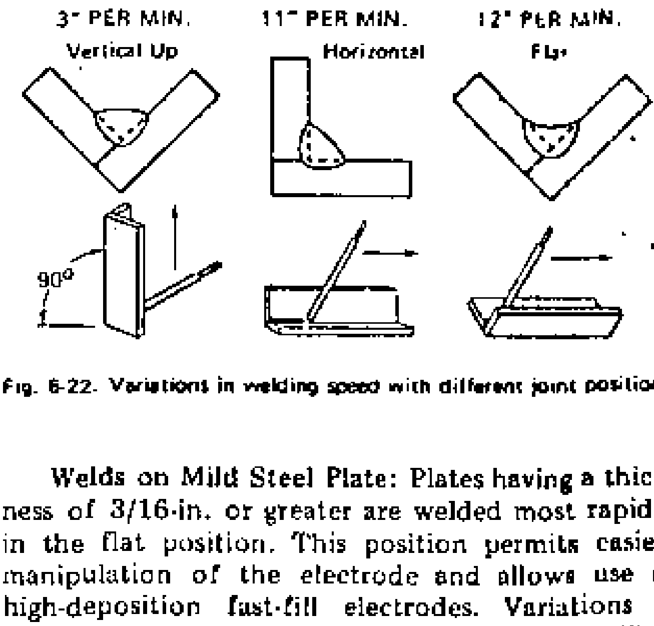


Fig. 6-22. Variations in welding speed with different joint positions

Welds on Mild Steel Plate: Plates having a thickness of 3/16-in. or greater are welded most rapidly in the flat position. This position permits easiest manipulation of the electrode and allows use of high-deposition fast-fill electrodes. Variations in welding speed with different joint positions are illustrated in Fig. 6-22. For more information, refer to portions of this section dealing with fast-fill electrodes. If a weld is to be made in the vertical or overhead position, refer to the discussion on fast-freeze electrodes.

Welds on High-Carbon and Low-Alloy Steel: These steels can be welded most readily in the level position. Refer to the discussion on low-hydrogen electrodes.

Joint Geometry and Fitup

Joint dimensions specified in the Procedure Tables are chosen for fast welding speeds consistent with weld quality. Departure from the recom-

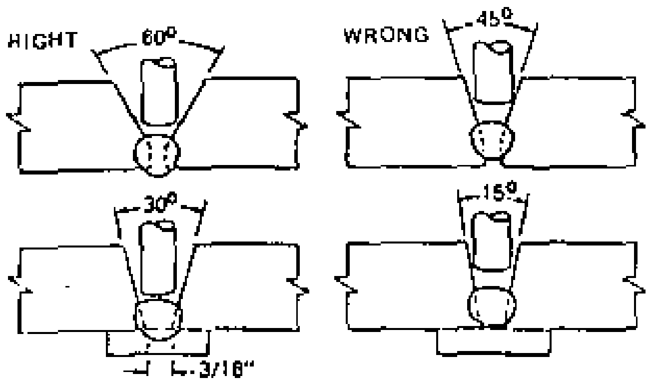


Fig. 6-23. Correct and incorrect bevels for good bead shape and adequate penetration.

mended joint geometry may reduce welding speed or cause welding problems.

Fitup must be consistent for the entire joint. Sheet metal and most fillet and lap joints must be clamped tightly their entire length. Gaps or bevels must be accurately controlled over the entire joint. Any variations in a joint make it necessary for the operator to reduce the welding speed to avoid burn-through and force him to make time-consuming manipulations of the electrodes.

Sufficient bevel is required for good bead shape and adequate penetration (Fig. 6-23). Insufficient bevel prevents adequate entry of the electrode into the joint. A deep, narrow bead also has a tendency to crack. However, excess bevel wastes material. Sufficient gap is needed for full penetration (Fig. 6-24). Excessive gap wastes metal and slows welding speed. Either a 1/8-in. land or a backup strip is required for fast welding and good quality with thick plate (Fig. 6-25).

Feather-edge preparations require a slow costly seal bead. However, double-V butt joints without a

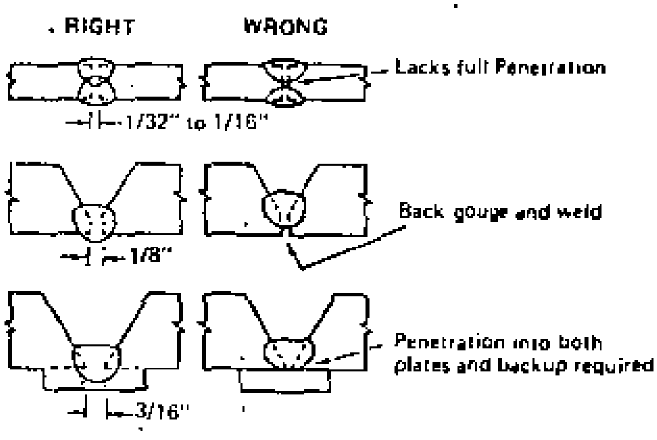


Fig. 6-24. Correct and incorrect gaps for proper penetration.

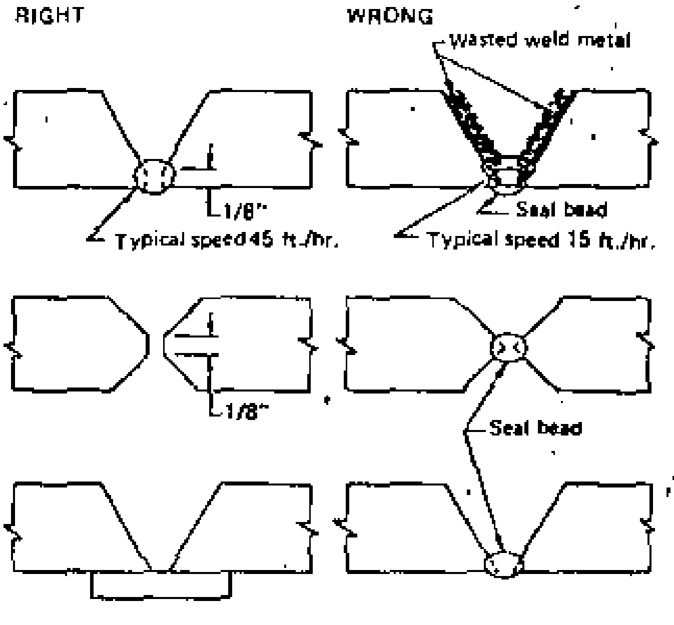


Fig. 6-25. Proper joint geometry for thick-plate welding.

land are practical when the seal bead cost is offset by easier edge preparation and the gap can be limited to about 3/32-in.

Weld seal beads on flat work with 3/16-in. E6010 electrodes at about 150 amp DCRP. Use 1/8-in. electrode at about 90 amp DCRP for vertical, overhead, and horizontal butt welds. Employ a combination whipping technique and circulating motion in the crater.

When low-hydrogen seal beads are required, use the appropriate EXX18 electrode. Weld with the same electrode sizes and about 20 amp higher current than recommended for E6010. Employ stringer bead technique with a slight weave when needed.

Back-gouging from the second side is needed: 1. For X-ray quality. 2. When irregular gap or poor technique produces a poor bead. 3. When a heavy bead is needed to prevent burnthrough of semi-automatic fill beads.

Joint Cleanliness

To avoid porosity and attain the speeds indicated in the Procedure Tables, remove excessive scale, rust, moisture, paint, oil, and grease from the surface of the joints.

If paint, dirt, or rust cannot be removed — as is sometimes the case in maintenance welding — use E6010 or E6011 electrodes to penetrate through the contaminants deeply into the base metal. Slow the travel speed to allow time for gas bubbles to boil out of the molten weld before it freezes.

Electrode Size

Large electrodes permit welding at high currents and high deposition rates. Therefore, use the largest electrode practical consistent with good weld quality. Electrode size is limited by many factors, but the most important considerations usually are:

1. High currents increase penetration. Therefore, electrode size is limited on sheet metal and with root passes where burnthrough can occur.
2. The maximum electrode size practical for vertical and overhead welding is 3/16-in. The 5/32-in. electrode is the maximum size for low-hydrogen electrodes.
3. High DC current increases arc blow. When arc blow is a problem, either use AC or limit the current.
4. Joint dimensions sometimes limit the electrode diameter that will fit into the joint.

Preheat and Interpass Temperature

The use of preheat and minimum interpass temperatures may be dictated by the composition of the steel, by the thickness of the material, or by the degree of joint restraint. Preheating may be mandatory if the welding is done according to a code. For example, the preheating requirements in the AISC specification for structural steel buildings are shown in Table 6-18. Other codes, such as the AWS Building Code D1.0-69 and the AWS Bridge Code D2.0-69, have similar requirements. (See Section 3.3)

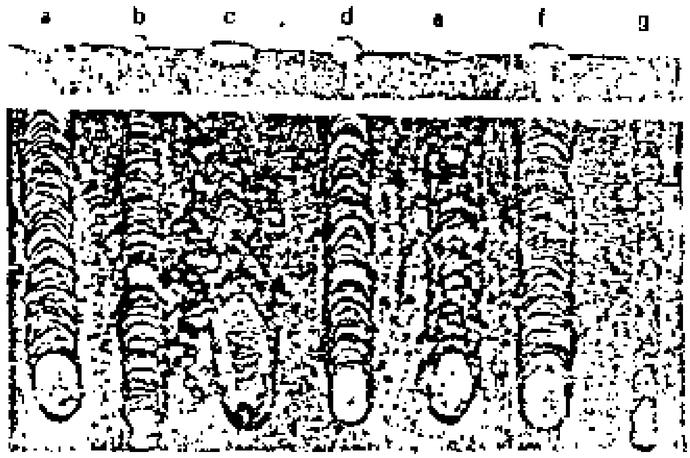


Fig. 6-26. Effect of welding variables on bead characteristics. Proper current, travel speed, and arc length (a). Current too low (b). Current too high (c). Arc length too short (d). Arc length too long (e). Travel speed too slow (f). Travel speed too fast (g).

TROUBLE SHOOTING

Many operating variables can affect the quality and appearance of the weld. The effects produced by the most important of these variables are illustrated in Fig. 6-26. Common undesirable effects are

TABLE 6.18. MINIMUM PREHEAT AND INTERPASS TEMPERATURE. AWS D1.1-Rev. 1-73, 2-74, Table 4.2[1,2] (Degrees F)

	Welding Process				
	Shielded Metal-Arc Welding with other than Low-Hydrogen Electrode	Shielded Metal-Arc Welding with Low-Hydrogen Electrodes; Submerged-Arc Welding; Gas Metal-Arc Welding; or Flux-Cored Arc Welding		Shielded Metal-Arc Welding with Low-Hydrogen Electrodes; Submerged-Arc Welding with Carbon or Alloy Steel Wire, Neutral Flux; Gas Metal-Arc Welding; or Flux-Cored Arc Welding	Submerged Arc Welding with Carbon Steel Wire, Alloy Flux
Thickness of Thickest Part at Point of Welding – Inches	ASTM A36[4], A53 Gr. B, A106, A131, A139, A375, A381 Gr. Y35, A500, A501, A516 Gr. 55 and 60, A524, A529, A570 Gr. D and E, A573 Gr. 65, API 5L Gr. B; ABS Gr. A, B, C, CS, D, E, R	ASTM A36, A106, A131, A139, A242 Weldable Grade, A375, A381 Gr. Y35, A441, A516 Gr. 65 and 70, A524, A529, A537 Class 1 and 2, A570 Gr. D and E, A572 Gr. 42, 45, 50, A573 Gr. 65, A588, A618, API 5L Gr. B and 5LX Gr. 42; ABS Gr. A, B, C, CS, D, E, R, AH, DH, EH	ASTM A572 Grades 55, 60 and 65	ASTM A514, A517	ASTM A514, A517
To 3/4, incl.	None[3]	None[3]	70	50	50
Over 3/4 to 1-1/2, incl.	150	70	150	125	200
Over 1-1/2 to 2-1/2, incl.	225	150	225	175	300
Over 2-1/2	300	225	300	225	400

1 Welding shall not be done when the ambient temperature is lower than zero F. When the base metal is below the temperature listed for the welding process being used and the thickness of material being welded, it shall be preheated (except as otherwise provided) in such manner that the surfaces of the parts on which weld metal is being deposited are at or above the specified minimum temperature for a distance equal to the thickness of the part being welded, but not less than 3 in., both laterally and in advance of the welding. Preheat and interpass temperatures must be sufficient to prevent crack formation. Temperature above the minimum shown may be required for highly restrained welds. For quenched and tempered steel the maximum preheat and interpass temperature shall not exceed 400°F for thickness up to 1-1/2 in., inclusive, and 450°F for greater thicknesses. Heat input when welding quenched and tempered steel shall not exceed the steel producer's recommendation.

2 In joints involving combinations of base metals, preheat shall be as specified for the higher strength steel being welded.

3 When the base metal temperature is below 32°F, preheat the base metal to at least 70°F and maintain this minimum temperature during welding.

4 Only low hydrogen electrodes shall be used for welding A36 steel more than 1 inch thick for bridges.

Fig. 6-27. Undesirable bead appearance caused by weld spatter.

shown in Figs. 6-27 through 6-29. Methods for correcting undesirable characteristics are discussed in the following paragraphs. Not discussed here is arc blow, which is covered in Section 3.2.

Weld Spatter

Spatter does not affect weld strength but does produce a poor appearance and increases cleaning costs. To control excessive spatter:

1. Try lowering the current. Be sure the current is within the recommended range for the type and size electrode (See Table 6-12.)
2. Be sure the polarity is correct for the electrode type.
3. Try a shorter arc length.
4. If the molten metal is running in front of the arc, change the electrode angle.
5. Watch for arc blow.
6. Be sure the electrode is not too wet.

Undercut

Generally, the only harm from undercutting is impaired appearance. However, undercutting may also impair weld strength, particularly when the weld is loaded in tension or subjected to fatigue. To minimize undercut:

1. Reduce current, travel speed, or electrode size until the puddle is manageable.
2. Change electrode angle so the arc force holds the metal in the corners. Use a uniform travel speed and avoid excessive weaving.

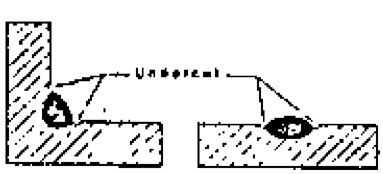


Fig. 6-28. Undercut in a weld. The effect is undesirable from the appearance standpoint and may weaken the joint.

Rough Welding

If polarity and current are within the electrode manufacturer's recommendations but the arc action is rough and erratic, the electrodes may be wet. Try electrodes from a fresh container. If the problem occurs frequently, store open containers of electrodes in a heated cabinet.

Porosity and Surface Holes

Most porosity is not visible. But severe porosity can weaken the weld. The following practices minimize porosity:

1. Remove scale, rust, paint, moisture, or dirt from the joint. Generally use an E6010 or E6011 electrode for dirty steel.
2. Keep the puddle molten for a long time, so that gases may boil out before the metal freezes.
3. Steels very low in carbon or manganese or those high in sulfur or phosphorus should be

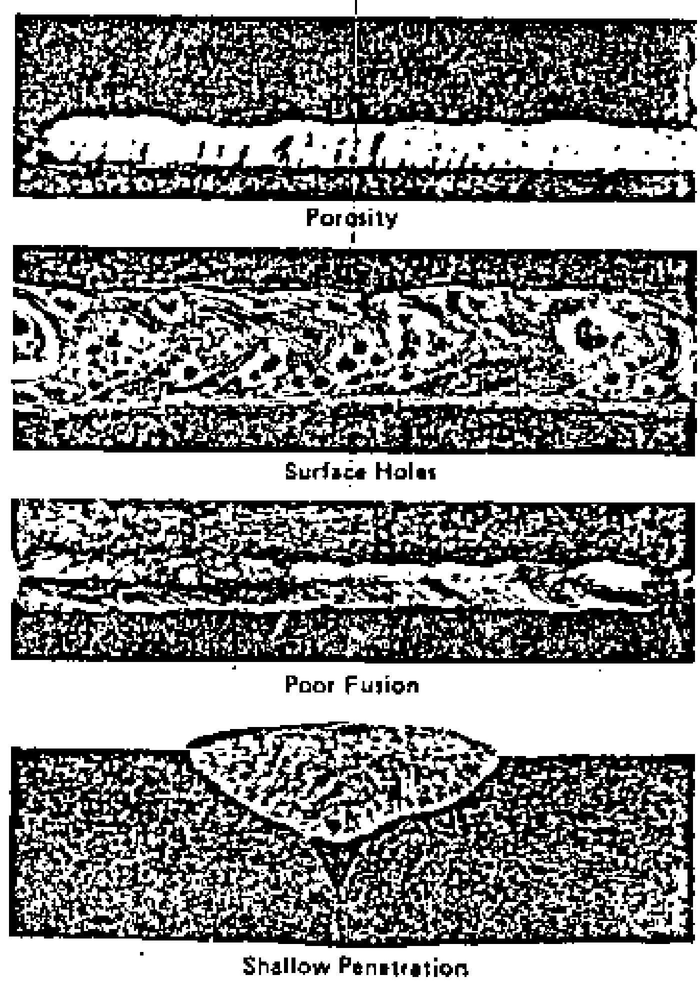


Fig. 6-29. Undesirable effects caused by improper procedures and techniques.

welded with a low-hydrogen electrode. Minimize admixture of base metal with weld metal by using low currents and fast travel speeds for less penetration.

4. Try using a short arc length; short arcs are required for low-hydrogen electrodes.

Surface holes can be avoided by many of the practices used to minimize porosity.

Poor Fusion

Proper fusion exists when the weld bonds to both walls of the joint and forms a solid bead across the joint. Lack of fusion is often visible and must be avoided for a sound weld. To correct poor fusion:

1. Try a higher current and a stringer-bead technique.
2. Be sure the edges of the joint are clean, or use an E6010 or E6011 electrode.
3. If gap is excessive, provide better fitup or use a weave technique to fill the gap.

Shallow Penetration

Penetration refers to the depth the weld enters into the base metal. For full-strength welds, penetration to the bottom of the joint is required. To overcome shallow penetration:

1. Try higher currents or slower travel.
2. Use small electrodes to reach into deep, narrow grooves.
3. Allow some gap (free space) at the bottom of the joint.

Cracking

Many different types of cracks may occur throughout a weld. Some are visible and some are not. However, all cracks are potentially serious, because they can lead to complete failure of the weld. The following suggestions may help control potential cracking. Practices to minimize cracks are shown in Fig. 6-30.

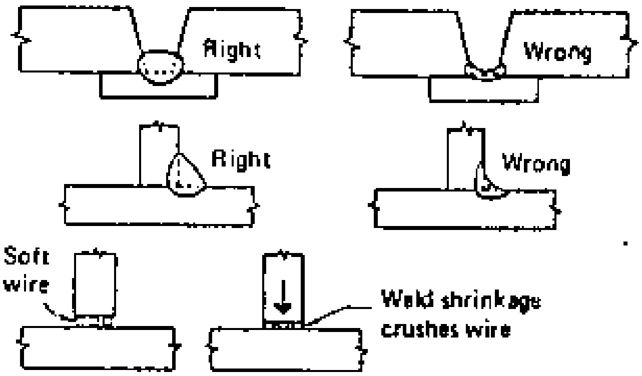


Fig. 6-30. Factors in controlling weld cracking. Illustrated are correct and incorrect joint geometries and bead shapes and a technique to permit stress relaxation in an otherwise rigid joint.

Most cracking is attributed to high-carbon or alloy content or high-sulfur content in the base metal. To control this type of cracking:

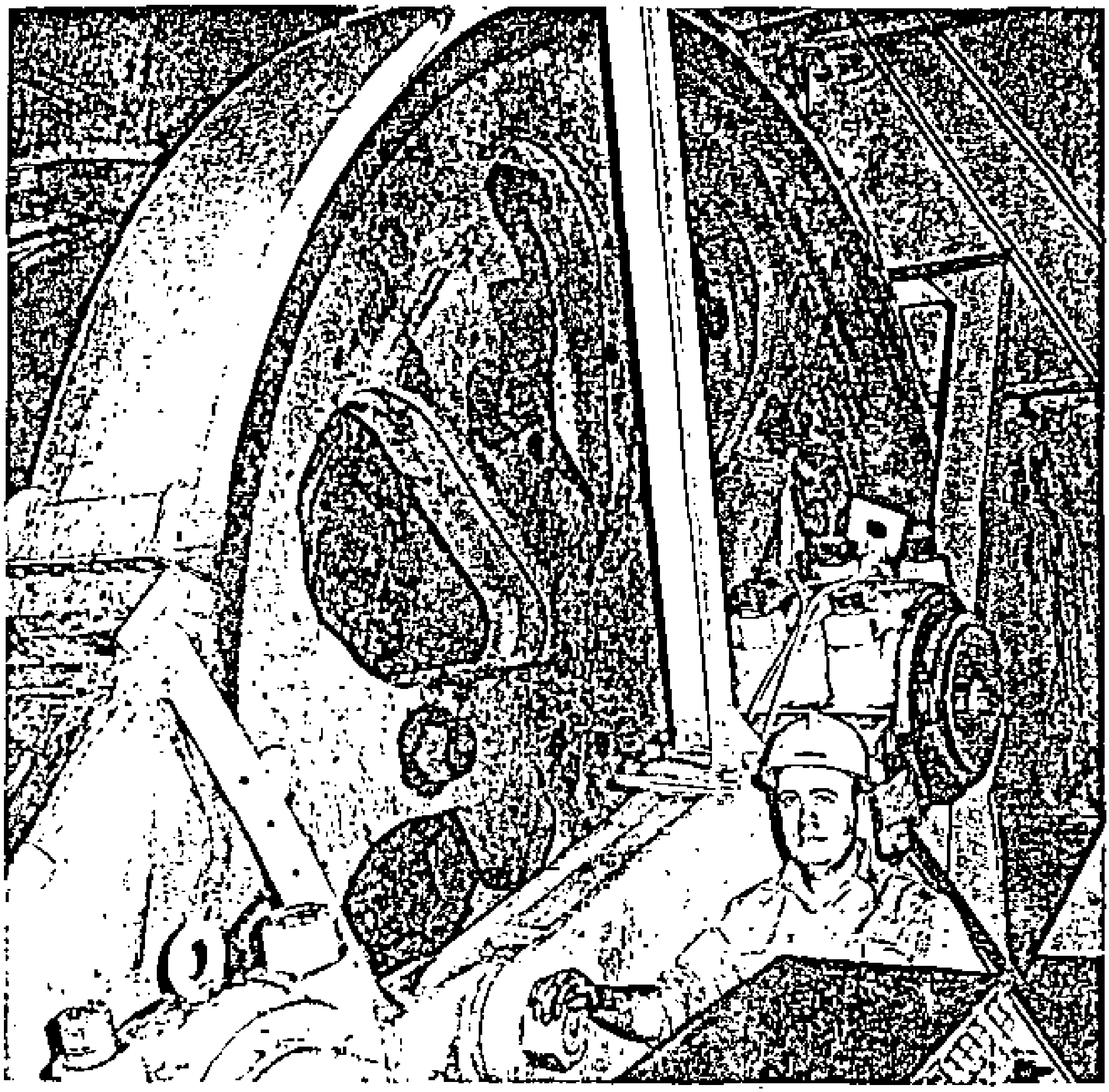
1. Use low-hydrogen electrodes.
2. Preheat. Use high preheats for heavier plate and rigid joints.
3. Reduce penetration by using low currents and small electrodes. This reduces the amount of alloy added to the weld from melted base metal.

To control crater cracking, fill each crater before breaking the arc. Use a back-stepping technique so as to end each weld on the crater of the previous weld.

On multiple-pass or fillet welds, be sure the first bead is of sufficient size and of flat or convex shape to resist cracking until the later beads can be added for support. To increase bead size, use slower travel speed, a short arc, or weld 5° uphill. Always continue welding while the plate is hot.

Rigid parts are more prone to cracking. If possible, weld toward the unrestrained end. Leave a 1/32-in. gap between plates for free shrinkage movement as the weld cools. Peen each bead while it is still hot to relieve stresses.

For more on cracking, see Section 6.1.



Arc welding was the only practical means of fabricating this large bull gear for a huge stripper shovel.

INTRODUCTION TO WELDING PROCEDURES

The ideal welding procedure is the one that will produce acceptable quality welds at the lowest over-all cost. So many factors influence the optimum welding conditions that it is impossible to write procedures for each set of conditions. In selecting a procedure, the best approach is to study the conditions of the application and then choose the procedure that most nearly accommodates them. The procedures given here are typical, and it may be necessary to make adjustments for a particular application to produce a satisfactory weld.

For some joints, different procedures are offered to suit the weld quality — code quality and commercial quality — that may be required.

Code-Quality Procedures

Code-quality procedures are intended to provide the highest level of quality and appearance. To accomplish this, conservative currents and travel speeds are recommended.

These procedures are aimed at producing welds that will meet the requirements of the commonly used codes: AWS Structural, AISC Buildings and Bridges, ASME Pressure Vessels, AASHO Bridges, and others. Code-quality welds are intended to be defect-free to the extent that they will measure up to the nondestructive testing requirements normally imposed by these codes. This implies crack-free, pressure-tight welds, with little or no porosity or undercut.

The specific requirements of codes are so numerous and varied that code-quality procedures may not satisfy every detail of a specific code. Procedure qualification tests are recommended to confirm the acceptability of chosen procedures.

All butt welds made to code quality are full-penetration; fillet welds are full-size, as required by most codes. (The theoretical throat, rather than the true throat, is used as the basis of calculating strength.)

Commercial-Quality Procedures

Commercial quality implies a level of quality and appearance that will meet the nominal requirements imposed on most of the welding done commercially. These welds will be pressure-tight and crack-free. They will have good appearance, and they will meet the normal strength requirements of the joint.

Procedures for commercial-quality welds are not as conservative as code-quality procedures; speeds and currents are generally higher. Welds made according to these procedures may have minor defects that would be objectionable to the more demanding codes.

It is recommended that appropriate tests be performed to confirm the acceptability of the selected procedure for the application at hand prior to putting it into production.

Weldability of Material

Weldability (see Section 6.1) of a steel has a considerable effect on the welding procedure. For some joints, more than one procedure is offered because of the marginal weldability of the steel.

Good weldability indicates a steel with a composition that is within the preferred range (see Table 6-1) — one whose chemistry does not limit the welding speed.

Fair weldability indicates a steel with one or more elements outside the preferred range or one that contains one or more alloys. These steels require a lower welding speed or a mild preheat, or both, to minimize defects such as porosity, cracking, and undercut.

Poor weldability steels are those with compositions outside the preferred range, alloy additions, segregations, previous heat-treatment, or some other condition that makes them difficult to weld. These steels require still lower welding speeds, preheat, possibly a postheat, and careful electrode selection to obtain a satisfactory weld.

The addition of alloys to steel that enhance the mechanical properties or hardenability usually have an adverse effect on weldability. In general, the weldability of low-alloy steels is never better than "fair."

DATA SHEET

Article to be Welded ______________________ Job No. __________

Plate Specs or Analysis ______________________

Welding Process ______________ Submitted by: ______________ Date: __________

JOINT PREPARATION — BEAD PLACEMENT, SIZE, SEQUENCE

WORK ANGLE — DRAG ANGLE
ELECTRODE ANGLE TO JOINT

Pass No	AC DC (+ −)	Amps	Volts	Travel Speed "/Min	Electrode Type	Elect. Size	Stick-Out	Flux Type					

Special Comments ______________________

Procedures Notes

In the following fillet-weld procedures, the fillet size is always associated with a particular plate thickness. This relationship is given solely for the purpose of designing a welding procedure and does not imply that a certain size fillet is the only size applicable to that plate thickness. In some of the procedures, the fillet size shown is larger than necessary to meet code requirements for the plate thickness. In such instances, select the procedure for the proper weld size and quality. If the thickness of the plate being welded is appreciably greater than that specified in the procedure, a reduction in welding speed and current will probably be required.

The procedure data given have been developed to provide the most economical procedures for various applications. In some cases, more than one type or size of electrode is recommended for the same joint. In small shops, electrode selection may depend on the available power source; consequently, some joints have procedures for either AC or DC welders.

With some joints procedures for two different types of electrodes are given — for example, E7014 or E7024, E7018 or E7028. This allows a choice of electrodes so the one with the better usability characteristics can be selected.

Any procedure for a poor or fair welding quality steel may be used on a steel of a better welding quality.

Travel speed is given as a range. The electrode required and the total time are based on the middle of the range.

Unless otherwise indicated, both members of the joint are the same thickness.

Pounds-of-electrode data include all ordinary deposition losses. These values are in terms of pounds of electrode needed to be purchased.

Total time is the arc time only and does not allow for operating factor.

After a satisfactory welding procedure has been established, all the data should be recorded and filed for future reference. This information is invaluable if the same job or a similar job occurs at a later date. A suggested data sheet is shown on the opposite page.

The presented procedures are offered as a starting point and may require changes to meet the requirements of specific applications. Because the many variables in design, fabrication, and erection or assembly affect the results obtained in applying this type of information, the serviceability of the product or structure is the responsibility of the builder.

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

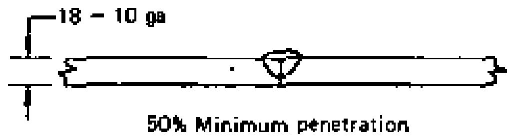


Plate Thickness (in.) †	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)*
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(+)	40†	70†	80	120	135
Arc Speed (in./min)	22 – 26	30 – 35	25 – 30	20 – 24	17 – 21
Electrode Req'd (lb/ft)	0.0244	0.0287	0.0262	0.0487	0.0695
Total Time (hr/ft of weld)	0.00833	0.00615	0.00727	0.00909	0.0105

* Use 1/16 in. gap and whip the electrode.
† DC(−)

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

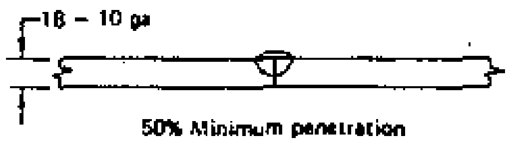


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)*
Pass	1	1	1	1	1
Electrode Class	E6011	E6011	E6011	E6011	E6011
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) AC	50	100	105	130	145
Arc Speed (in./min)	20 – 24	28 – 33	26 – 31	24 – 29	22 – 27
Electrode Req'd (lb/ft)	0.0251	0.0326	0.0367	0.0527	0.0648
Total Time (hr/ft of weld)	0.00909	0.00656	0.00702	0.00756	0.00817

* Use 1/16 in. gap and whip the electrode.

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Code
Steel Weldability: Good
Welded From: One side

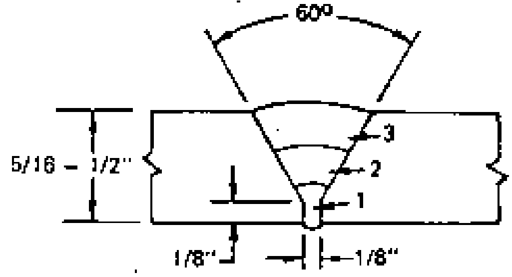
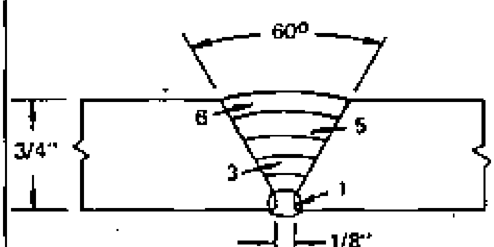


Plate Thickness (in.)	5/16		3/8		1/2		
Pass	1	2	1	2 & 3	1	2	3
Electrode Class	E6011	E6027	E6011	E6027	E6011	E6011	E6027
Size	5/32	5/32	5/32	5/32	5/32	1/4	1/4
Current (amp) AC	135	240	135	240	135	275	400
Arc Speed (in./min)	5.5-6.5	12.0-14.0	5.5-6.5	12.0-14.0	5.5-6.5	8.0-10.0	10.0-12.0
Electrode Req'd (lb/ft)	0.168	0.142	0.168	0.284	0.168	0.229	0.354
Total Time (hr/ft of weld)	0.0487		0.0641		0.0717		

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Code
Steel Weldability: Good
Welded From: One side



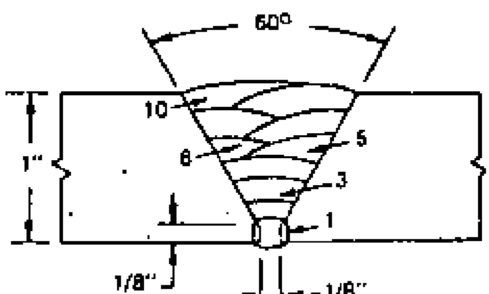


Plate Thickness (in.)	3/4			1		
Pass	1	2	3 – 6	1	2	3 – 10
Electrode Class	E6011	E6011	E6027	E6011	E6011	E6027
Size	5/32	1/4	1/4	5/32	1/4	1/4
Current (amp) AC	135	275	400	135	275	400
Arc Speed (in./min)	5.5 – 6.5	8.0 – 10.0	11.0 – 13.0	5.5 – 6.5	8.0 – 10.0	11.0 – 13.0
Electrode Req'd (lb/ft)	0.168	0.228	1.47	0.168	0.228	2.94
Total Time (hr/ft of weld)	0.122			0.189		

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

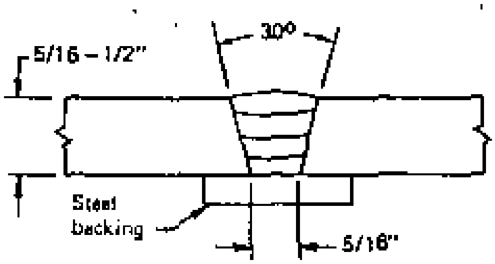


Plate Thickness (in.)	5/16		3/8		1/2	
Pass	1	2 – 3	1	2 – 3	1	2 – 4
Electrode Class	E6027	E6027	E6027	E6027	E6027	E6027
Size	3/16	1/4	3/16	1/4	3/16	1/4
Current (amp) AC	300	400	300	400	300	400
Arc Speed (in./min)	13.0-15.0	15.0-18.0	13.0-15.0	11.5-13.5	13.0-15.0	12.5-14.5
Electrode Req'd (lb/ft)	0.228	0.524	0.228	0.697	0.228	1.00
Total Time (hr/ft of weld)	0.0385		0.0463		0.0605	

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

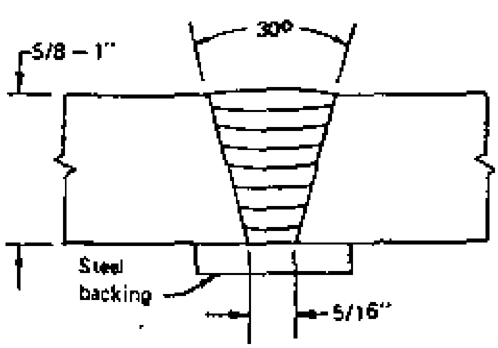


Plate Thickness (in.)	5/8		3/4		1	
Pass	1	2 – 5	1	2 – 6	1	2 – 8
Electrode Class	E6027	E6027	E6027	E6027	E6027	E6027
Size	3/16	1/4	3/16	1/4	3/16	1/4
Current (amp) AC	300	400	300	400	300	400
Arc Speed (in./min)	13.0-15.0	12.5-14.5	13.0-15.0	12.5-14.5	13.0-15.0	12.5-14.5
Electrode Req'd (lb/ft)	0.228	1.35	0.228	1.69	0.228	2.37
Total Time (hr/ft of weld)	0.0759		0.0913		0.122	

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Code
Steel Weldability: Good
Welded From: Two sides

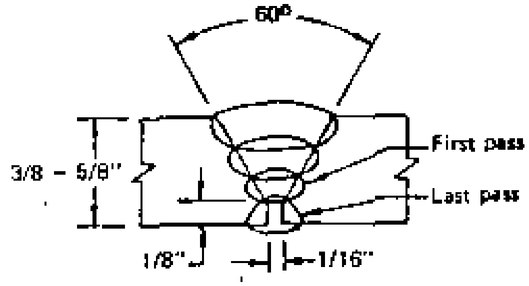


Plate Thickness (in.)	3/8		1/2		5/8		
Pass	1	2 & 3	1	2 & 3	1	2 & 3	4
Electrode Class	E6011	E6027	E6011	E6027	E6011	E6027	E6027
Size	3/16	3/16	1/4	7/32	1/4	1/4	7/32
Current (amp) AC	175	280	275	340	275	376	340
Arc Speed (in./min)	8.0-10.0	14.5-17.5	7.0-9.0	13.5-15.5	7.0-9.0	12.5-14.5	11.5-13.5
Electrode Req'd (lb/ft)	0.148	0.366	0.239	0.480	0.241	0.795	0.235
Total Time (hr/ft of weld)	0.0472		0.0526		0.0706		

Back gouge first pass before welding last pass.

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Code
Steel Weldability: Good
Welded From: Two sides

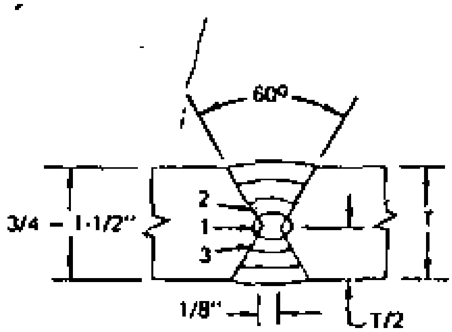


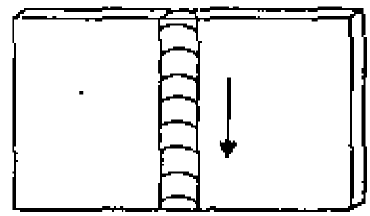
Plate Thickness (in.)	3/4			1			1-1/2		
Pass	1	2 & 3	4 & 5	1	2 & 3	4 – 7	1	2 & 3	4 – 10
Electrode Class	E6011	E6011	E6027	E6011	E6011	E6027	E6011	E6011	E6027
Size	3/16	1/4	1/4	3/16	1/4	1/4	3/16	1/4	1/4
Current (amp) AC	135	275	400	135	275	400	135	275	400
Arc Speed (in./min)	5.5-6.5	8.0-10.0	11.0-13.0	5.5-6.5	8.0-10.0	11.0-13.0	5.5-6.5	8.0-10.0	9.5-11.5
Electrode Req'd (lb/ft)	0.190	0.400	0.728	0.190	0.400	1.45	0.190	0.400	3.04
Total Time (hr/ft of weld)	0.111			0.144			0.211		

Back gouge first pass before welding third pass. Complete third pass side before turning over.

SHIELDED METAL-ARC (MANUAL)

Position: Vertical down
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

18 – 10 ga



50% Minimum penetration

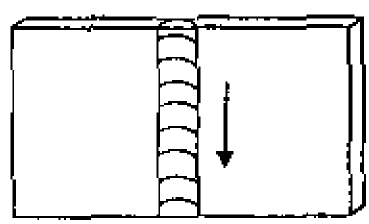
Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)*
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(+)	45†	75†	90	130	160
Arc Speed (in./min)	25 – 30	33 – 38	27 – 32	22 – 27	18 – 22
Electrode Req'd (lb/ft)	0.0234	0.0281	0.0272	0.0478	0.0730
Total Time (hr/ft of weld)	0.00727	0.00555	0.00678	0.00817	0.00100

* Use 1/16 in. gap and whip the electrode.
† Use DC(–)

SHIELDED METAL-ARC (MANUAL)

Position: Vertical down
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

18 – 10 ga



50% Minimum penetration

Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)*
Pass	1	1	1	1	1
Electrode Class	E6011	E6011	E6011	E6011	E6011
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) AC	55	110	115	140	155
Arc Speed (in./min)	23 – 28	29 – 34	27 – 32	26 – 31	24 – 28
Electrode Req'd (lb/ft)	0.0236	0.0345	0.0376	0.0523	0.0640
Total Time (hr/ft of weld)	0.00785	0.00635	0.00678	0.00703	0.00755

* Use 1/16 in. gap and whip the electrode.

SHIELDED METAL-ARC (MANUAL)

Position: Vertical up
Weld Quality Level: Code
Steel Weldability: Good
Welded From: One side

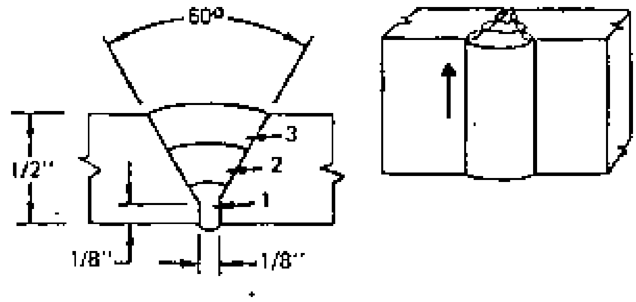


Plate Thickness (in.)	1/4	5/16	3/8	1/2
Pass	1 & 2	1 & 2	1 & 2	1 – 3
Electrode Class	E6010	E6010	E6010	E6010
Size	5/32	5/32	3/16	3/16
Current (amp) DC(+)	110	120	150	170
Arc Speed (in./min)*	5.2-5.8	3.8-4.2	4.8-5.3	3.8-4.2
Electrode Req'd (lb/ft)	0.323	0.440	0.586	0.990
Total Time (hr/ft of weld)	0.0901	0.118	0.130	0.152

* First pass only. Vary speed on succeeding passes to obtain proper weld size.

SHIELDED METAL-ARC (MANUAL)

Position: Vertical up
Weld Quality Level: Code
Steel Weldability: Good
Welded From: One side

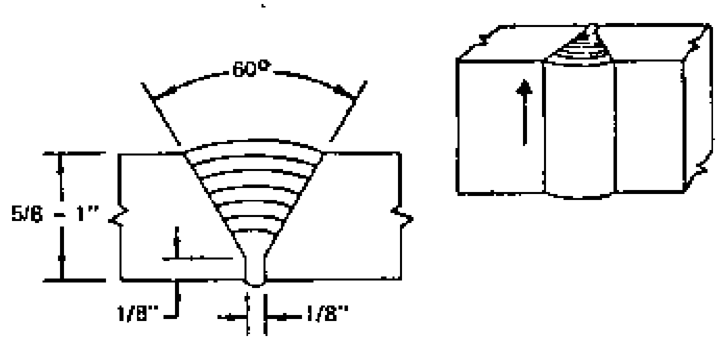


Plate Thickness (in.)	5/8	3/4	1
Pass	1 – 4	1 – 6	1 – 10
Electrode Class	E6010	E6010	E6010
Size	3/16	3/16	3/16
Current (amp) DC(+)	170	170	170
Arc Speed (in./min)*	3.8 – 4.2	3.8 – 4.2	3.8 – 4.2
Electrode Req'd (lb/ft)	1.48	2.08	3.56
Total Time (hr/ft of weld)	0.228	0.318	0.547

* First pass only. Vary speed on succeeding passes to obtain proper weld size.

SHIELDED METAL-ARC (MANUAL)

Position: Vertical up
Weld Quality Level: Code
Steel Weldability: Fair
Welded From: One side

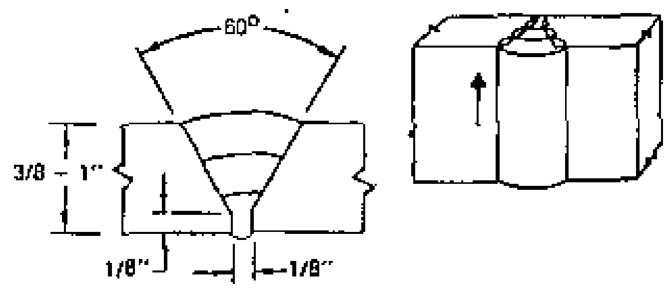


Plate Thickness (in.)	3/8		1/2		3/4		1	
Pass	1	2	1	2 – 3	1	2 – 7	1	2 – 11
Electrode Class	E6010	E7018	E6010	E7018	E6010	E7018	E6010	E7018
Size	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32
Current (amp) DC(+)	160	160	160	160	160	160	160	160
Arc Speed (in./min)	4.3-4.7	3.2-3.5*	4.3-4.7	3.2-3.5*	4.3-4.7	3.2-3.5*	4.3-4.7	3.2-3.5*
Electrode Req'd (lb/ft)	0.281	0.341	0.281	0.758	0.281	1.93	0.281	3.52
Total Time (hr/ft of weld)	0.104		0.176		0.381		0.659	

* Second pass only. Vary speed on succeeding passes to obtain proper weld size.

SHIELDED METAL-ARC (MANUAL)

Position: Vertical up
Weld Quality Level: Code
Steel Weldability: Good
Welded From: Two sides

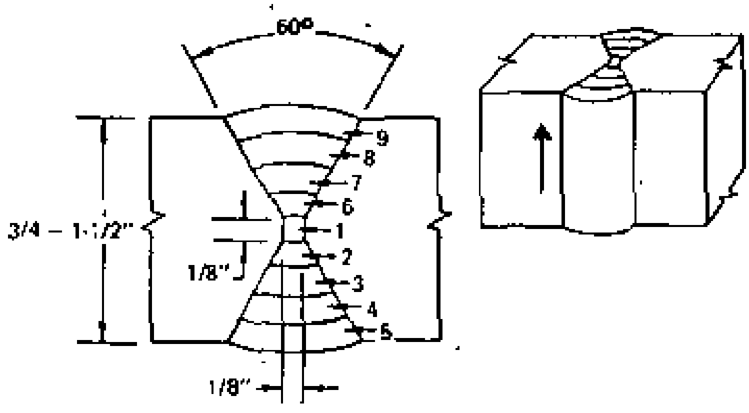


Plate Thickness (in.)	3/4		1		1-1/4		1-1/2	
Pass	1	2 – 5	1	2 – 7	1	2 – 7	1	2 – 9
Electrode Class	E6010	E7018	E6010	E7018	E6010	E7018	E6010	E7018
Size	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32
Current (amp) DC(+)	140	160	140	160	140	160	140	160
Arc Speed (in./min)	3.5-4.1	4.1-4.9	3.5-4.1	3.5-4.1	3.9-4.1	2.3-2.9	3.5-4.1	2.4-3.0
Electrode Req'd (lb/ft)	0.240	0.900	0.240	1.66	0.240	2.40	0.240	3.16
Total Time (hr/ft of weld)	0.230		0.367		0.514		0.645	

Gouge out seam for first pass on second side.

SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Code
Steel Weldability: Fair
Welded From: One side

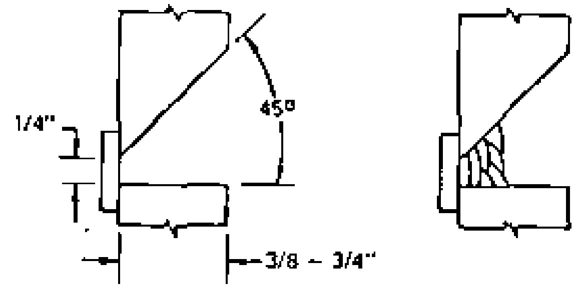


Plate Thickness (in.)	3/8		1/2		5/8		3/4	
Pass	1	2 – 5	1	2 – 7	1	2 – 9	1	2 – 11
Electrode Class	E7018		E7018		E7018		E7018	
Size (in.)	3/16		3/16		3/16		3/16	
Current (amp) DC(+)	240		240		240		240	
Arc Speed (in./min)	4.5-5.5	8.5-9.5	4.5-5.5	7.5-8.5	4.5-5.5	6.7-7.4	5.5-6.5	6.2-6.8
Electrode Req'd (lb/ft)	0.867		1.35		1.75		2.42	
Total Time (hr/ft of weld)	0.118		0.182		0.270		0.345	

SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Code
Steel Weldability: Fair
Welded From: One side

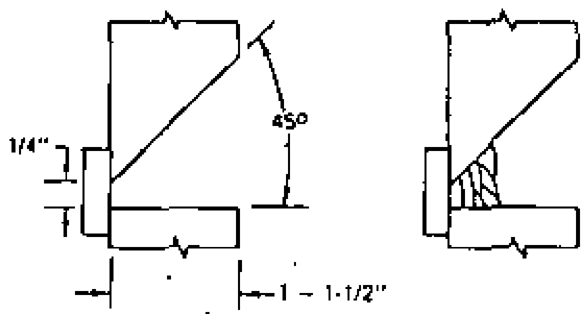


Plate Thickness (in.)		1		1-1/4		1-1/2	
Pass	1*	2 – 13	14 – 19†	2 – 17	18 – 24†	2 – 22	23 – 31†
Electrode Class	E7018	E7018		E7018		E7018	
Size (in.)	3/16	7/32	3/16	7/32	3/16	7/32	3/16
Current (amp) DC(+)	240	280	240	280	240	280	240
Arc Speed (in./min)	5 – 6	6.2-6.8	9.5-10.5	5.7-6.3	9.5-10.5	5.2-5.8	9.5-10.5
Electrode Req'd (lb/ft)		3.39	.994	4.82	1.23	6.40	1.60
Total Time (hr/ft of weld)		0.526		.714		1.00	

* First pass for all thicknesses.
† Cover passes.

SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Commercial
Steel Weldability: Fair
Welded From: Two sides

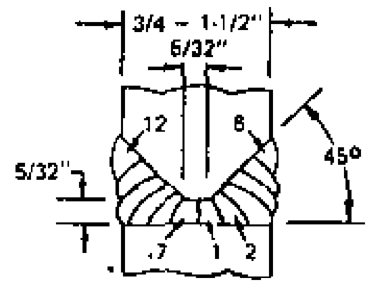


Plate Thickness (in.)	3/4		1		1-1/4		1-1/2	
Pass	1	2 – 6	1	2 – 10	1	2 – 10	1	2 – 12
Electrode Class	E7018	E7018	E7018	E7018	E7018	E7018	E7018	E7018
Size	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16
Current (amp) DC(+)	240	240	240	240	240	240	240	240
Arc Speed (in./min)	5.5-6.5	9.0-11.0	4.4-5.2	8.5-10.5	3.8-4.6	5.5-6.5	3.7-4.3	4.6-5.4
Electrode Req'd (lb/ft)	0.956		1.47		2.60		3.84	
Total Time (hr/ft of weld)	0.133		0.230		0.347		0.490	

Fill first pass side. Back gouge as required before welding second side.

SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Code
Steel Weldability: Fair
Welded From: One side

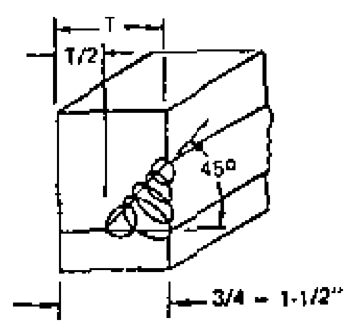
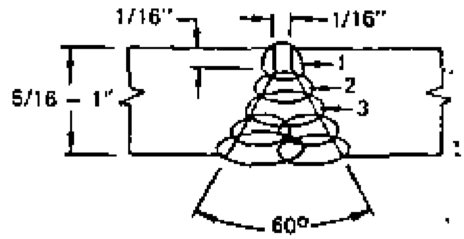


Plate Thickness (in.)		3/4	1	1-1/4	1-1/2
Pass	1*	2 – 3	2 – 5	2 – 6	2 – 8
Electrode Class	E7018	E7018	E7018	E7018	E7018
Size (in.)	3/16	3/16	3/16	3/16	3/16
Current (amp) DC(+)	240	240	240	240	240
Arc Speed (in./min)	4.0-6.0	9.5-10.5	9.0-10.0	5.7-6.3	4.7-5.3
Electrode Req'd (lb/ft)		0.470	0.740	1.80	1.92
Total Time (hr/ft of weld)		0.0800	0.116	0.178	0.250

* First pass for all thicknesses.

SHIELDED METAL-ARC (MANUAL)

Position: Overhead
Weld Quality Level: Code
Steel Weldability: Fair
Welded From: One side



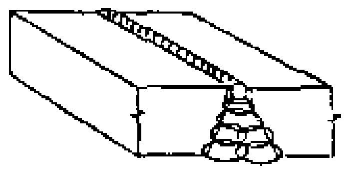
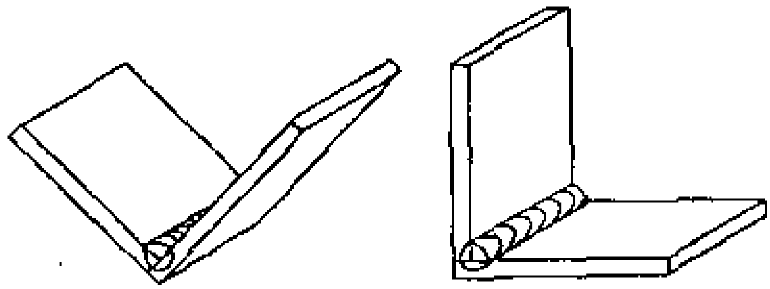


Plate Thickness (in.)	5/16		3/8		1/2		3/4		1	
Pass	1	2	1	2 – 3	1	2 – 5	1	2 – 9	1	2 – 13
Electrode Class	E6010	E7018	E6010	E7018	E6010	E7018	E6010	E7018	E6010	E7018
Size	1/8	5/32	1/8	5/32	1/8	5/32	1/8	5/32	1/8	5/32
Current (amp) DC(+)	110	170	110	170	110	170	110	170	110	170
Arc Speed (in./min)	4.3 – 4.7	3.4 – 3.8	4.3 – 4.7	3.3 – 3.7	4.3 – 4.7	3.6 – 4.0	4.3 – 4.7	4.3 – 4.7	4.3 – 4.7	3.6 – 4.0
Electrode Req'd (lb/ft)	0.155	0.327	0.155	0.671	0.155	0.918	0.155	2.08	0.155	3.70
Total Time (hr/ft of weld)	0.0999		0.158		0.202		0.399		0.575	

Split layers after third pass, as shown in sketch.

SHIELDED METAL-ARC (MANUAL)

Position: Flat and horizontal
Weld Quality Level: Commercial
Steel Weldability: Good

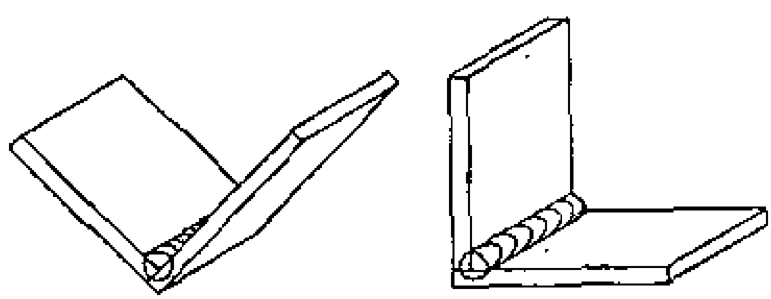


18 – 10 ga

Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6012	E6012	E6012	E6012
Size	3/32	1/8	5/32	3/16	3/16
Current (amp) DC(–)	70	95	140	190	200
Arc Speed (in./min)	14 – 18	15 – 19	16 – 20	20 – 24	16 – 20
Electrode Req'd (lb/ft)	0.0413	0.0583	0.0848	0.0866	0.112
Total Time (hr/ft of weld)	0.0125	0.0118	0.0111	0.00910	0.0111

SHIELDED METAL-ARC (MANUAL)

Position: Flat and horizontal
Weld Quality Level: Commercial
Steel Weldability: Good

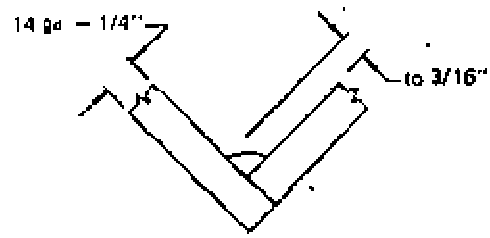


18 – 10 ga

Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6013	E6013	E6013	E6013
Size	3/32	1/8	5/32	5/32	3/16
Current (amp) AC	70	105	155	160	210
Arc Speed (in./min)	14 – 18	14 – 18	15 – 19	14 – 18	14 – 18
Electrode Req'd (lb/ft)	0.0413	0.0495	0.0670	0.0742	0.0826
Total Time (hr/ft of weld)	0.0125	0.0125	0.0118	0.0125	0.0125

SHIELDED METAL-ARC (MANUAL)

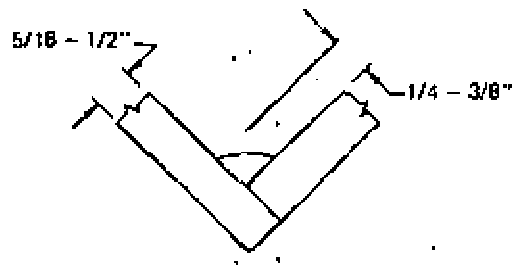
Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good



Weld Size, L (in.)				5/32	5/32	3/16	3/16
Plate Thickness (in.)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)	3/16		1/4	
Pass	1	1	1	1	1	1	1
Electrode Class	E7024	E7024	E7024	E7024	E7024	E7024	E7024
Size	3/32	1/8	1/8	1/8	5/32	5/32	3/16
Current (amp) AC	95	150	160	180	210	230	270
Arc Speed (in./min)	14.5-16.0	16.5-18.5	16.5-18.5	15.0-16.5	16.0-18.0	14.0-15.5	15.5-17.5
Electrode Req'd (lb/ft)	0.0485	0.0760	0.0822	0.102	0.117	0.144	0.162
Total Time (hr/ft of weld)	0.0131	0.0114	0.0114	0.0127	0.0117	0.0136	0.0121

SHIELDED METAL-ARC (MANUAL)

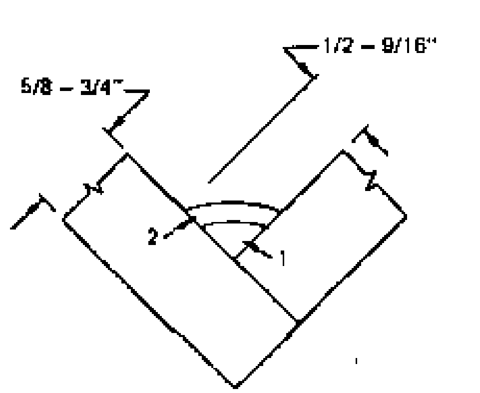
Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good

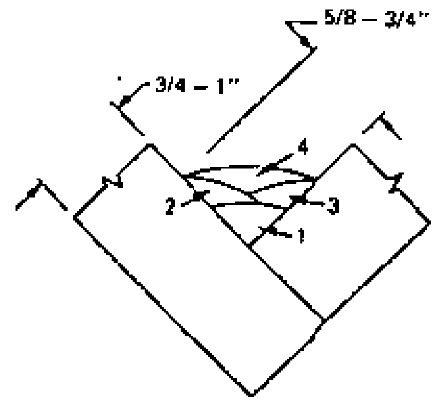


Weld Size, L (in.)	1/4	1/4	9/32	5/16	3/8
Plate Thickness (in.)	5/16		3/8		1/2
Pass	1	1	1	1	1
Electrode Class	E7024	E7024	E7024	E7024	E7024
Size	3/16	7/32	1/4	1/4	5/16
Current (amp) AC	275	325	375	375	475
Arc Speed (in./min)	14.0-16.0	16.0-18.0	17.0-19.0	14.0-15.0	11.0-12.0
Electrode Req'd (lb/ft)	0.19	0.20	0.22	0.29	0.39
Total Time (hr/ft of weld)	0.0133	0.0118	0.0131	0.138	0.174

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Commercial
Weldability: Good

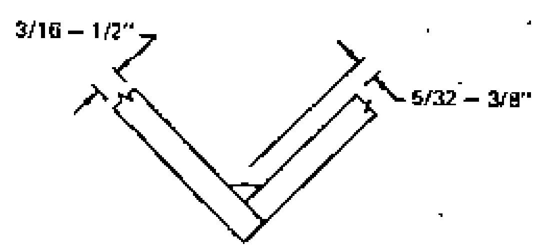




Weld Size, L (in.)	1/2		9/16		5/8		3/4	
Plate Thickness (in.)	5/8		3/4		3/4		1	
Pass	1	2	1	2	1	2 & 3	1	2 – 4
Electrode Class	E7024	E7024	E7024	E7024	E7024	E7024	E7024	E7024
Size	5/16	5/16	5/16	5/16	5/16	5/16	5/16	5/16
Current (amp) AC	475	550	475	550	475	550	475	550
Arc Speed (in./min)	13.0-15.0	14.0-16.0	13.0-15.0	10.0-11.0	13.0-15.0	14.0-15.0	13.0-15.0	13.0-14.0
Electrode Req'd (lb/ft)	0.67		0.86		1.07		1.46	
Total Time (hr/ft of weld)	0.0276		0.0333		0.0429		0.587	

SHIELDED METAL-ARC (MANUAL)

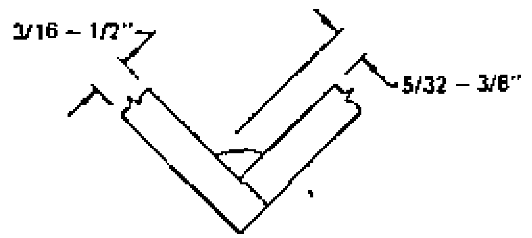
Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good



Weld Size, L (in.)	5/32	3/16	1/4	5/16	3/8
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2
Pass	1	1	1	1	1
Electrode Class	E7014	E7014	E7014	E7014	E7014
Size	5/32	3/16	7/32	1/4	5/16
Current (amp) AC	200	250	310	370	450
Arc Speed (in./min)	12.5-13.5	12.0-13.0	11.0-12.0	9.0-10.0	7.5-8.5
Electrode Req'd (lb/ft)	0.0980	0.121	0.181	0.270	0.375
Total Time (hr/ft of weld)	0.0154	0.0160	0.0174	0.0211	0.0250

SHIELDED METAL-ARC (MANUAL)

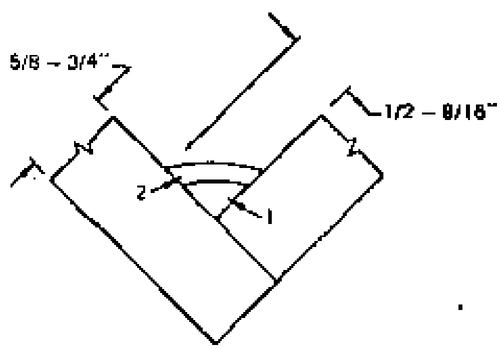
Position: Flat
Weld Quality Level: Code
Steel Weldability: Good

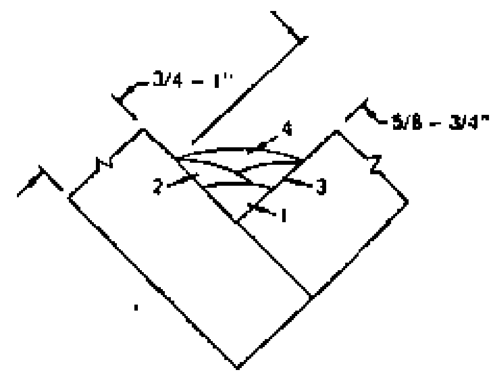


Weld Size, L (in.)	5/32	3/16		1/4		9/32	5/16	3/8
Plate Thickness (in.)	3/16	1/4		5/16		3/8		1/2
Pass	1	1	1	1	1	1	1	1
Electrode Class	E6027	E6027	E6027	E6027	E6027	E6027	E6027	E6027
Size	5/32	5/32	3/16	3/16	7/32	1/4	1/4	1/4
Current (amp) AC	210	270	260	270	335	380	390	400
Arc Speed (in./min)	15.5-17.0	13.5-15.0	15.5-17.0	12.5-14.0	14.5-16.0	14.0-15.5	11.0-12.0	9.5-10.5
Electrode Req'd (lb/ft)	0.119	0.146	0.167	0.215	0.228	0.268	0.343	0.428
Total Time (hr/ft of weld)	0.0123	0.0140	0.0123	0.0151	0.0131	0.0136	0.0174	0.0200

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Code
Steel Weldability: Good

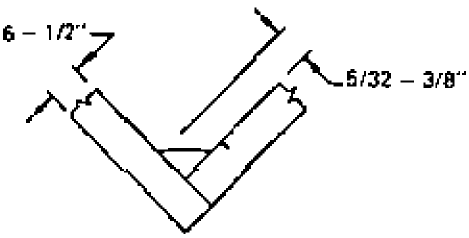




Weld Size, L (in.)	1/2		9/16		5/8		3/4	
Plate Thickness (in.)	5/8		3/4		3/4		1	
Pass	1	2	1	2	1	2 & 3	1	2 – 4
Electrode Class	E6027	E6027	E6027	E6027	E6027	E6027	E6027	E6027
Size	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4
Current (amp) AC	400	400	400	400	400	400	400	400
Arc Speed (in./min)	11.5-12.5	11.5-12.5	11.5-12.5	7.5-8.5	11.5-12.5	11.0-12.0	11.5-12.5	10.0-11.0
Electrode Req'd (lb/ft)	0.727		0.936		1.12		1.58	
Total Time (hr/ft of weld)	0.0333		0.0417		0.512		0.0737	

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Code
Steel Weldability: Poor

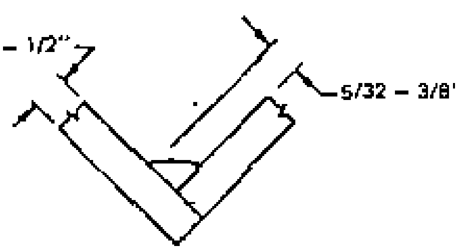


Weld Size, L (in.)	5/32	3/16	1/4	5/16	3/8
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2
Pass	1	1	1	1	1
Electrode Class	E7028	E7028	E7028	E7028	E7028
Size	5/32	3/16	3/16	7/32	1/4
Current (amp) AC	215	260	280	330	400
Arc Speed (in./min)	13.5-15.0	13.5-15.0	11.0-12.0	10.0-12.0	8.5-9.5
Electrode Req'd (lb/ft)	0.104	0.147	0.208	0.285	0.437
Total Time (hr/ft of weld)	0.0140	0.0140	0.0175	0.0175	0.222

Preheat may be necessary depending on plate material.

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Code
Steel Weldability: Poor

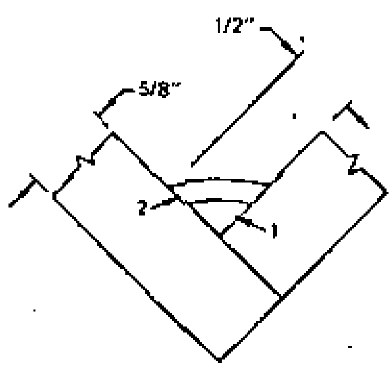


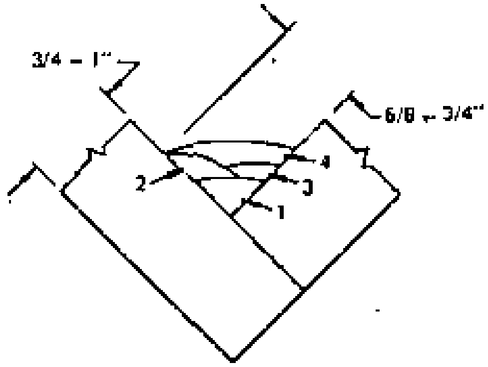
Weld Size, L (in.)	5/32	3/16	1/4	5/16	3/8
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2
Pass	1	1	1	1	1
Electrode Class	E7018	E7018	E7018	E7018	E7018
Size	3/16	7/32	7/32	1/4	1/4
Current (amp) AC	240	275	275	350	360
Arc Speed (in./min)	13.5-15.0	13.0-14.0	8.0-10.0	7.0-8.0	6.0-6.8
Electrode Req'd (lb/ft)	0.109	0.132	0.195	0.272	0.409
Total Time (hr/ft of weld)	0.0140	0.0149	0.0202	0.0270	0.0313

Preheat may be necessary depending on plate material.

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Code
Steel Weldability: Poor



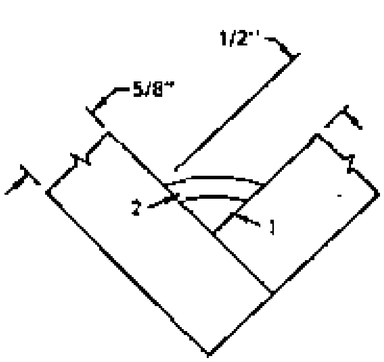


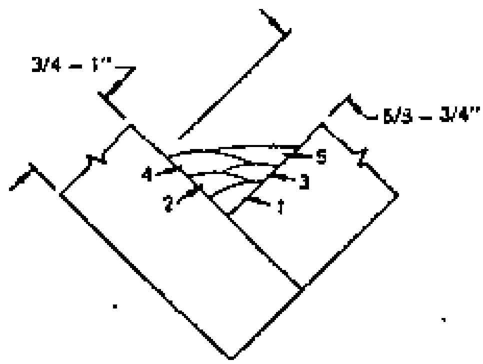
Weld Size, L (in.)	1/2	5/8	3/4
Plate Thickness (in.)	5/8	3/4	1
Pass	1 & 2	1 – 3	1 – 4
Electrode Class	E7028	E7028	E7028
Size	1/4	1/4	1/4
Current (amp) AC	400	400	400
Arc Speed (in./min)	9.5 – 11.5	9.0 – 11.0	9.0 – 11.0
Electrode Req'd (lb/ft)	0.776	1.24	1.79
Total Time (hr/ft of weld)	0.0384	0.0615	0.0887

Preheat may be necessary depending on plate material.

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Code
Steel Weldability: Poor



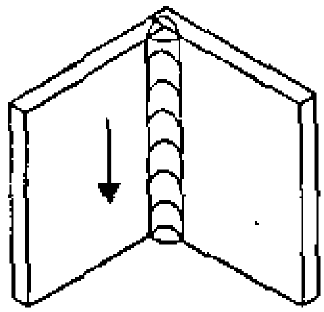


Weld Size, L (in.)	1/2	5/8	3/4
Plate Thickness (in.)	5/8	3/4	1
Pass	1 & 2	1 – 4	1 – 5
Electrode Class	E7018	E7018	E7018
Size	1/4	1/4	1/4
Current (amp) AC	350	350	350
Arc Speed (in./min)	6.9 – 7.6	6.7 – 7.5	6.6 – 7.4
Electrode Req'd (lb/ft)	0.727	1.14	1.60
Total Time (hr/ft of weld)	0.0565	0.114	0.123

Preheat may be necessary depending on plate material.

SHIELDED METAL-ARC (MANUAL)

Position: Vertical down
Weld Quality Level: Commercial
Steel Weldability: Good

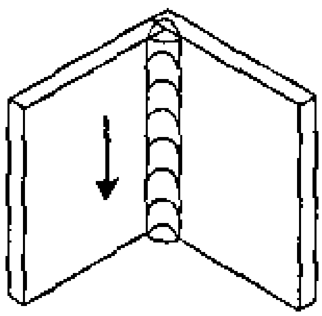


18 – 10 ga

Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6012	E6012	E6012	E6012
Size	3/32	1/8	5/32	3/16	3/16
Current (amp) DC(–)	70	105	160	200	210
Arc Speed (in./min)	17 – 21	18 – 22	21 – 25	23 – 28	21 – 25
Electrode Req'd (lb/ft)	0.0374	0.0542	0.0713	0.0792	0.0930
Total Time (hr/ft of weld)	0.0105	0.0100	0.00870	0.00785	0.00870

SHIELDED METAL-ARC (MANUAL)

Position: Vertical down
Quality: Commercial
Weldability: Good

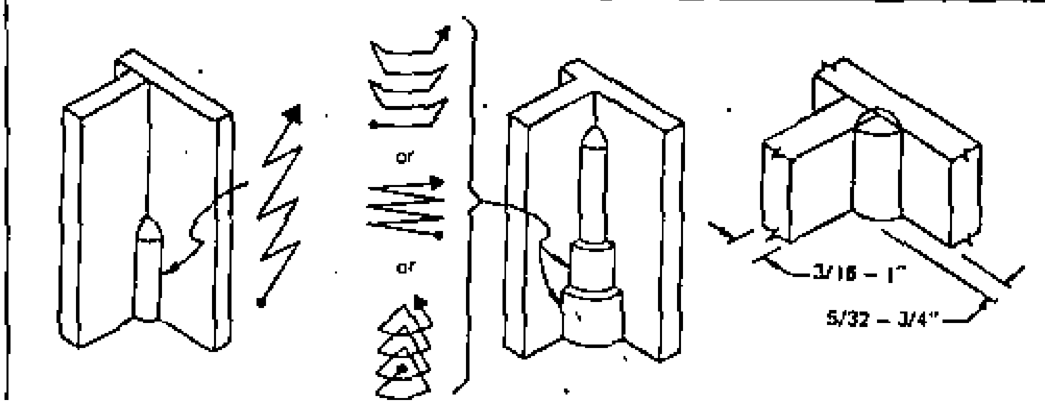


18 – 10 ga

Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6013	E6013	E6013	E6013
Size	3/32	1/8	5/32	5/32	3/16
Current (amp) AC	75	115	165	170	226
Arc Speed (in./min)	16 – 20	17 – 21	19 – 23	18 – 22	16 – 20
Electrode Req'd (lb/ft)	0.0418	0.0463	0.0583	0.0636	0.0916
Total Time (hr/ft of weld)	0.0111	0.0105	0.00953	0.0100	0.0111

SHIELDED METAL-ARC (MANUAL)

Position: Vertical
Weld Quality Level: Code
Steel Weldability: Good

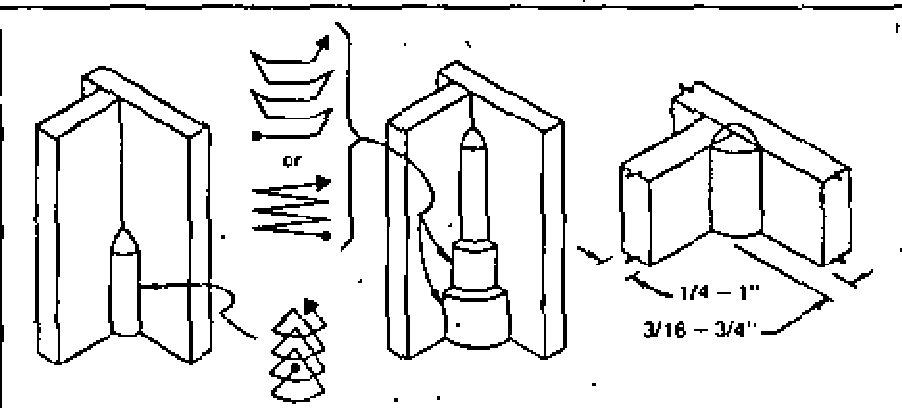


Weld Size, L (in.)	5/32	3/16	1/4	5/16	3/8	1/2	5/8	3/4
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2	5/8	3/4	1
Pass	1	1	1	1	1	1 – 2	1 – 3	1 – 4
Electrode Class	E6010	E6010	E6010	E6010	E6010	E6010	E6010	E6010
Size	5/32	3/16	3/16	3/16	3/16	3/16	3/16	3/16
Current (amp) DC(+)	120	150	155	155	155	160	160	160
Arc Speed (in./min)	10.5-11.5	7.4-8.2	5.0-5.5	3.0-3.3	2.0-2.2	4.3-4.7*	4.3-4.7*	4.3-4.7*
Electrode Req'd (lb/ft)	0.0712	0.137	0.211	0.346	0.514	0.850	1.31	1.93
Total Time (hr/ft of weld)	0.0182	0.0256	0.0381	0.0635	0.0852	0.147	0.227	0.333
Direction of welding	Down	Up	Up	Up	Up	Up	Up	Up

* First pass only. Vary speed on succeeding passes to obtain proper weld size.

SHIELDED METAL-ARC (MANUAL)

Position: Vertical
Weld Quality Level: Code
Steel Weldability: Fair

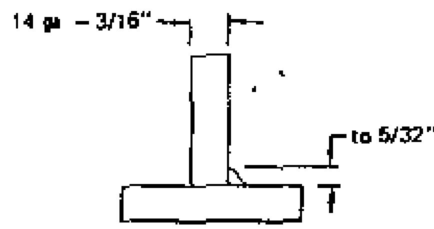


Weld Size, L (in.)	3/16	1/4	5/16	3/8	1/2	5/8	3/4
Plate Thickness (in.)	1/4	5/16	3/8	1/2	5/8	3/4	1
Pass	1	1	1	1	1	1 – 2	1 – 3
Electrode Class	E7018	E7018	E7018	E7018	E7018	E7018	E7018
Size	1/8	1/8	1/8	5/32	5/32	5/32	5/32
Current (amp) DC(+)	135	140	140	150	150	150	150
Arc Speed (in./min)	5.4-5.8	3.8-4.2	2.3-2.5	1.8-2.0	1.1-1.3	1.9-2.1*	1.9-2.1*
Electrode Req'd (lb/ft)	0.155	0.231	0.371	0.556	0.925	1.41	2.11
Total Time (hr/ft of weld)	0.0357	0.0500	0.0833	0.105	0.167	0.261	0.389

* First pass only. Vary speed on succeeding passes to obtain proper size.

SHIELDED METAL-ARC (MANUAL)

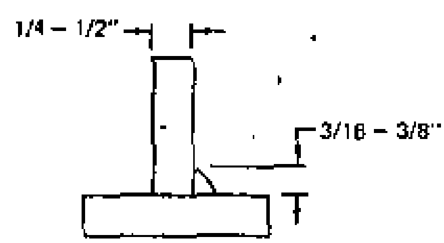
Position: Horizontal
Weld Quality Level: Commercial
Steel Weldability: Good



Weld Size, L (in.)				5/32	
Plate Thickness (in.)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)	3/16	
Pass	1	1	1	1	1
Electrode Class	E7024	E7024	E7024	E7024	E7024
Size	3/32	1/8	1/8	1/8	5/32
Current (amp) AC	95	150	160	180	210
Arc Speed (in./min)	14.0-16.0	16.0-18.5	16.0-18.5	14.5-16.5	15.5-18.0
Electrode Req'd (lb/ft)	0.0495	0.0770	0.0833	0.104	0.119
Total Time (hr/ft of weld)	0.0133	0.0116	0.0116	0.0129	0.0119

SHIELDED METAL-ARC (MANUAL)

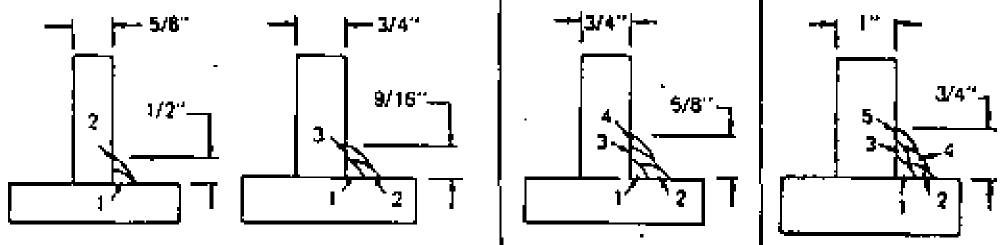
Position: Horizontal
Weld Quality Level: Commercial
Steel Weldability: Good



Weld Size, L (in.)	3/16		1/4		9/32	5/16	3/8
Plate Thickness (in.)	1/4		5/16		3/8		1/2
Pass	1	1	1	1	1	1	1
Electrode Class	E7024	E7024	E7024	E7024	E7024	E7024	E7024
Size	5/32	3/16	3/16	7/32	1/4	1/4	1/4
Current (amp) AC	230	270	275	325	375	375	375
Arc Speed (in./min)	13.5-15.0	15.0-17.0	14.0-15.0	16.0-18.0	16.0-18.0	13.0-14.0	10.5-11.5
Electrode Req'd (lb/ft)	0.150	0.166	0.20	0.21	0.23	0.30	0.41
Total Time (hr/ft of weld)	0.0141	0.0125	0.0138	0.0118	0.0118	0.0148	0.0182

SHIELDED METAL-ARC (MANUAL)

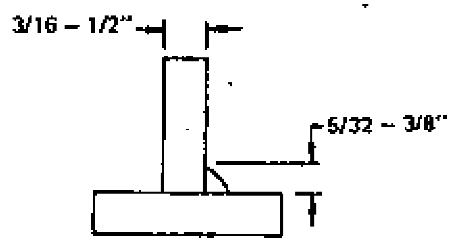
Position: Horizontal
Weld Quality Level: Commercial
Steel Weldability: Good



Weld Size, L (in.)	1/2		9/16		5/8		3/4	
Plate Thickness (in.)	5/8		3/4		3/4		1	
Pass	1	2 & 3	1	2 & 3	1	2 – 4	1	2 – 5
Electrode Class	E7024	E7024	E7024	E7024	E7024	E7024	E7024	E7024
Size	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4
Current (amp) AC	375	375	375	375	375	375	375	375
Arc Speed (in./min)	10.5-11.5	11.0-12.0	10.5-11.5	14.0-16.0	10.5-11.5	14.0-16.0	10.5-11.5	12.0-13.0
Electrode Req'd (lb/ft)	0.73		0.92		1.15		1.62	
Total Time (hr/ft of weld)	0.0356		0.0449		0.0582		0.0822	

SHIELDED METAL-ARC (MANUAL)

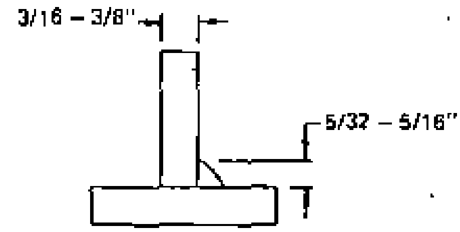
Position: Horizontal
Weld Quality Level: Code
Steel Weldability: Good



Weld Size, L (in.)	5/32	3/16		1/4		9/32	5/16	3/8
Plate Thickness (in.)	3/16	1/4		5/16		3/8		1/2
Pass	1	1	1	1	1	1	1	1
Electrode Class	E6027	E6027	E6027	E6027	E6027	E6027	E6027	E6027
Size	5/32	5/32	3/16	3/16	7/32	7/32	7/32	1/4
Current (amp) AC	210	220	250	260	320	325	335	360
Arc Speed (in./min)	14.5-16.0	13.0-14.5	14.5-16.0	11.5-12.5	13.0-14.5	11.5-12.5	9.5-10.5	7.5-8.5
Electrode Req'd (lb/ft)	0.128	0.151	0.173	0.224	0.241	0.281	0.356	0.463
Total Time (hr/ft of weld)	0.0131	0.0145	0.0131	0.0167	0.0145	0.0167	0.0200	0.0250

SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Code
Steel Weldability: Poor

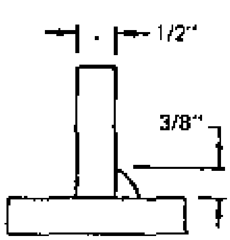


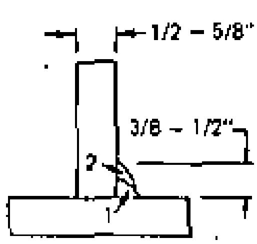
Weld Size, L (in.)	5/32	3/16	1/4		5/16	
Plate Thickness (in.)	3/16	1/4	5/16		3/8	
Pass	1	1	1	1	1	1
Electrode Class	E7028	E7028	E7028	E7028	E7028	E7028
Size	5/32	3/16	3/16	7/32	7/32	1/4
Current (amp) AC	215	260	280	335	335	390
Arc Speed (in./min)	12.5-13.5	11.5-12.5	9.5-10.5	12.0-13.0	9.5-10.5	11.5-12.5
Electrode Req'd (lb/ft)*	0.112	0.157	0.235	0.236	0.320	0.330
Total Time (hr/ft of weld)	0.0152	0.0167	0.0200	0.0160	0.0200	0.0167

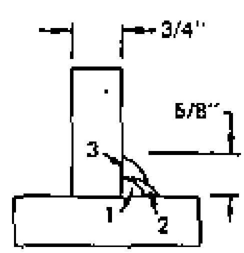
Preheat may be necessary depending on plate material.

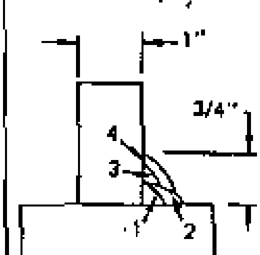
SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Code
Steel Weldability: Poor









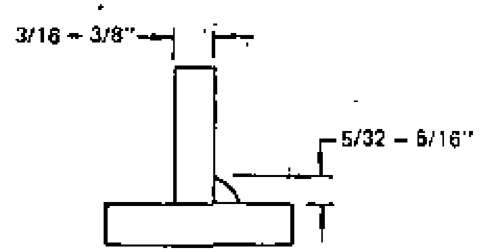
Weld Size, L (in.)	3/8*	3/8	1/2	5/8	3/4
Plate Thickness (in.)	1/2	1/2	5/8	3/4	1
Pass	1	1 – 2	1 – 2	1 – 3	1 – 4
Electrode Class	E7028	E7028	E7028	E7028	E7028
Size	1/4	7/32	1/4	1/4	1/4
Current (amp) AC	390	335	390	390	390
Arc Speed (in./min)	7.5 – 8.5	11.5 – 12.5	9.0 – 10.0	9.0 – 10.0	8.0 – 9.0
Electrode Req'd (lb/ft)	0.483	0.483	0.819	1.28	1.82
Total Time (hr/ft of weld)	0.0250	0.0333	0.0422	0.633	0.940

Preheat may be necessary depending on plate material.

* May not be full 3/8 in. on the vertical leg

SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Code
Steel Weldability: Poor

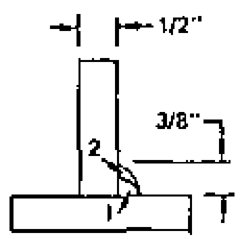


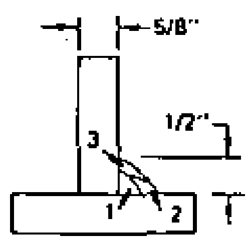
Weld Size, L (in.)	5/32	3/16	1/4	5/16
Plate Thickness (in.)	3/16	1/4	5/16	3/8
Pass	1	1	1	1
Electrode Class	E7018	E7018	E7018	E7018
Size	3/16	7/32	7/32	1/4
Current (amp) AC	240	275	275	350
Arc Speed (in./min)	12.5 – 13.5	11.0 – 12.0	8.5 – 9.5	6.5 – 7.5
Electrode Req'd (lb/ft)	0.111	0.140	0.203	0.335
Total Time (hr/ft of weld)	0.0154	0.0174	0.0222	0.0286

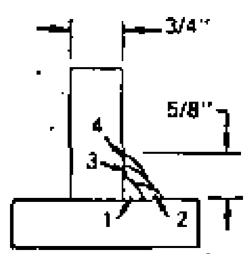
Preheat may be necessary depending on plate material.

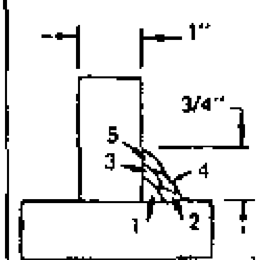
SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Code
Steel Weldability: Poor







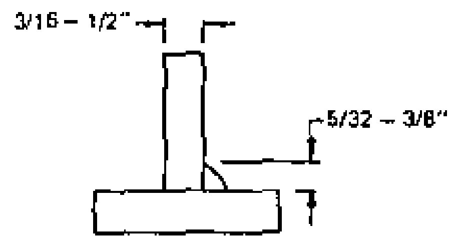


Weld Size, L (in.)	3/8	1/2	5/8	3/4
Plate Thickness (in.)	1/2	5/8	3/4	1
Pass	1 & 2	1 – 3	1 – 4	1 – 5
Electrode Class	E7018	E7018	E7018	E7018
Size	1/4	1/4	1/4	1/4
Current (amp) AC	350	350	350	350
Arc Speed (in./min)	9.5 – 11.5	9.5 – 10.5	8.0 – 9.0	7.0 – 8.0
Electrode Req'd (lb/ft)	0.480	0.785	1.18	1.62
Total Time (hr/ft of weld)	0.0390	0.0600	0.0940	0.133

Preheat may be necessary depending on plate material.

SHIELDED METAL-ARC (MANUAL)

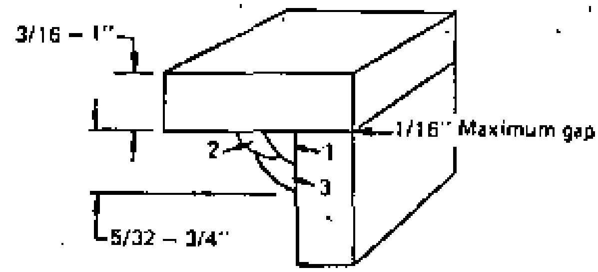
Position: Horizontal
Weld Quality Level: Commercial
Steel Weldability: Good



Weld Size, L (in.)	5/32	3/16	1/4	5/16	3/8
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2
Pass	1	1	1	1	1
Electrode Class	E7014	E7014	E7014	E7014	E7014
Size	5/32	3/16	7/32	1/4	5/16
Current (amp) AC	200	250	310	370	450
Arc Speed (in./min)	10.5-11.5	11.5-12.5	11.0-12.0	9.0-10.0	7.0-8.0
Electrode Req'd (lb/ft)	0.128	0.127	0.191	0.270	0.388
Total Time (hr/ft of weld)	0.0182	0.0167	0.0174	0.0211	0.0267

SHIELDED METAL-ARC (MANUAL)

Position: Overhead
Weld Quality Level: Code
Steel Weldability: Good



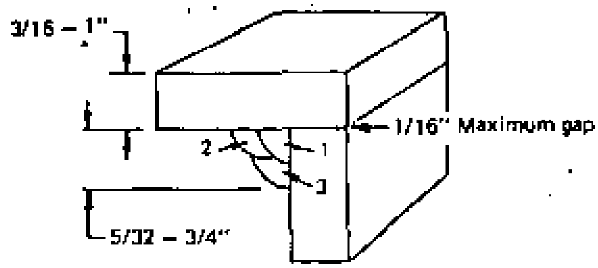
Weld Size, L (in.)	5/32	3/16	1/4	5/16	3/8	1/2	5/8	3/4
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2	5/8	3/4	1
Pass	1	1	1	1 – 2	1 – 3	1 – 6	1 – 10	1 – 15
Electrode Class	E6010	E6010	E6010	E6010	E6010	E6010	E6010	E6010
Size	5/32	3/16	3/16	3/16	3/16	3/16	3/16	3/16
Current (amp) DC(+)	130	170	170	170	170	170	170	170
Arc Speed (in./min)*	7.0-7.7	8.5-9.4	4.8-5.3	6.6-7.3	6.6-7.3	6.6-7.3	6.6-7.3	6.6-7.3
Electrode Req'd (lb/ft)	0.100	0.145	0.253	0.369	0.532	0.945	1.48	2.13
Total Time (hr/ft of weld)	0.0272	0.0223	0.0398	0.0567	0.0820	0.145	0.228	0.328

On 1/2 in. plate and thicker, place the first pass of each layer on the top plate.

* First pass only. Vary speed on succeeding passes to obtain proper weld size.

SHIELDED METAL-ARC (MANUAL)

Position: Overhead
Weld Quality Level: Code
Steel Weldability: Fair



Weld Size, L (in.)	5/32	3/16	1/4	5/16	3/8	1/2	5/8	3/4
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2	5/8	3/4	1
Pass	1	1	1 – 2	1 – 3	1 – 4	1 – 6	1 – 10	1 – 15
Electrode Class	E7018	E7018	E7018	E7018	E7018	E7018	E7018	E7018
Size	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32
Current (amp) DC(+)	170	170	170	170	170	170	170	170
Arc Speed (in./min)*	10.5-11.5	7.2-8.0	8.2-9.1	8.2-9.1	8.5-9.4	7.0-7.7	7.2-8.0	8.1-8.9
Electrode Req'd (lb/ft)	0.107	0.156	0.277	0.394	0.670	1.01	1.69	2.29
Total Time (hr/ft of weld)	0.0182	0.0264	0.0463	0.0670	0.0967	0.172	0.269	0.388

On 3/8 in. plate and thicker place the first pass of each layer on the top plate.

* First pass only. Vary succeeding passes to obtain proper weld size.

SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Commercial
Steel Weldability: Good

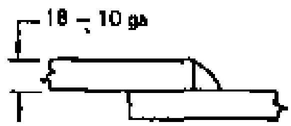
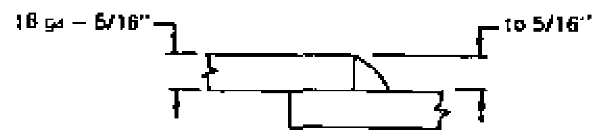


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6012	E6012	E6012	E6012
Size	3/32	1/8	5/32	3/16	3/16
Current (amp) DC(–)	70	105	145	200	210
Arc Speed (in./min)	19 – 23	21 – 26	20 – 24	18 – 22	14 – 18
Electrode Req'd (lb/ft)	0.0339	0.0427	0.0717	0.101	0.134
Total Time (hr/ft of weld)	0.00953	0.00851	0.00910	0.0100	0.0125

SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Commercial
Steel Weldability: Good



Weld Size, L (in.)						3/16	1/4	5/16
Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)	3/16	1/4	5/16
Pass	1	1	1	1	1	1	1	1
Electrode Class	E6013	E6013	E6013	E6013	E6013	E7024	E7024	E7024
Size	3/32	1/8	5/32	5/32	3/16	3/16	7/32	7/32
Current (amp) AC	75	115	160	185	215	290	360	360
Arc Speed (in./min)	15 – 19	16 – 20	16 – 20	14 – 18	13 – 17	14 – 17	14 – 16	12 – 14
Electrode Req'd (lb/ft)	0.0389	0.0490	0.0667	0.0773	0.103	0.170	0.211	0.253
Total Time (hr/ft of weld)	0.0118	0.0111	0.0111	0.0125	0.0133	0.0129	0.0133	0.0155

SHIELDED METAL-ARC (MANUAL)

Position: Vertical down
Weld Quality Level: Commercial
Steel Weldability: Good

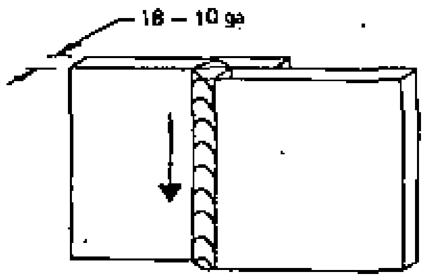


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6012	E6012	E6012	E6012
Size	3/32	1/8	5/32	3/16	3/16
Current (amp) DC(–)	75	115	155	210	220
Arc Speed (in./min)	22 – 27	27 – 32	27 – 32	25 – 30	22 – 27
Electrode Req'd (lb/ft)	0.0316	0.0375	0.0576	0.0781	0.0930
Total Time (hr/ft of weld)	0.00817	0.00678	0.00678	0.00728	0.00817

SHIELDED METAL-ARC (MANUAL)

Position: Vertical down
Weld Quality Level: Commercial
Steel Weldability: Good

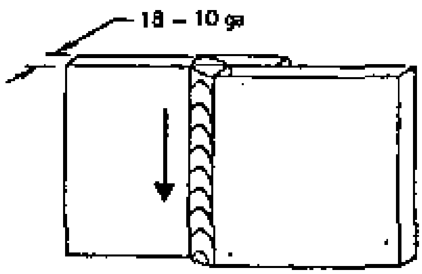


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6013	E6013	E6013	E6013
Size	3/32	1/8	5/32	5/32	3/16
Current (amp) AC	85	125	170	175	225
Arc Speed (in./min)	19 – 23	20 – 24	21 – 26	19 – 23	16 – 20
Electrode Req'd (lb/ft)	0.0358	0.0444	0.0546	0.0631	0.0922
Total Time (hr/ft of weld)	0.00953	0.00910	0.00850	0.00953	0.0111

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

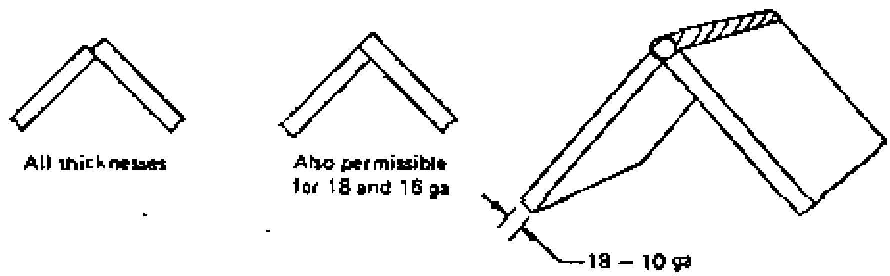
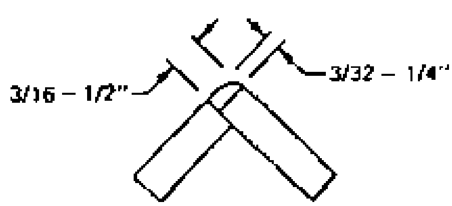


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(–)	45	80	85	110	165*
Arc Speed (in./min)	30 – 35	35 – 40	35 – 40	33 – 38	27 – 32
Electrode Req'd (lb/ft)	0.0197	0.0282	0.0300	0.0432	0.0606
Total Time (hr/ft of weld)	0.00616	0.00533	0.00533	0.00583	0.00678

* Use DC(+)

SHIELDED METAL-ARC (MANUAL)

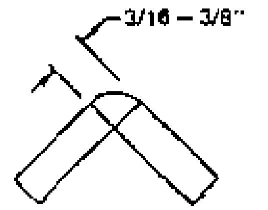
Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

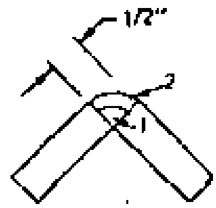


Weld Size, L (in.)	3/32	1/8	5/32	3/16	1/4
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2
Pass	1	1	1	1	1
Electrode Class	E7024	E7024	E7024	E7024	E7024
Size	5/32	3/16	7/32	7/32	1/4
Current (amp) AC	215	275	350	360	410
Arc Speed (in./min)	22.0-27.0	19.0-23.0	18.5-22.5	16.5-19.5	14 – 17
Electrode Req'd (lb/ft)	0.0750	0.114	0.152	0.175	0.250
Total Time (hr/ft of weld)	0.00820	0.00952	0.00975	0.0111	0.0130

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side





Weld Size, L (in.)	3/16	1/4	5/16	3/8	1/2
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2
Pass	1	1	1	1	1 & 2
Electrode Class	E7024	E7024	E7024	E7024	E7024
Size	3/16	7/32	7/32	1/4	1/4
Current (amp) AC	250	320	350	400	410
Arc Speed (in./min)	21.0 – 25.0	18.0 – 22.0	14.5 – 17.5	13.0 – 16.0	11.5 – 14.5
Electrode Req'd (lb/ft)	0.101	0.133	0.198	0.240	0.530
Total Time (hr/ft of weld)	0.00870	0.0100	0.0125	0.0139	0.0308

SHIELDED METAL-ARC (MANUAL)

Position: Vertical down
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

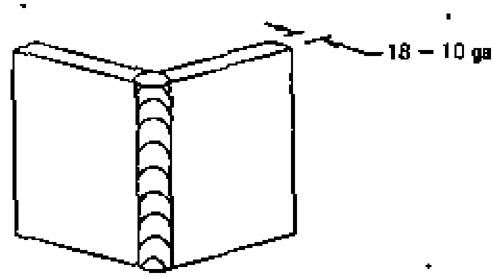


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(–)	50	90	95	120	170*
Arc Speed (in./min)	35 – 40	40 – 45	40 – 45	37 – 42	33 – 38
Electrode Req'd (lb/ft)	0.0184	0.0278	0.0293	0.0438	0.0461
Total Time (hr/ft of weld)	0.00533	0.00471	0.00471	0.00507	0.00563

* DC(+)

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good

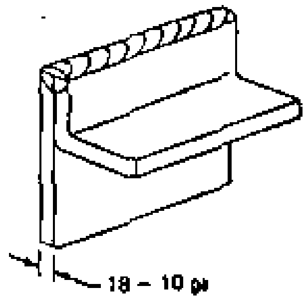


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(+)	50	80	85	115	140
Arc Speed (in/min)	45 – 50	43 – 48	40 – 45	40 – 45	37 – 42
Electrode Req'd (lb/ft)	0.0145	0.0232	0.0263	0.0382	0.0476
Total Time (hr/ft of weld)	0.00421	0.00439	0.00471	0.00471	0.00505

SHIELDED METAL-ARC (MANUAL)

Position: Vertical down
Weld Quality Level: Commercial
Steel Weldability: Good

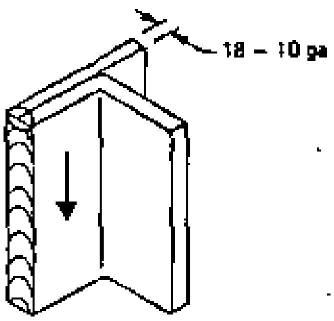


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(−)	55	90	85	125	155
Arc Speed (in./min)	53 – 58	50 – 55	47 – 52	47 – 52	43 – 48
Electrode Req'd (lb/ft)	0.0141	0.0226	0.0251	0.0358	0.0473
Total Time (hr/ft of weld)	0.00361	0.00381	0.00404	0.00404	0.00439

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good

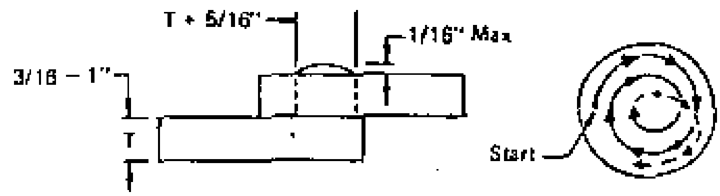


Plate Thickness (in.)	3/16	5/16	3/8	1/2	3/4	1
Electrode Class	E7018	E7018	E7018	E7018	E7018	E7018
Size	1/8	3/16	3/16	7/32	1/4	1/4
Current (amp) AC	140	250	250	300	350	350
Arc Speed (in./min)						
Electrode Req'd*	0.0164	0.0440	0.0642	0.113	0.300	0.605
Total Time* (hr)	0.00417	0.00500	0.00731	0.0118	0.0236	0.0475

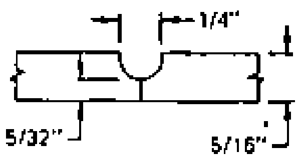
Weld with spiral motion and continue as long as slag can be kept molten or until the weld is completed.

* Per weld

† Thickness of the weld may be reduced to 5/8 inch per AWS Structural Welding Code 2.8.8.

SHIELDED METAL-ARC (MANUAL)
Special Procedures for ASTM A203 and A537 Steels

Position: Flat
Weld Quality Level: Code
Steel Weldability: Poor
Welded From: Two sides



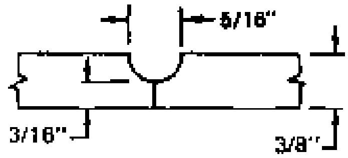


Plate Thickness (in.)	5/16		3/8	
Pass	1 & 2	3 & 4*	1 – 3	4 – 6*
Electrode Class1				
Size	5/32	5/32	5/32	5/32
Current (amp) DC(+)	150	150	150	150
Arc Speed (in./min)	9 – 11	8 – 10	9 – 11	8 – 10
Electrode Req'd (lb/ft)	0.48		0.65	
Total Time (hr/ft of weld)	0.0844		0.127	
Interpass Temperature, Max. (°F)	150		150	

Position: Flat
Weld Quality Level: Code
Steel Weldability: Poor
Welded From: Two sides

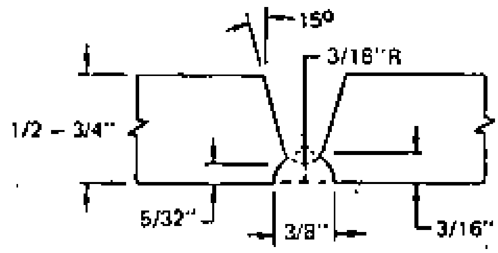


Plate Thickness (in.)	1/2		5/8		3/4	
Pass	1 – 5	6 – 8*	1 – 7	8 – 10*	1 – 10	11 – 13*
Electrode Class1						
Size	5/32	5/32	5/32	5/32	5/32	5/32
Current (amp) DC(+)	150	150	150	150	150	150
Arc Speed (in./min)	7 – 9	8 – 10	7 – 9	8 – 10	7 – 9	8 – 10
Electrode Req'd (lb/ft)	1.40		1.79		2.25	
Total Time (hr/ft of weld)	0.186		0.238		0.313	
Interpass Temperature, Max. (°F)	175		200		225	

* Second side is gouged after first side is completed.

1 See Tables 6-13 and 6-17.

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PROCEDIMIENTOS DE CONSTRUCCION

DE ESTRUCTURAS DE ACERO

SOLDADURA

ING. JOSE LUIS SANCHEZ MARTINEZ

JULIO, 1979

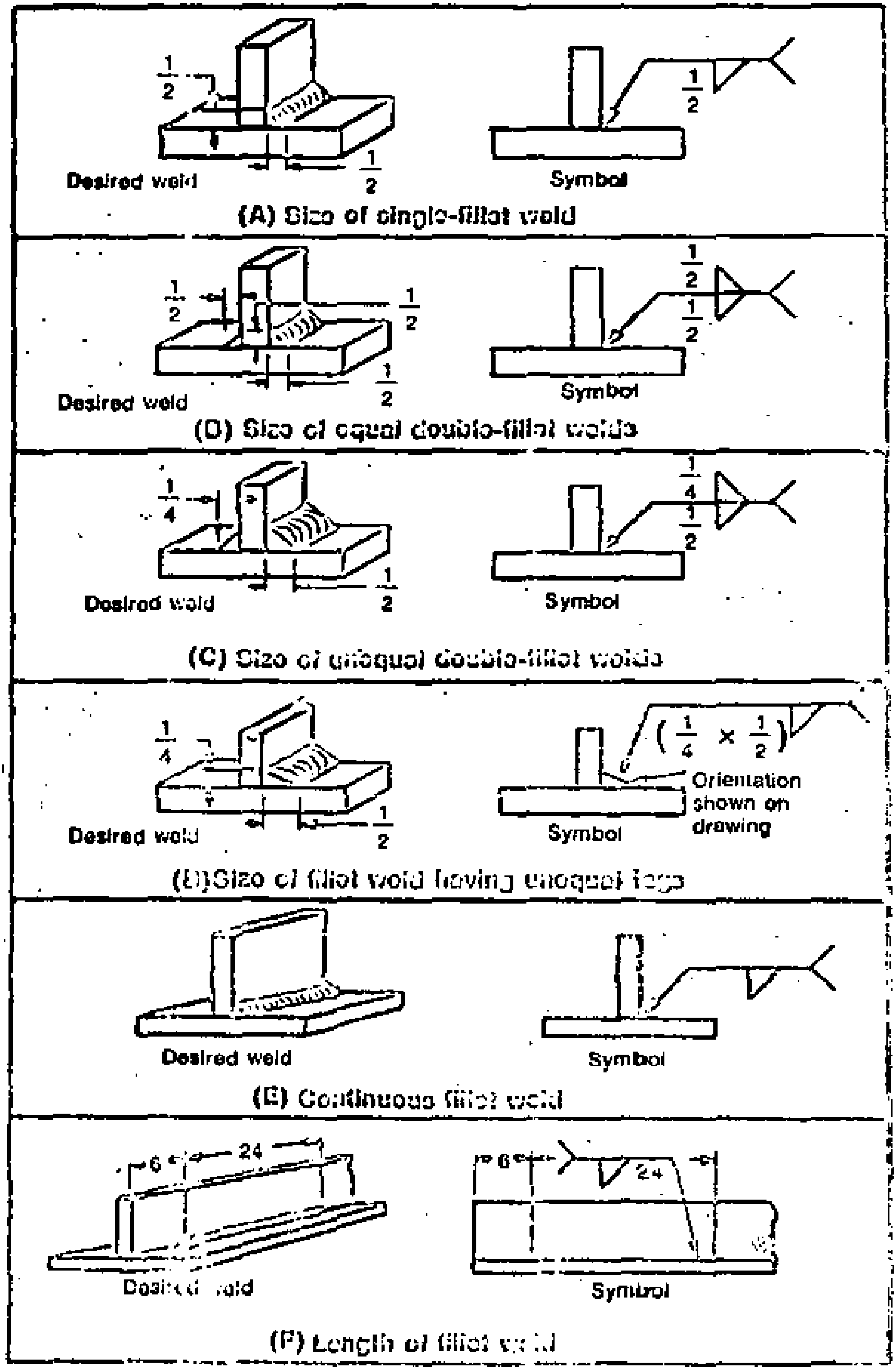


Fig. [illegible]—Application of dimensions to fillet weld symbols.

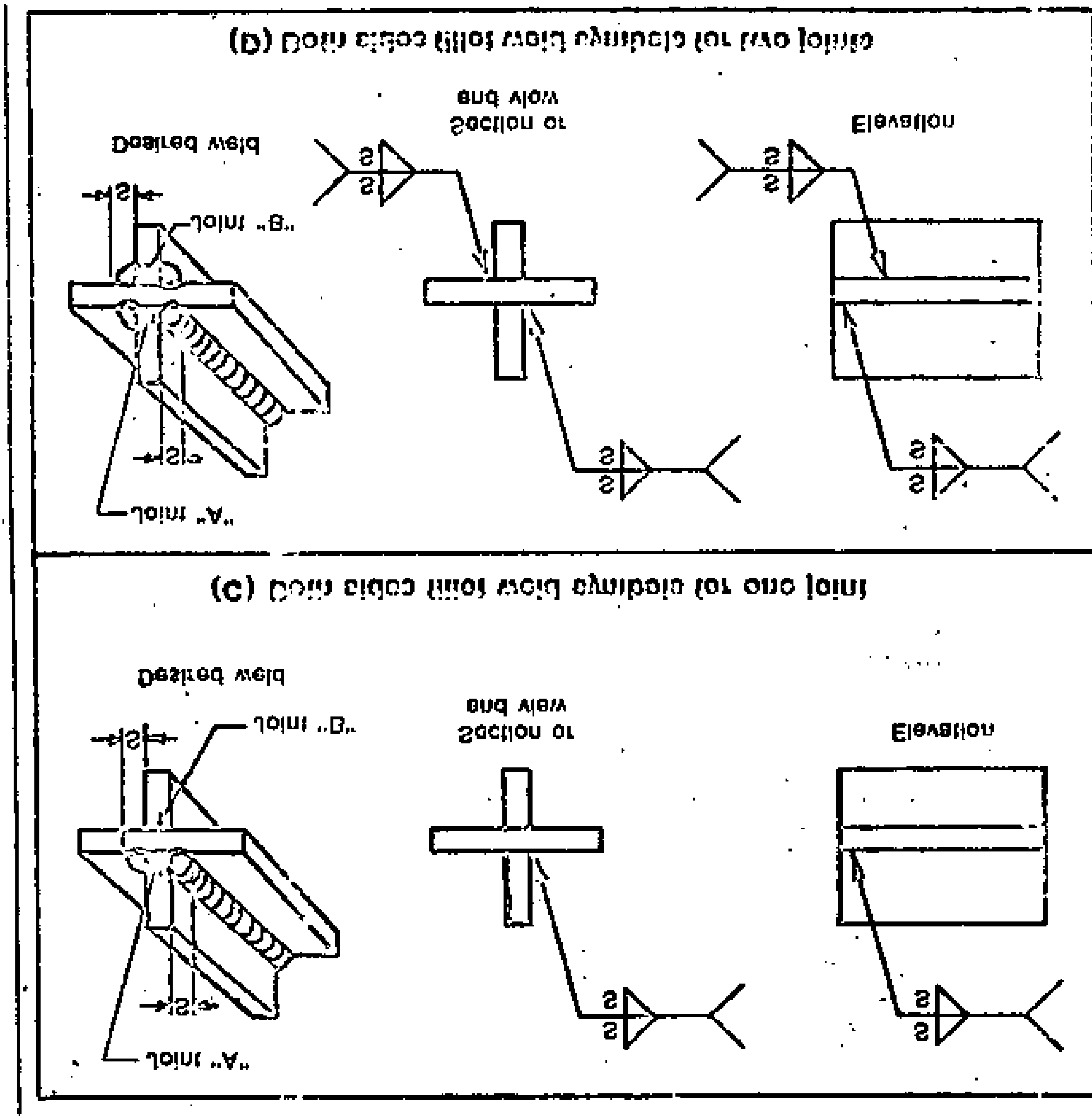
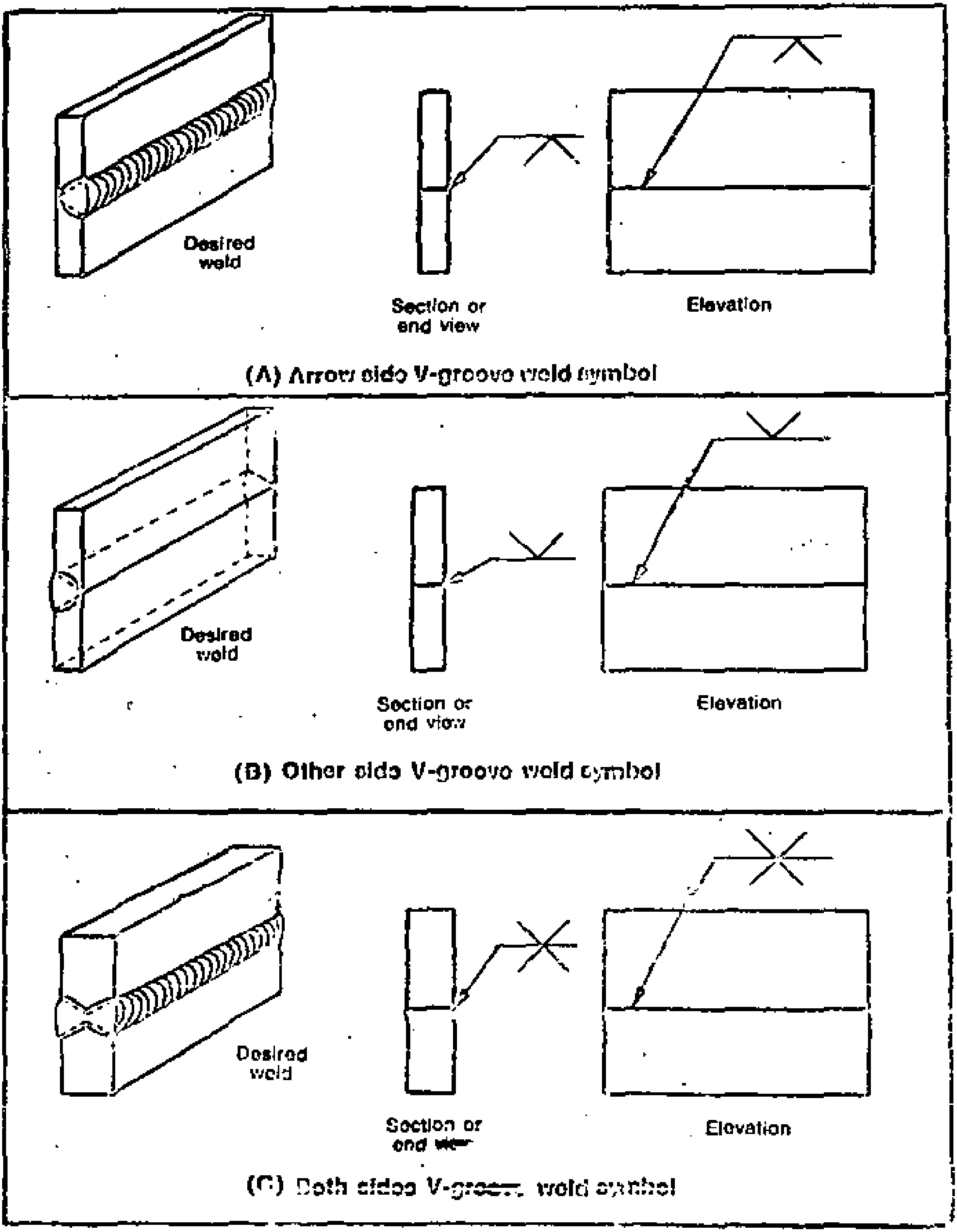


Fig. 15 (cont.)—Application of fillet weld symbols.



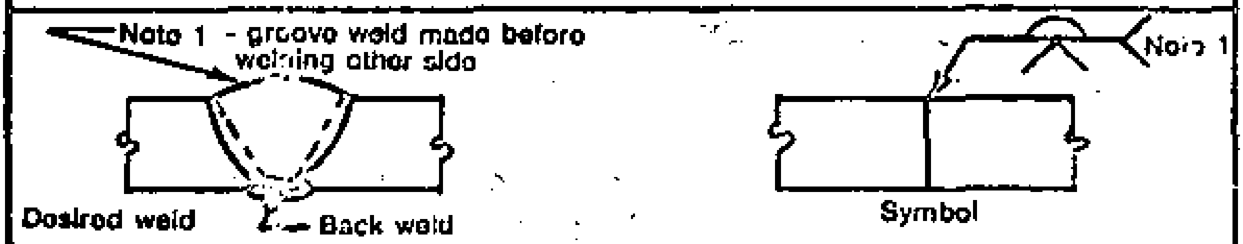
(A) Arrow side V-groove weld symbol

(B) Other side V-groove weld symbol

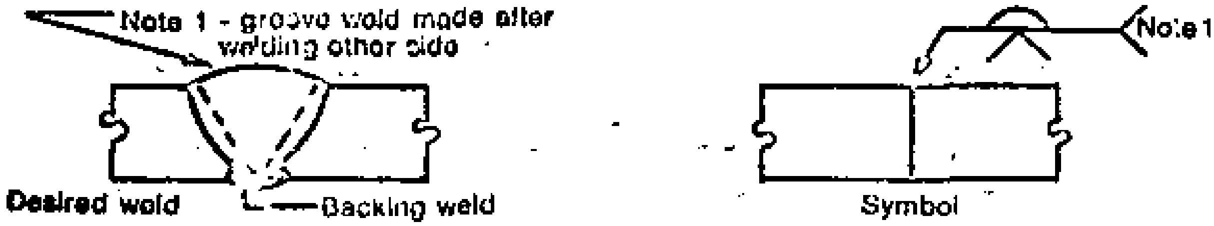
(C) Both sides V-groove weld symbol

Fig. 5—Application of arrow side and other side convention.

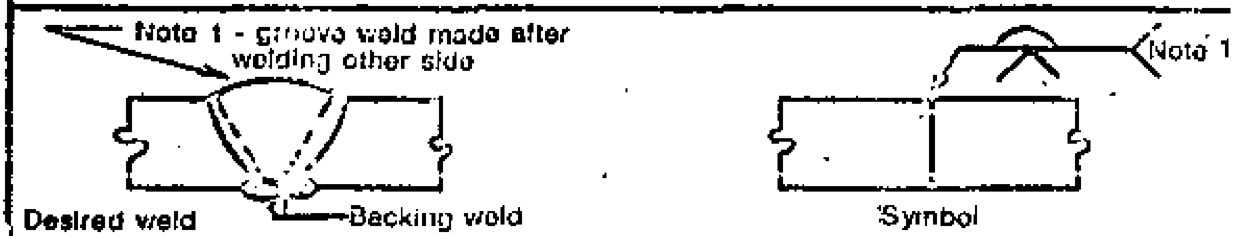
(A) Use of back or backing weld symbol to indicate single-pass back weld



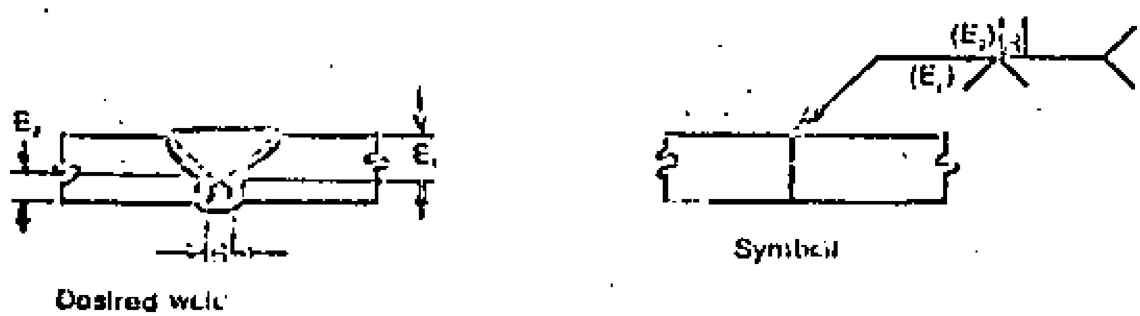
(B) Use of back or backing weld symbol to indicate multiple pass back weld



(C) Use of back or backing weld symbol to indicate single pass backing weld



(D) Use of back or backing weld symbol to indicate multiple pass backing weld



(E) Use of back weld with root opening

Fig. 58—Application of back or backing weld symbol.

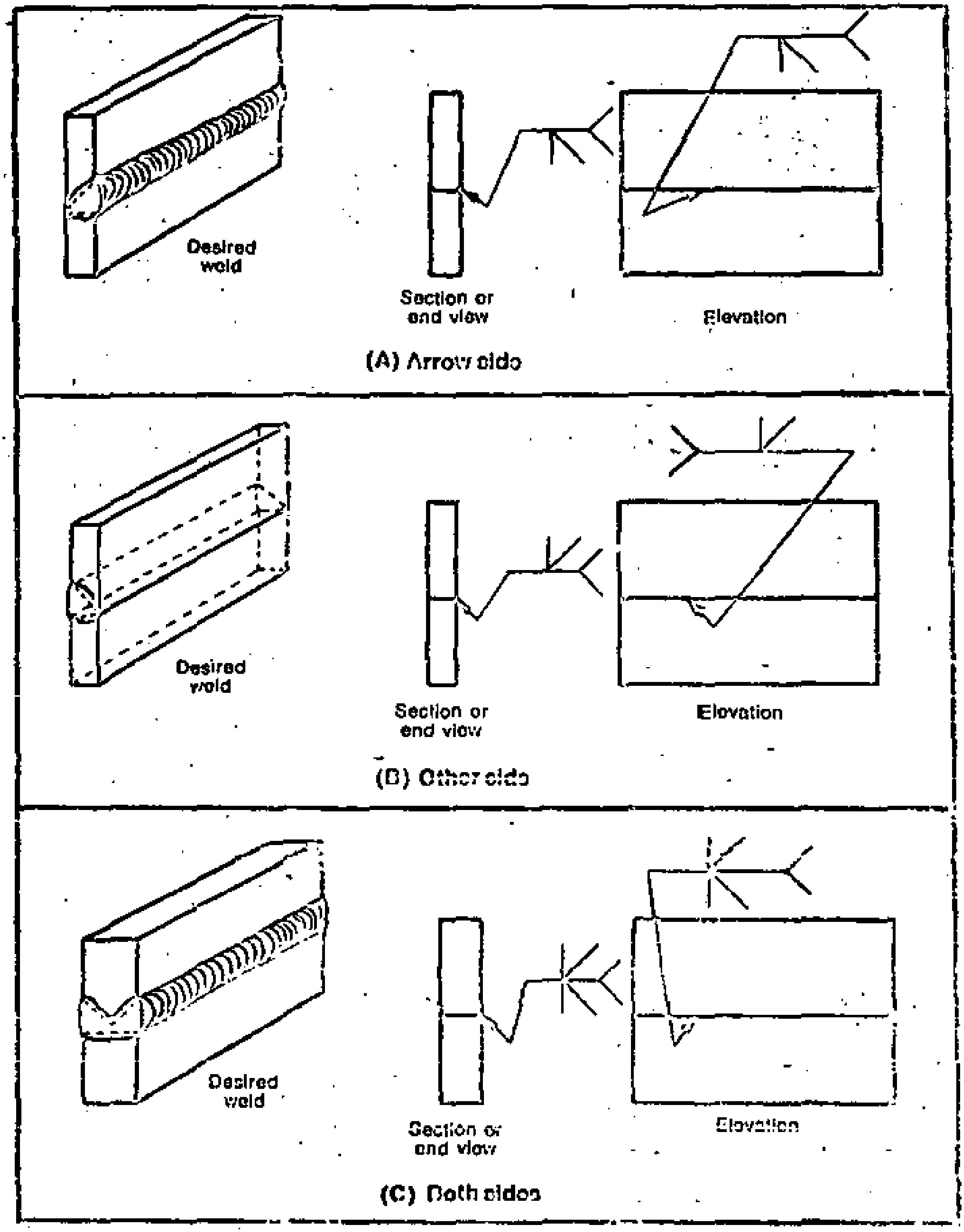
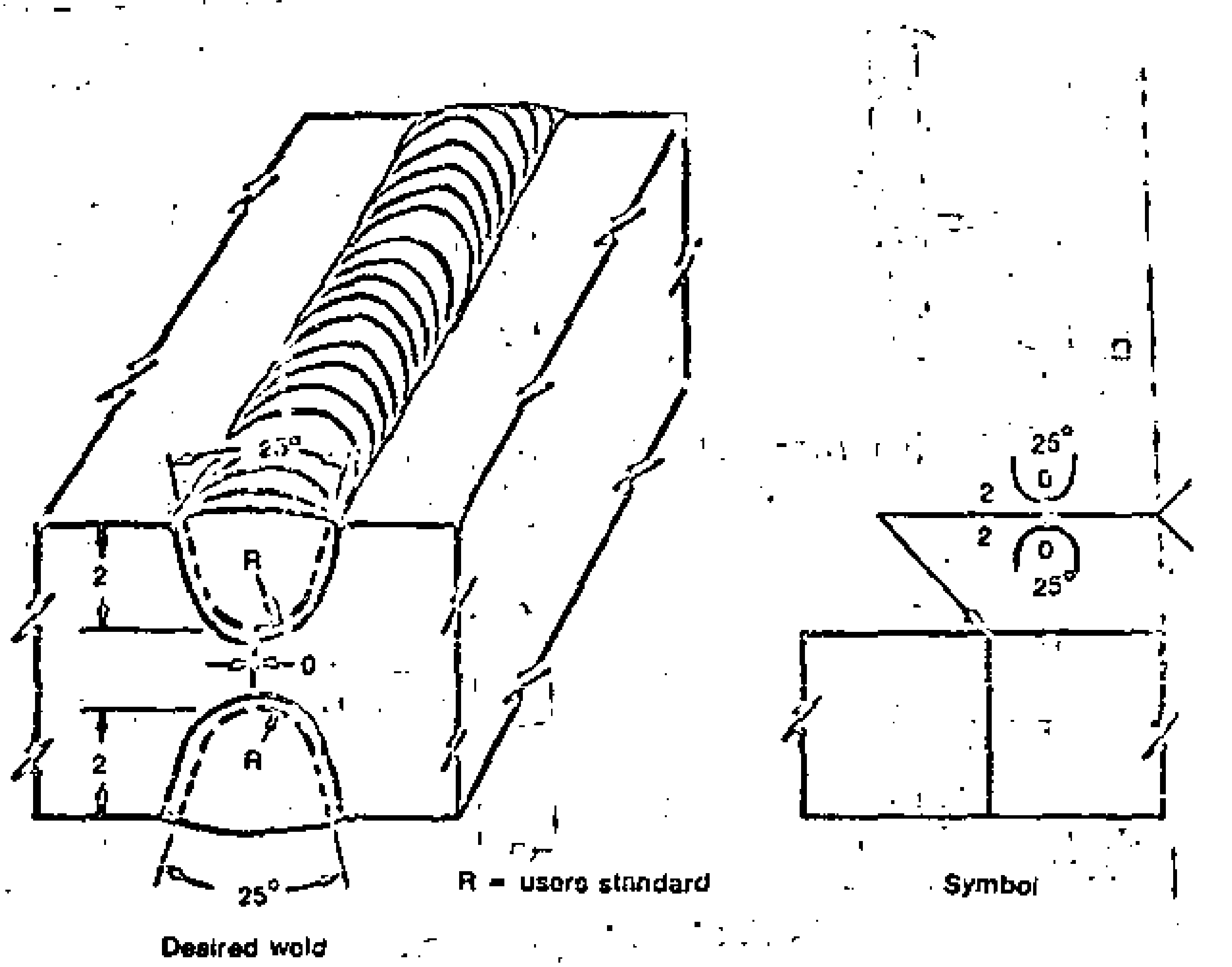


Fig. 9—Application of break in arrow of welding symbol (bevel-groove weld).



Groove weld symbol showing use of combined dimensions

Fig. 24—Application of dimensions to groove weld symbols.

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PROCEDIMIENTO DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

SUPERVISION Y CONTROL DE CALIDAD

ING. RAUL GRANADOS

JULIO, 1979

La supervisión consiste en una serie de técnicas encauzadas a lograr que el trabajo encomendado a un contratista, cumpla con los requisitos de calidad establecidos en el proyecto, representados por los planos estructurales, de fabricación y de montaje, así como por las especificaciones y demás requisitos establecidos en el contrato.

Adicionalmente el supervisor puede tener a su cargo el control del programa de fabricación y montaje y en algunos casos se le encomienda también el control económico, mediante la revisión de las estimaciones basadas en el avance de la obra.

La falta de supervisión en una construcción, redundará en una calidad inadecuada, que a su vez se traduce en una pérdida o disminución del coeficiente de seguridad de la misma. Es decir el " ahorro " que supuestamente se tiene al prescindir de la supervisión, se reflejará en deficiencias constructivas, cuyas consecuencias se manifiestan durante el mismo proceso constructivo, dando lugar a modificaciones o adaptaciones al proyecto o retrasos en el programa de construcción y posteriormente en deficiencias en el funcionamiento de la misma, que en algunos casos se traducen en reparaciones o gastos de mantenimiento excepcionales, mientras que en otros, pueden dar lugar a situaciones de peligro o inseguridad para la construcción.

Es decir el costo de la supervisión se puede justificar por los beneficios que de ella se derivan, reflejados en la calidad de una construcción la que a su vez se manifiesta en el buen comportamiento de la misma a lo largo de su vida útil. Adicionalmente durante el proceso constructivo, se evitarán retrasos y modificaciones que repercuten en el costo de la obra.

DISTRIBUCION APROXIMADA DEL COSTO DE UNA CONSTRUCCION DE TIPO URBANO MEDIO EN LA CIUDAD DE MEXICO (EDIFICIO)

Excavación y Cimentación		10 %
Estructura		15 % (*)
Instalaciones		25 %
Elevadores		3 %
Fachadas		20 %
Acabados		27 %
	TOTAL	100 %

(*) En una construcción fabril o industrial, el costo de la estructura es mayor (30 - 40 %).

DISTRIBUCION APROXIMADA DEL COSTO DE UNA ESTRUCTURA METALICA EN LA CIUDAD DE MEXICO.

Costo del material		35 %
Planos de Fabricación		2 %
Fabricación		40 %
Transporte y Montaje		20 %
Supervisión		3 %
	TOTAL	100 %

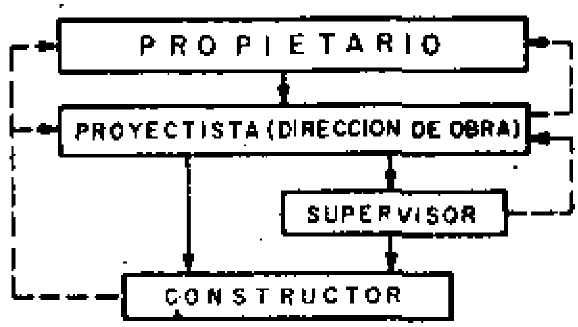
CARACTERISTICAS DE UNA BUENA SUPERVISION

Una buena supervisión debe ser :

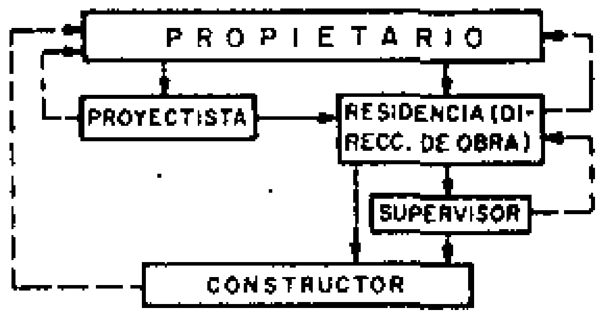
a).- OPORTUNA . La actitud del supervisor debe ser preventiva mas que correctiva, es decir antes de cada una de las etapas constructivas es cuando debe ejercer su principal función.

b).- CONTINUA . Todas las etapas constructivas son importantes y requieren de una inspección, de tiempo completo.

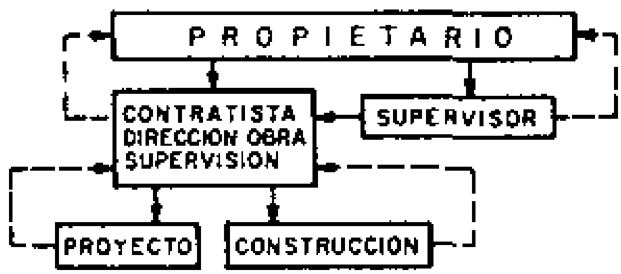
c).- ESTRICTA. El principal objetivo de la supervisión es lograr que la construcción se realice con apego a los planos , especificaciones y programa, sin embargo el supervisor debe mantener en mente, la idea de que la unificación de sus esfuerzos con los del contratista, redundará en los mejores beneficios para la obra.



a) El supervisor depende del proyectista y director de la obra



b) El supervisor es un auxiliar de la residencia de la obra



c) La supervisión es ejercida directamente por el propietario de la obra

——— Líneas de acción

– – – – Líneas de responsabilidad

Fig 5.1. Posiciones usuales en que se ubica la supervisión durante la construcción de una obra

CONSTRUCCIONES DE ACERO

ETAPAS PRELIMINARES

Elaboración de planos de fabricación, anclas y montaje.

Visitas al lugar de la obra para prever problemas de almacenamiento, montaje, etc.

Elaboración de un levantamiento para verificar posición de anclas o de estructura existente si se trata de una ampliación.

Preparación de probetas para verificación de calidad de los materiales.

FABRICACION

Recepción, almacenamiento y clasificación del material.

Enderezado del material

Trazo

Operaciones de corte, punzonado, biselado.

Armado

Soldadura de taller.
Correcciones y reparaciones
Limpieza

Marcaje de piezas terminadas.

Pintura de taller

Estiba y preparación para embarque

Transporte

MONTAJE

Recepción, clasificación estiba de las piezas.

Erección de los elementos primarios verticales y conexión con apoyos y anclas. (Columnas)

Plomeo de los elementos verticales y arriostramiento temporal.

Montaje de elementos de cierre (Trabes) y conexión preliminar con clips.

Nivelación y alineamiento de elementos horizontales y verificación del plomeo de los verticales.

Soldadura de campo o colocación de tornillos (según el caso).

Colocación de accesorios especiales como conectores de cortante.

Limpieza y remoción de clips y otros elementos.

Resanes de pintura.

FUNCIONES DEL SUPERVISOR

Para elaborar una guía de supervisión es necesario tener en cuenta todas las etapas que intervienen en la construcción, mismas que se muestran en la tabla adjunta. De acuerdo con esas etapas, se puede elaborar una lista de conceptos, de acuerdo al orden en que se realiza la construcción.

CONCEPTOS

1) Preliminares.

a) Estudio de planos, especificaciones, reglamentos y documentos que acompañan al contrato.

b) Definición ante el contratista de obligaciones y alcance de la supervisión. Definición de tolerancias.

c) Visitas al lugar de la obra (preferentemente en compañía del contratista).

d) Estudio de los planos del levantamiento preliminar con objeto de solucionar posibles errores en la posición de anclas o estructura existente.

e) Aprobación de métodos y equipo de fabricación y montaje.

f) Muestreo y ensaye de probetas a tensión y doblado en un laboratorio de materiales. Verificación de resultados de calidad de pruebas mecánicas.

g) Calificación de soldadores.

h) Aprobación del programa general de obra.

i) Preparación de formas de comunicación con el contratista, director de obra, propietario, etc.

j) Apertura de una bitácora de obra y registro de firmas.

2) Fabricación

a) Inspección visual de la apariencia y almacenamiento del material. (placas, perfiles, electrodos)

b) Solicitación de pruebas no destructivas, en caso de mostrar el material defectos aparentes (grietas, hojeaduras).

c) Verificación del acabado del material (placas, perfiles) después de la operación de enderezado (Norma B 252 1974, D.G.N.).

d) Verificación de cortes, biseles, agujeros y otras preparaciones.

e) Verificación del armado de las piezas. Preparación y limpieza de las juntas, colocación de placas de respaldo y de extensión, geometría de las piezas. Colocación de elementos auxiliares para control de distorsiones (prensas, cartabones, atiesadores). Posición de las piezas para ejecutar soldaduras en posición plana u horizontal.

f) Inspección de la soldadura de taller. Esta es una de las etapas mas importantes de la fabricación y requiere un tratamiento especial. Sin embargo la inspección visual representa un aspecto importante de la supervisión y una garantía de buenos resultados. Los puntos más importantes por verificar en esta etapa son:

ras. En caso necesario se removerán por medio de un método especial denominado " arco - aire ", consistente en la aplicación de un electrodo de Carbono por medio de una soldadora acoplada a una compresora que proporciona aire a presión y elimina el metal de aporte de la soldadura. No es recomendable el empleo de soplete para esta operación.

h) Verificación de la geometría de las piezas después de la soldadura y corrección de defectos (distorsiones).

i) Verificación del acabado final de las piezas. Esmerilado, relleñado, limpieza general.

j) Verificación de la pintura de taller. En algunas estructuras, la pintura debe cumplir con especificaciones especiales de pintura, tales como preparación de la superficie con chorro de arena, aplicación de diferentes capas de pintura cuya composición química debe verificarse, así como su espesor, color, textura, etc.

k) Verificación del marcaje de las piezas para su embarque de acuerdo a los planos de fabricación y montaje y colocación de etiqueta o marca de aprobación final.

l) Verificación del manejo, estiba y preparación de las piezas para el transporte.

m) Control del avance de la fabricación y elaboración de reportes.

TABLA (B) ROTACION DE LA TUERCA A PARTIR DE

LA CONDICION DE " APRIETE AJUSTADO "

DISPOSICION DE LAS CARAS EXTERIORES DE LAS PARTES POR ATORNILLAR		
AMBAS CARAS NORMALES AL EJE DEL TORNILLO O UNA CARA NORMAL AL EJE Y LA OTRA INCLINADA 1:20 (SIN USAR RONDANAS BISELADAS).		AMBAS CARAS INCLINADAS 1:20 CON RESPECTO AL EJE DEL TORNILLO (SIN USAR RONDANAS BISELADAS).
Longitud del Tornillo no mayor de 8 diámetros ni de 8"	Longitud del tornillo mayor de 8 diámetros ó 8"	Para todas las longitudes de los tornillos
1/2 Vuelta	2/3 Vuelta	3/4 Vuelta

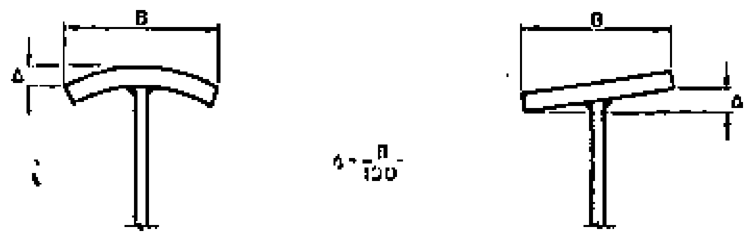
METODOS DE ENSAYO NO DESTRUCTIVO

	OCULAR	RADIOGRAFICO	PARTICULAS MAGNETICAS	PENETRANTE LIQUIDO	ULTRASONICO
EQUIPO REQUERIDO	Lente de aumento. Plantilla para medir cordones. Regla de bolsillo. Escantillón. Normas de buena ejecución.	Unidades comerciales para rayos X o gamma, para examen de soldaduras, y de piezas fundidas o forjadas. Películas y instalaciones para su procesamiento. Equipo para la inspección fluoroscópica.	Equipo especial de tipo comercial para ensayos. Polvos magnéticos, en forma seca o húmeda; pueden ser fluorescentes para su observación bajo luz ultravioleta.	Equipos comerciales, que contengan penetrantes fluorescente o líquidos, y reveladores. Equipo para la aplicación del revelador. Luz ultravioleta para el método fluorescente.	Equipo especial de tipo comercial ya sea para el tipo de pulsación-eco o de transmisión. Gráficos tipos de referencia, para la interpretación de gráficos de radiofrecuencia o visuales.
PERMITE RECONOCER	Defectos superficiales - grietas, porosidad, cráteres sin llenar, inclusiones de escoria. Alabeo, cordones exiguos, cordones desmedidos, cordones de conformación pobre, desalineamiento, presentación impropia.	Defectos interiores macroscópicos - grietas, porosidad, sopladuras, inclusiones no metálicas, penetración incompleta de la raíz, socavación, carámbanos y perforación.	Excelente para reconocer las discontinuidades de la superficie - especialmente las grietas en la superficie.	Grietas en la superficie no visibles fácilmente al ojo desnudo. Excelente para hallar fugas en las soldaduras.	Defectos en y debajo de la superficie, incluyendo aquellos demasiado pequeños para descubrirse por otro método. Especial para descubrir defectos de tipo laminar debajo de la superficie.
VENTAJAS	Costo reducido Puede aplicarse mientras se ejecuta el trabajo. Permite la corrección de los defectos. Señala procedimientos erroneos.	El empleo de película permite la obtención de un documento permanente. Puede observarse en la pantalla fluoroscópica, para inspección interna a costo reducido.	Es de empleo más fácil que la inspección radiográfica. Permite la sensibilidad regulable. Método de costo relativamente reducido.	Aplicable a materiales magnéticos y no magnéticos. De empleo fácil. De costo reducido.	Muy sensible. Permite la comprobación de juntas inaccesibles a la radiografía.

LIMITACIONES	Puede aplicarse únicamente a los defectos superficiales. No prevee registro permanente.	Requiere habilidad en la selección de ángulos de exposición, la soldadora a emplearse, y la interpretación de los resultados. Requiere medidas de seguridad. No resulta, en general, aceptable para la inspección de soldaduras en ángulo interior.	Puede emplearse únicamente con materiales magnéticos. Requiere habilidad para descubrir e interpretar los defectos o las configuraciones no significativas. Resulta de empleo difícil sobre las superficies ásperas.	Pueden descubrirse solamente los defectos superficiales. No puede emplearse eficazmente con piezas calientes.	Requiere mucha competencia interpretar las configuraciones del tipo pulsación-eco. No resulta fácil la obtención de gráficos de tipo permanente.
OBSERVACIONES	Debe constituir el primer método de inspección, no importa cuáles sean las otras técnicas que se exijan. Constituye el único tipo de inspección " productivo ". Es responsabilidad primordial de todas las personas que contribuyen al trabajo de soldadura.	Muchos códigos requieren el examen por rayos - X. Es útil para la capacitación de los soldadores y la aprobación de los procedimientos. A causa de su costo, debe limitarse a aquellas zonas donde los métodos restantes no provean la seguridad requerida.	Los defectos alargados paralelos al campo magnético podrán no indicar la conformación; por ello, el campo deberá aplicarse en dos direcciones, a o cerca de ángulos rectos entre sí.	En recipientes de paredes delgadas, revelará las fugas que no podrán determinarse con las pruebas neumáticas usuales. Las condiciones reveladoras en la superficie (humo, escoria) pueden llevar a indicaciones equivocas.	El equipo de tipo pulsación-eco resulta excelente para fines de inspección de las soldaduras. El equipo de tipo de transmisión simplifica la interpretación de las configuraciones, cuando se lo puede emplear.

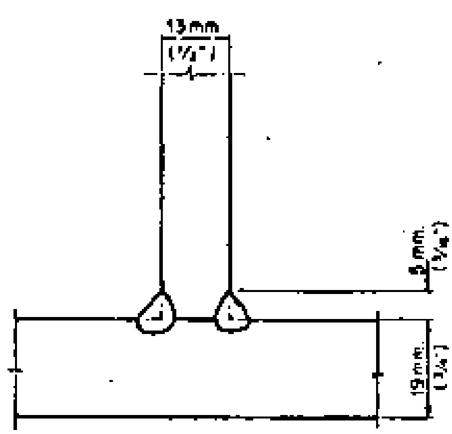
PERFILES COMPUESTOS DE TRES PLACAS SOLDADAS

Tolerancias permitidas .



DEFLEXION DEL PATIN

FUERA DE ESCUADRA DEL PATIN

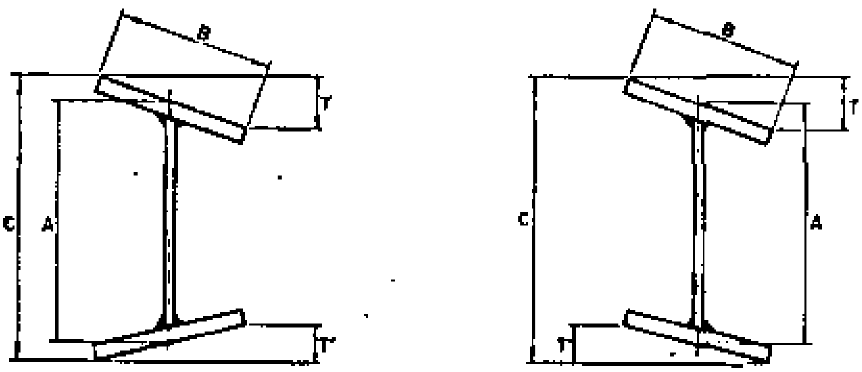


EJEMPLO TIPICO DE SOLDADURA

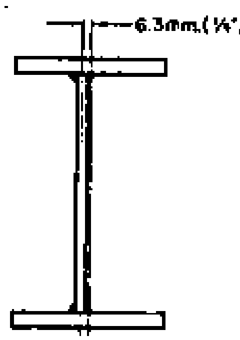
Espesor del material de la pieza más gruesa unida en mm y pulg.	Dimensión mínima de soldadura de filete en mm y pulgadas. Soldadura manual o automática (un electrodo)	Dimensión mínima de soldadura de filete en mm y pulgadas Soldadura automática (dos electrodos)
Hasta 13 mm (1/2") inclusive	5.0 (3/16")	5.0 (3/16")
De 14 a 19mm (9/16" a 3/4") incl	6.0 (1/4")	5.0 (3/16")
De 21 a 32mm (13/16" a 1 1/4") incl	8.0 (5/16")	7.0 (9/32")
De 33 a 51mm (1 5/16" a 2") incl.	10.0 (3/8")	8.0 (5/16")

PERFILES COMPUESTOS DE TRES PLACAS SOLDADAS

Tolerancias permitidas



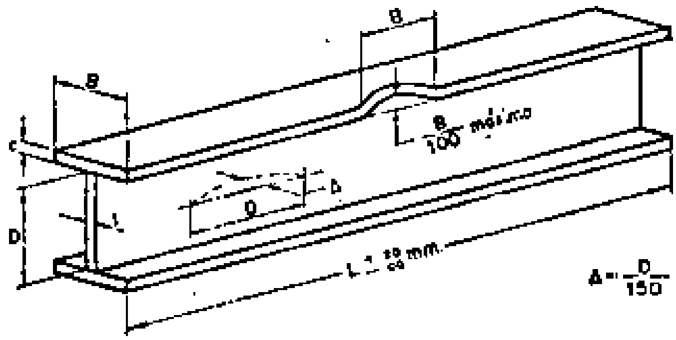
PERALTE NOMINAL "A" en mm. y Pulgadas	TOLERANCIAS PERMITIDAS en mm. y Pulgadas					
	PERALTE "A"		PATIN "B"		Fuera de Paralelismo T + T'	C menos el peralte nominal A
	Mas	Menos	Mas	Menos		
Hasta 305 mm.(12") inclusive	3.2	3.2	6.3	4.8	6	6
	1/8	1/8	1/4	3/16	1/4	5/16
Mas de 305mm.(12") inclusive	3.2	3.2	6.3	4.8	10	8
	1/8	1/8	1/4	3/16	3/8	5/16



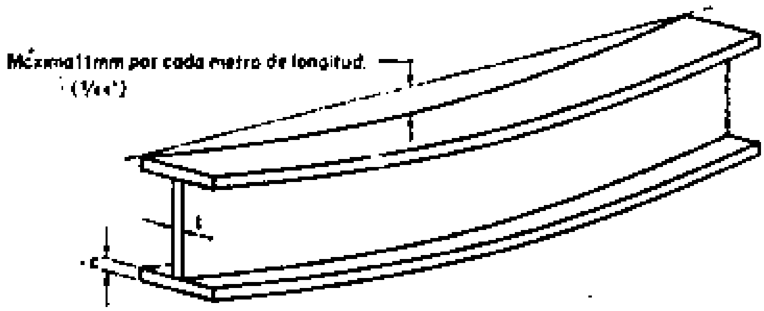
DESCENTRAMIENTO PERMITIDO DEL ALMA

PERFILES COMPUESTOS DE TRES PLACAS SOLDADAS

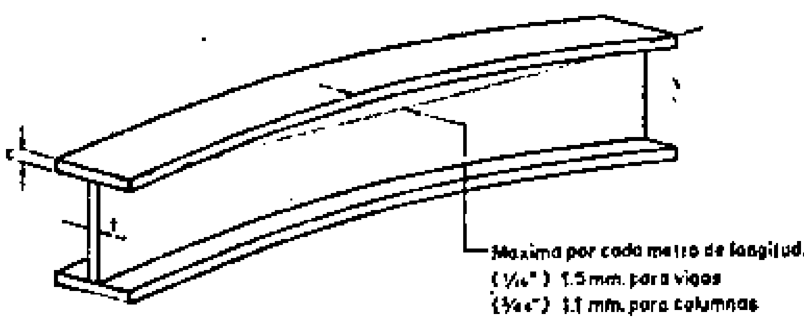
Tolerancias permitidas



COMBAMIENTO DEL PATIN Y ALMA



FLECHA VERTICAL



FLECHA.LATERAL

ESPECIFICACIONES GENERALES PARA LA FABRICACION Y MONTAJE
DE LA ESTRUCTURA PARA LAS TORRES DE MICROONDAS
DE TELEFONOS DE MEXICO, S.A.

1.- ALCANCE

LAS ESPECIFICACIONES CONSTRUCTIVAS SIGUIENTES SE REFIEREN - A LOS MIEMBROS DE LA ESTRUCTURA DE ACERO. CUANDO EXISTA DUDA - ACERCA DE LA APLICACION DE ESTAS NORMAS, LA DIRECCION DE LA OBRA TOMARA LA DECISION FINAL, BASANDOSE EN CODIGOS DE CONOCIDO PRES-TIGIO.

2.- PLANOS Y OTROS DOCUMENTOS

EL CONTRATISTA TENDRA EN LA OBRA UN LIBRO DE BITACORA EN - QUE SE ANOTARAN LAS FECHAS DE LAS DISTINTAS ETAPAS DE LA CONS-TRUCCION, ASI COMO LAS MODIFICACIONES QUE SE HAGAN A LOS PLANOS O A LAS ESPECIFICACIONES Y LA APROBACION O RECHAZO, POR PARTE DE LA DIRECCION, DE LA OBRA EJECUTADA.

ADEMAS SE TENDRAN EN LA OBRA TODOS LOS DOCUMENTOS QUE EXI-GEN LOS REGLAMENTOS VIGENTES ASI COMO LOS PLANOS ESTRUCTURALES, ARQUITECTONICOS Y DE INSTALACIONES Y LAS PRESENTES ESPECIFICA-CIONES.

3.- FUNCIONES DEL DIRECTOR DE LA OBRA

EL DIRECTOR DE LA OBRA GOZARA DE PLENA AUTORIDAD PARA VELAR POR EL CUMPLIMIENTO DE ESTAS ESPECIFICACIONES. PODRA DE JUZGARLO CONVENIENTE, ORDENAR REPARACIONES, REFUERZOS, EJECUCION DE -- PRUEBAS DE CARGA O DEMOLICION Y RECONSTRUCCION PARCIAL O TOTAL - DE LA OBRA SI SE HAN VARIADO LAS ESPECIFICACIONES O LOS PLANOS

4.- RESULTADOS DE MEDICIONES Y ENSAYES

LOS RESULTADOS DE TODA MEDICION Y ENSAYE QUE AQUI SE ESPECIFIQUE, SERAN COMUNICADOS A LA DIRECCION DE LA OBRA EN UN PLAZO INFERIOR A 72 HORAS, A PARTIR DEL MOMENTO QUE SE LLEVE A CA-- BO.

LAS MEDICIONES PODRAN SER VERIFICADAS POR EL DIRECTOR DE LA OBRA SI ESTE ASI LO JUZGA CONVENIENTE. LOS INSTRUMENTOS Y PERSONAL QUE SE REQUIERAN PARA TALES TRABAJOS, SERAN SUMINISTRADOS POR EL CONTRATISTA.

5.- MATERIALES

TODO EL MATERIAL EMPLEADO EN LA OBRA ES DEL TIPO DGN-B254-

1973 (ASTM A36), QUE TIENE LAS CARACTERISTICAS SIGUIENTES

A.- RESISTENCIA A LA TENSION, EN KG/CM2	4060 A 5600
B.- LIMITE DE FLUENCIA MINIMO, EN KG/CM2	2520
C.- ALARGAMIENTO MINIMO EN 200MM DE LONGITUD CALIBRADA, 0/0	20
D.- ALARGAMIENTO MINIMO EN 50MM DE LONGITUD CALIBRADA, 0/0	
PLACAS Y BARRAS	23
PERFILES	21

E.- CUANDO SE USE SOLDADURA MANUAL CON ELECTRODO RECUBIERTO LOS-ELECTRODOS SERAN DE LAS SERIES E60XX O E70XX (AWS A5.1 O A5.5).- Y SI SE EMPLEA SOLDADURA AUTOMATICA CON ELECTRODO SUMERGIDO SE - UTILIZARAN COMBINACIONES DE ELECTRODO Y FUNDENTE F6X-EXXX O F7X-EXXX (AWS A5.17 O A5.23).

PUEDEN UTILIZARSE OTROS PROCESOS DE SOLDADURA SIEMPRE QUE - ESTEN DE ACUERDO CON LAS NORMAS DE LA SOCIEDAD AMERICANA DE LA - SOLDADURA (STRUCTURAL WELDING CODE, AWS D1.1, ULTIMA EDICION) Y QUE SEAN APROBADOS POR LA DIRECCION DE LA OBRA.

6.- INSPECCION

EL FABRICANTE SE OBLIGA A ADMITIR EN SU TALLER, Y EN TODOS LOS LUGARES EN QUE SE ESTE FABRICANDO LA ESTRUCTURA, A LOS RE-PRESENTANTES QUE FIJE LA DIRECCION DE LA OBRA PARA LA REVISION -

DE LOS TRABAJOS RESPECTIVOS.

LA DIRECCION DE LA OBRA PUEDE EXIGIR DEL FABRICANTE EL NUMERO DE PRUEBAS FISICAS Y/O QUIMICAS QUE SEA NECESARIO PARA GARANTIZAR LA BUENA CALIDAD DEL MATERIAL EMPLEADO.

LA DIRECCION DE LA OBRA PUEDE EFECTUAR PRUEBAS NO DESTRUCTIVAS, CUANDO SEAN NECESARIAS PARA ASEGURARSE DE QUE LA ESTRUCTURA HA SIDO FABRICADA Y MONTADA CORRECTAMENTE.

7.- FABRICACION

ENDEREZADO DEL MATERIAL

TODO EL MATERIAL QUE VAYA A UTILIZARSE EN UNA ESTRUCTURA DEBE ESTAR RECTO, CONFORME A LA ESPECIFICACION ASTM A6 O A LAS PRESCRIPCIONES DE ESTA ESPECIFICACION, EXCEPTO EN LOS CASOS EN QUE EN LOS PLANOS DE PROYECTO SE INDIQUE QUE DEBE TENER FORMA CURVA. CUANDO SEA NECESARIO EL ENDEREZADO SE HARA EN FRIO, UTILIZANDO MEDIOS MECANICOS, O POR MEDIO DE LA APLICACION, CUIDADOSAMENTE SUPERVISADA, DE UNA CANTIDAD LIMITADA DE CALOR APLICADO EN ZONAS LOCALIZADAS.

LA TEMPERATURA DE LAS ZONAS CALENTADAS, MEDIDA POR MEDIO DE

PROCEDIMIENTOS ADECUADOS, NO DEBE SOBREPASAR 650 GRADOS CENTIGRADOS. LOS MISMOS PROCEDIMIENTOS PUEDEN UTILIZARSE PARA ENDEREZAR MIEMBROS DISTORSIONADOS POR LA SOLDADURA.

LAS PARTES QUE SE CALIENTEN DURANTE EL ENDEREZADO DEBEN ESTAR SUSTANCIALMENTE LIBRES DE ESFUERZOS Y DE FUERZAS EXTERIORES, EXCEPTO LOS RESULTANTES DE METODOS MECANICOS DE ENDEREZADO QUE SE UTILICEN EN COMBINACION CON LA APLICACION DE CALOR.

CORTES

LOS CORTES PUEDEN HACERSE CON CIZALLA, SIERRA O SOPLETE. ESTE DEBE, DE PREFERENCIA, GUIARSE MECANICAMENTE. LOS CORTES CON SOPLETE REQUIEREN UN ACABADO LISO Y LIBRE DE REBABAS. SE ADMITEN MUESCAS O DEPRESIONES OCASIONALES DE NO MAS DE 5MM DE PROFUNDIDAD. LAS QUE TENGAN PROFUNDIDADES MAYORES DEBEN ELIMINARSE CON ESMERIL. LOS CORTES EN ANGULO, EN ESQUINAS ENTRANTES, DEBEN HACERSE CON EL MAYOR RADIO POSIBLE, NUNCA MENOR DE 15MM.

CANTOS CEPILLADOS

LOS CANTOS DE PLACAS O PERFILES CORTADOS CON CIZALLA O SO-

PLETE NO NECESITAN CEPILLARSE, A MENOS QUE SE INDIQUE EN LOS DIBUJOS DE DETALLE.

CONSTRUCCIONES REMACHADAS Y ATORNILLADAS. AGUJEROS.

EL DIAMETRO DE LOS AGUJEROS PARA REMACHES O TORNILLOS DEBE SER 1.6 MM MAYOR QUE EL DIAMETRO NOMINAL DE ESTOS. LOS AGUJEROS PUEDEN PUNZONARSE EN MATERIAL DE GRUESO NO MAYOR QUE EL DIAMETRO NOMINAL DE LOS REMACHES O TORNILLOS MAS TRES MILIMETROS, PERO DEBEN TALADRARSE O PUNZONARSE A UN DIAMETRO MENOR Y DESPUES RIMARSE CUANDO EL MATERIAL ES MAS GRUESO.

EL DADO PARA LOS AGUJEROS SUBPUNZONADOS Y LA BROCA PARA LOS SUBTALADRADOS DEBE SER, COMO MINIMO, 1.6 MM MENOR QUE EL DIAMETRO NOMINAL DEL REMACHE O TORNILLO.

NO SE PERMITE EL USO DEL SOPLETE PARA HACER AGUJEROS.

CONSTRUCCION SOLDADA

PREPARACION DE SUPERFICIES

LAS SUPERFICIES Y BORDES QUE VAYAN A SOLDARSE SERAN LISOS,- UNIFORMES Y LIBRES DE MUESCAS, GRIETAS Y OTRAS DISCONTINUIDADES- QUE AFECTEN DESFAVORABLEMENTE LA CALIDAD O RESISTENCIA DE LA -- SOLDADURA.

LAS SUPERFICIES EN LAS QUE SE VAYA A DEPOSITAR SOLDADURA Y - LAS ADYACENTES A ELLAS ESTARAN TAMBIEN LIBRES DE COSTRAS, ESCO-- RIA, OXIDOS, HUMEDAD, GRASA, PINTURA O CUALQUIER MATERIAL EXTRA- NO QUE DIFICULTE LA SOLDADURA O PRODUZCA HUMOS PERJUDICIALES.

SE PERMITE QUE HAYA COSTRAS DE LAMINADO QUE RESISTAN UN CE- PILLADO VIGOROSO HECHO CON CEPILLO DE ALAMBRE, UNA CAPA ANTICO-- RROSIVA DELGADA O UN COMPUESTO PARA EVITAR LAS SALPICADURAS DE SOLDADURA, EXCEPTO EN LAS SUPERFICIES DE TRABES ARMADAS EN LAS QUE SE VAYA A HACER SOLDADURAS ENTRE ALMA Y PATIN CON ELECTRODO DE BAJO CONTENIDO DE CARBONO, EN LAS QUE DEBEN SUPRIMIRSE TODAS LAS COSTRAS DE LAMINADO.

CUANDO LA PREPARACION DE BORDES SE HAGA CON SOPLETE, ESTE -- DEBE GUIARSE MECANICAMENTE SIEMPRE QUE SEA POSIBLE.

COLOCACION DE LAS PIEZAS

LAS PARTES QUE SE VAN A UNIR POR MEDIO DE SOLDADURAS DE -- FILETE DEBEN COLOCARSE EN UN CONTACTO TAN INTIMO COMO SEA POSI-- BLE. LA SEPARACION ENTRE ESAS PARTES NO DEBE EXCEDER DE 5MM. - EXCEPTO CUANDO SE TRATE DE PLACAS DE 76MM (3'') O MAS DE GRUESO SI, DESPUES DE ENDEREZARLAS, LA SEPARACION NO PUEDE REDUCIRSE LO NECESARIO PARA SATISFACER ESA TOLERANCIA.

EN ESE CASO SE ADMITE UNA SEPARACION MAXIMA DE 8MM, SIEMPRE QUE SE EMPLEE UNA SOLDADURA DE SELLO O UN MATERIAL DE RESPALDO - ADECUADO PARA EVITAR FUGAS DE METAL FUNDIDO. SI LA SEPARACION- ES 1.6MM O MAYOR, EL TAMAÑO DE LA SOLDADURA DE FILETE SE AUMEN- TARA EN UNA CANTIDAD IGUAL A LA SEPARACION. LA SEPARACION EN- TRE LAS SUPERFICIES DE FALLA DE JUNTAS TRASLAPADAS Y ENTRE PAR-- TES QUE SE VAYAN A SOLDAR A TOPE Y LA PLACA DE RESPALDO NO DEBE EXCEDER DE 1.6MM.

SE PROHIBE EL USO DE RELLENOS, EXCEPTO EN LOS CASOS EN QUE ESTEN INDICADOS EN LOS DIBUJOS O SEAN APROBADOS ESPECIALMENTE -- POR LA DIRECCION DE LA OBRA.

EL AJUSTE ENTRE SUPERFICIES DE CONTACTO DE JUNTAS QUE NO - ESTEN COMPLETAMENTE SELLADAS POR LA SOLDADURA DEBE SER SUFICIEN- TE PARA IMPEDIR LA PENETRACION DEL AGUA DESPUES DE COLOCADA LA - PINTURA.

LOS MIEMBROS QUE VAN A SOLDARSE SE ALINEARAN CORRECTAMENTE, Y SE MANTENDRAN EN POSICION HASTA COMPLETAR LA COLOCACION DE LA SOLDADURA, POR MEDIO DE PERNOS, PRENSAS, CABLES U OTROS PROCEDIMIENTOS ADECUADOS, O UTILIZANDO PUNTOS DE SOLDADURA. DEBEN TENERSE EN CUENTA LAS DEFORMACIONES Y CONTRACCIONES OCASIONADAS POR LA SOLDADURA.

ALINEAMIENTO

LOS EXTREMOS DE LAS PARTES QUE VAN A UNIRSE POR MEDIO - DE SOLDADURAS A TOPE DE PENETRACION DEBEN ALINEARSE CUIDADOSAMENTE.

CUANDO LAS PARTES ESTAN RESTRINGIDAS EFECTIVAMENTE CONTRA LA FLEXION OCASIONADA POR DEFECTOS DE ALINEACION, SE PERMITE UNA -- EXCENTRICIDAD QUE NO EXCEDA DEL DIEZ POR CIENTO DEL GRUESO DE LA PIEZA UNIDA MAS DELGADA, NI DE 3MM. LA PENDIENTE MAXIMA QUE -- PUEDE DARSELE A UNA PIEZA PARA CORREGIR DEFECTOS DE ALINEACION ES DE 12MM EN 300MM. LAS EXCENTRICIDADES SE MIDEN ENTRE LOS -- EJES DE LAS PARTES.

TOLERANCIAS EN LAS REPARACIONES

CON LA EXCEPCION QUE SE SEÑALA EN EL PARRAFO SIGUIENTE , SI LAS DIMENSIONES DE LAS PREPARACIONES HECHAS PARA DEPOSITAR SOLDADURAS DE PENETRACION VARIAN DE LAS MOSTRADAS EN LOS PLANOS DE DETALLE EN CANTIDADES MAYORES QUE LAS TOLERANCIAS QUE SE INDICAN A CONTINUACION, DEBE AVISARSE A LA DIRECCION DE LA OBRA, QUIEN DECIDIRA SI SE ACEPTAN O CORRIGEN.

	JUNTAS EN LAS QUE NO SE TRABAJA LA RAIZ MM	JUNTAS EN LAS QUE SE TRABAJA LA RAIZ MM
CARA DE LA RAIZ DE LA JUNTA.	+ 1.6, -1.6	NO ESTA LIMITADA
ABERTURA DE LA RAIZ EN JUNTAS SIN PLACA DE RESPALDO.	+ 1.6, -1.6	+ 1.6, -3.2
ABERTURA DE LA RAIZ EN JUNTAS CON PLACA DE RESPALDO.	+ 6.4, -1.6	NO APLICABLE
ANGULO DEL BISEL DE LA JUNTA	+10, -5 GRADOS	+10, -5 GRADOS

PUEDEN ACEPTARSE ABERTURAS DE RAIZ MAYORES, PERO QUE NO EXCEDAN DE DOS VECES EL ESPESOR DE LA PARTE MAS DELGADA O 19MM., SIEMPRE QUE ANTES DE UNIR LAS PARTES SE CORRIJAN ESAS ABERTURAS POR MEDIO DE SOLDADURA, HASTA DARLES DIMENSIONES ACEPTABLES.

PUNTOS DE SOLDADURA

LOS PUNTOS DE SOLDADURA ESTARAN SUJETOS A LOS MISMOS REQUISITOS DE CALIDAD QUE LAS SOLDADURAS FINALES, CON LAS EXCEPCIONES SIGUIENTES

1.- EL PRECALENTAMIENTO NO ES OBLIGATORIO CUANDO SE VAYAN A DEPOSITAR PUNTOS DE SOLDADURA DE UN SOLO PASO QUE SERAN FUNDIDOS E INCORPORADOS EN SOLDADURAS CONTINUAS DE ARCO SUMERGIDO.

2.- NO ES NECESARIO CORREGIR DISCONTINUIDADES TALES COMO SOCAVACIONES, CRATERES SIN RELLENAR Y POROSIDAD ANTES DE HACER LA SOLDADURA FINAL DE ARCO SUMERGIDO.

LOS PUNTOS QUE SE VAYAN A INCORPORAR EN LA SOLDADURA FINAL SE HARAN CON ELECTRODOS QUE CUMPLAN TODOS LOS REQUISITOS DE LAS-

FICIO NO NECESITAN PINTARSE, Y LAS QUE VAYAN A QUEDAR AHOGADAS - EN CONCRETO NO DEBEN PINTARSE. TODO EL MATERIAL RESTANTE RECIBIRA EN EL TALLER UNA MANO DE PINTURA ANTICORROSIVA, APLICADA -- CUIDADOSA Y UNIFORMEMENTE SOBRE SUPERFICIES SECAS Y LIMPIAS, POR MEDIO DE BROCHA, PISTOLA DE AIRE, RODILLO O INMERSION.

EL OBJETO DE LA PINTURA DE TALLER ES PROTEGER EL ACERO DURANTE UN PERIODO DE TIEMPO CORTO, AUN CUANDO SIRVA COMO BASE PARA LA PINTURA FINAL QUE SE EFECTUARA EN OBRA.

LAS SUPERFICIES QUE SEAN INACCESIBLES DESPUES DEL ARMADO - DE LAS PIEZAS DEBEN PINTARSE ANTES.

TODAS LAS SUPERFICIES QUE SE ENCUENTREN A NO MAS DE 5 CM - DE DISTANCIA DE LAS ZONAS EN QUE SE DEPOSITEN SOLDADURAS DE TALLER O DE CAMPO DEBEN ESTAR LIBRES DE MATERIALES QUE DIFICULTEN LA OBTENCION DE SOLDADURAS SANAS O QUE PRODUZCAN HUMOS PERJUDICIALES.

CUANDO UN ELEMENTO ESTRUCTURAL ESTE EXPUESTO A LOS AGENTES ATMOSFERICOS, TODAS LAS PARTES QUE LO COMPONEN DEBEN SER ACCESIBLES DE MANERA QUE PUEDAN LIMPIARSE Y PINTARSE.

B.- MONTAJE

CONDICIONES GENERALES.

EL MONTAJE DEBE EFECTUARSE CON EQUIPO APROPIADO, QUE OFREZCA LA MAYOR SEGURIDAD POSIBLE. DURANTE LA CARGA, TRANSPORTE Y DESCARGA DEL MATERIAL, Y DURANTE EL MONTAJE, SE ADOPTARAN LAS PRECAUCIONES NECESARIAS PARA NO PRODUCIR DEFORMACIONES NI ESFUERZOS EXCESIVOS. SI A PESAR DE ELLO ALGUNAS DE LAS PIEZAS SE MALTRATAN Y DEFORMAN, DEBEN SER ENDEREZADAS O REPUESTAS, SEGUN SEA EL CASO, ANTES DE MONTARLAS, PERMITIENDOSE LAS MISMAS TOLERANCIAS QUE EN TRABAJOS DE TALLER.

ANCLAS

ANTES DE INICIAR LA COLOCACION DE LA ESTRUCTURA SE REVISARA LA POSICION DE LAS ANCLAS, QUE HABRAN SIDO COLOCADAS PREVIAMENTE, Y EN CASO DE QUE HAYA DISCREPANCIAS CON RESPECTO A LAS POSICIONES MOSTRADAS EN PLANOS SE TOMARAN LAS PROVIDENCIAS NECESARIAS PARA CORREGIRLAS O COMPENSARLAS.

CONEXIONES PROVISIONALES

DE SU CALIDAD. EN SOLDADURAS DE CAMPO SE AUMENTARA EL NUMERO DE PRUEBAS, Y ESTAS SE EFECTUARAN EN TODAS LAS SOLDADURAS DE PENETRACION EN MATERIAL DE MAS DE DOS CENTIMETROS DE GRUESO Y EN UN PORCENTAJE ELEVADO DE LAS SOLDADURAS EFECTUADAS SOBRE CABEZA.

RECHAZO

EL MATERIAL O LA OBRA DE MANO QUE NO ESTE DE ACUERDO CON LAS NORMAS INCLUIDAS EN ESTAS ESPECIFICACIONES PUEDEN RECHAZARSE EN CUALQUIER MOMENTO DURANTE LA EJECUCION DEL TRABAJO.

INSPECCION DE LA SOLDADURA

LA INSPECCION DE LOS TRABAJOS DE SOLDADURA SE LLEVARA A CABO DE ACUERDO CON LAS NORMAS DE LA SECCION 6 DE LA ULTIMA REVISION DEL CODIGO PARA SOLDADURA ESTRUCTURAL DE LA SOCIEDAD AMERICANA DE LA SOLDADURA.

ESTAS ESPECIFICACIONES SE COMPLEMENTARAN CON LA ULTIMA EDICION DEL CODIGO DE PRACTICA DEL INSTITUTO AMERICANO DE LA CONSTRUCCION EN ACERO (CODE OF STANDARD PRACTICE FOR STEEL BUILDINGS AND BRIDGES, AISC).

Selección del tipo y tamaño adecuado del electrodo.

Corriente y voltaje por emplear.

Precalentamiento si se especifica.

Limpieza de la junta antes de la colocación del primer cordón.

Limpieza y martilleo entre la colocación de dos cordones consecutivos (en soldaduras de varios pases).

Limpieza final para remover la escoria.

Verificación de tamaño y longitud del cordón.

Verificación de presencia de defectos visuales.

Cuando se cuenta con un inspector experimentado la inspección visual representa el mejor y más económico método de inspección. En ausencia de éste o como comprobación, se emplean otros métodos de inspección, aunque su función mas que preventiva es correctiva. Algunos de estos métodos son:

Método de las Partículas Magnéticas.- Consiste en colocar limaduras de hierro sobre la soldadura en la que se supone existen grietas interiores y hacer pasar una corriente eléctrica. Las configuraciones que adoptan las limaduras de hierro, indicarán a un técnico experimentado, la presencia de grietas.

Método de Tinturas Penetrantes.- Se aplica una tintura sobre la superficie de la soldadura, misma que penetrará en las grietas --

existentes. Se elimina el sobrante y por medio de un material absorbente se obtiene una cantidad de tintura que dará idea de la profundidad de las grietas.

Método de Ultrasonido.- Consiste en el empleo de un instrumento que emite ondas de sonido a través del material o de una soldadura. La variación de la velocidad de transmisión del sonido, indicará la presencia de defectos internos. Este método es caro.

Método de Radiografías.- Consiste en hacer pasar rayos X o rayos gama producidos por una fuente radioactiva, a través de una soldadura, mismos que se reciben en una placa sensible que reproducirá la imagen de la soldadura y sus posibles defectos en forma de fotografía.

Este es el método más común de inspección no destructiva y se emplea en soldaduras a tope ya que en soldaduras de filete se proyectaría también la imagen del metal base.

Posteriormente se estudiará mas a fondo la soldadura desde el punto de vista de la inspección.

9) Evaluación de los resultados de la inspección de la soldadura. De acuerdo con los defectos detectados visualmente o por medio de radiografías, se ordenarán las reparaciones requeridas a las soldadu