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 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

'cdcs. 12/VI/79.

DIRECTORIO DE PROFESORES DEL CURSO
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PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

TUBERIA DE ACERO PARA CONDUCCION DE FLUIDOS

L.3

ING. VICENTE VILLASEÑOR BIANCHI

JULIO, 1979.

" HISTORIA DE LA TUBERIA DE ACERO "

Durante el Siglo XX, se han alcanzado considerables adelantos en la fabricación de tubo de acero para agua, particularmente en cuanto respecta a tubo fabricado bajo el proceso de soldado automático, que posee importantes características favorables, entre ellas los siete principales requisitos de toda buena tubería : Durabilidad, fuerza, economía, capacidad de carga, seguridad, adaptabilidad e impermeabilidad.

A través del tiempo han venido fijándose estrictas especificaciones para las propiedades físicas y químicas del acero con el que se hace el tubo. Se han dado pasos muy importantes en cuanto a los procedimientos de fabricación, inspección, prueba, unión y recubrimiento del tubo de acero; existe a disposición de cualquier persona, una amplia variedad de medidas, calidades, grosor de las paredes y largos.

Lo anterior incluye el más moderno criterio de diseños para tubos de acero con diámetro de hasta 240" (aprox. 6.20 metros), bajo condiciones normales de presión interior y carga exterior. Aparte del texto se suministran valiosas gráficas y cuadros técnicos, así como amplia bibliografía. La aplicación de los principios y datos suministrados se basará en un criterio responsable y en la experiencia.

INVESTIGACION Y FOMENTO

Los principales productores de acero, fabricantes de tubo, productores y diseñadores de materias para protección a tubos en los Estados Unidos, son miembros de la Steel Plate Fabricators Association (Asociación de Fabricantes de Placa de Acero) y mantienen instalaciones muy amplias donde se investiga la metalúrgica, la soldadura y los forros interiores y exteriores de los tubos, teniendo continuamente en estudio nuevas evoluciones, mejoras en técnica y procesos de fabricación. Además esas compañías tienen representantes que se dedican activamente a preparar normas, claves y especificaciones. Mediante estas actividades, los miembros de la Steel Plate Fabricators Association, se mantienen a la vanguardia en cuanto a métodos modernos de fabricación y evolución del producto, lo que garantiza al usuario que recibe el producto más moderno y adelantado, de la más alta calidad y al precio más bajo posible.

INVESTIGACIONES EN CUANTO A DURABILIDAD

Desde hace miles de años conoció el hombre los secretos de la conducción de agua a través de tuberías toscas. Desde mucho antes del nacimiento de Jesucristo, ya los chinos transportaban agua usando el bambú como tubo; un babilonio que reinó hace 4500 años tenía un cuarto de baño con drenaje de tubo de barro cocido. Unos 800 años antes de Cristo, Cartago contaba con tanque municipal; y exis ten fuertes evidencias de que los romanos contaban con muy buenos sistemas de suministro de agua.

Sin embargo, a medida que las ciudades crecían y empezaban a construirse casas más cerca una de la otra, se agudizó el problema de un adecuado suministro de agua y se intensificaron los esfuerzos para construir sistemas de tubería más durables; ésto ocurrió principalmente en los principios de la historia de Estados Unidos cuando se utilizaban todos los medios posibles de atraer nuevos pobladores a las ciudades que nacían. El hierro que se usaba en Europa desde 1685, para tuberías, era escaso en Estados Unidos, donde resultaba mucho más valioso como material para hacer mosquetones. De manera que las primeras líneas de tubería que dieron servicio a ciudades como Nueva York, Boston y Filadelfia fueron hechas, allá por 1752, con trozos de madera taladrados.

El ingenio de los americanos continuaba trabajando para resolver el problema de producir tubos verdaderamente durables; por 1825 se descubrió un método para hacerlos con tiras largas de metal caliente; puede decirse que ésto fué la primera base de la fabricación de tubos fuertes a bajo costo. Surgieron en diversas ciudades las fábricas de tubo de hierro dulce; y con el proceso Bessemer en 1855 y el proceso Siemens - Martin en 1861, pudo disponerse de acero, la forma más fuerte y versátil del fierro, para fabricación de tubos. Habían terminado los largos años de desarrollo gradual para combinar la durabilidad, vitalmente necesaria, con la fuerza; y estaba listo el tubo de acero para desempeñar su dramático papel en el progreso del país.

RECORDS DE SERVICIOS PROLONGADOS

Los récords disponibles descubren instalaciones de tubería de acero tendidas en — 1863, que aún continúan en uso, en una línea de 5 millas de largo (aprox. 8 - Km.), para suministro de agua a la ciudad de San Francisco. A partir de 1870, y junto con otras líneas de tubo riveteado y de 1887 con la instalación del primer tubo soldado, dichos récords muestran ejemplos de tuberías de acero que todavía - funcionan después de más de 50 años de haber sido tendidas. Estos récords de servicios largos atestiguan la durabilidad básica del acero, si tomamos en consideración que la mayoría de las tuberías fueron tendidas antes del advenimiento de los modernos forros protectores interiores y exteriores. Es particularmente interesante - el mejoramiento contínuo que tiene lugar en la calidad del acero. Las cañerías - modernas para agua, con los forros convenientes, pueden en la actualidad diseñarse para duración ilimitada.

Actualmente se encuentran en servicio en las principales ciudades de Estados Unidos, que son más de 200, un total de más de 100 millones de pies (unos 30.5 - millones de metros) de tubería de acero; cifra que aumenta considerablemente si tomamos en cuenta la tubería que se usa en miles de municipios pequeños y en - los proyectos distritales, estatales y nacionales donde se requiere el uso de tubería conductora de agua. Además, muchas ciudades y gobiernos del extranjero han sido importantes usuarios de tubería de acero durante muchos años.

USUARIOS DURANTE MUCHO TIEMPO

La siguiente lista ilustra la longevidad y utilidad, como principales características de la tubería de acero para agua :

Año de Instalación	Localización	Diámetro en Pulgadas	Longitud	Espesor	Años en Servicio (1975)
1858	Railroad Flat, Cal.	22" - 11"	—	16 Ga.	117
1870	Pioche, Nev.	5"	8,000'	14 Ga.	105
1874	Pittburgh, Pa.	50"	2,900'	—	101
1881	Lawrence, Mass.	77"	—	3/8"	94
1884	San Francisco, Cal.	33"	2,409'	1/4"	91
1888	San Francisco, Cal.	22"	12,000'	—	87
1889	Nephi, Utah.	3"	1,500'	16 Ga.	86
1890	Santa Cruz, Cal.	14"	—	9 Ga.	85
1891	Newark, N. J.	36"	23,980'	1/4"	84
1892	Butte, Mont.	20"	3,114'	—	83
1895	Pittburgh, Pa.	60"	49,000'	1/2"	80
1895	Kearney, N. J.	42"	8,800'	—	80
1896	Bayonne, N. J.	30"	44,000'	—	79
1897	Patterson, N. J.	42"	18,600'	5/16"	78
1898	Albany, N. Y.	48"	8,000'	—	77
1899	Newark, N. J.	51" - 48"	17,000'	1/4"	76
1900	Marquette, Mich.	42"	600'	—	75
1901	Seattle, Wash.	42"	61,000'	—	74
1903	Pittsburgh, Pa.	48"	4,000'	1/2"	72
1903	Chino, Cal.	12" - 4"	—	14 & 16 Ga.	72
1904	Toronto, Ont., Canada	72"	6,000'	—	71
1905	Tillamook, Ore.	10"	24,000'	3/16"	70
1905	Altadena, Cal.	8" & 4"	5,000'	16 Ga.	70
1905	Springfield, Mass.	42" - 54"	63,500'	—	70
1906	Honolulu, T. H.	30"	8,000'	—	69
1907	Trenton, N. J.	48"	7,000'	5/16"	68
1907	Montreal, Canadá	36"	11,000'	—	68
1908	Missoula, Mont.	6"	20,000'	3/16"	67
1908	Philadelphia, Pa.	132"	1,590'	—	67
1909	Boulder, Colo.	60"	2,640'	1/2"	66
1910	Pasadena, Cal.	10" - 6"	6,000'	14 Ga.	65

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Año de Instalación	Localización	Diámetro en Pulgadas	Longitud	Espesor	Años en Servicio (1975)
1910	Seattle, Wash.	42" - 24"	23,600'	14 Ga.	65
1910	Brooklyn, N. Y.	48"	16,200'	—	65
1911	Glendora, Cal.	9"	5,000'	14 Ga.	64
1911	Seattle, Wash.	42" - 24"	16,000'	1/4"	64
1911	Marquette, Mich.	66"	8,000'	—	64
1912	Seattle, Wash.	42"	13,243'	—	63
1912	Rochester, N. Y.	66" -	9,200'	—	63
1912	Montclair, N. J.	24"	7,343'	—	63
1913	Utica, N. Y.	36"	1,000'	1/4"	62
1913	Kansas City, Mo.	48"	1,220'	—	62
1913	Lock Raven, Md.	120"	2,464'	7/16"	62
1914	Gardana, Cal.	12" - 4"	—	16 Ga.	61
1914	New York, N. Y.	66"	12,500'	7/16"-1/2"	61
1914	Essex Junction, Vt.	108" & 36"	2,440'	—	61
1914	Miami, Ariz.	152"	1,670'	1/4" - 3/8"	61
1915	Lewiston, Mont.	16"	30,000'	1/4" - 3/16"	60
1915	Ottawa, Canadá.	51"	15,000'	—	60

VENTAJAS DEL TUBO DE ACERO PARA AGUA

Seleccion del Material.-

Al decir que el tubo de acero tiene " ventajas " queremos expresar que cuenta con atributos que lo hacen mejor que otros materiales para conducir agua. Las condiciones actuales de los trabajos de construcción, con sus exigencias en cuanto a cargas y tensiones y situaciones de emergencia a las que deben someterse, hacen indispensable a los maestros de obras, ingenieros y contratistas sobre quienes recae la responsabilidad de diseñar, construir y mantener en servicio las tuberías de agua, la selección del mejor material. Y, el material seleccionado debe calificar se como el mejor, en todos los aspectos.

Los comparaciones hechas con otros materiales de uso común, revelan que la tubería de acero recibe la mejor calificación en todos los aspectos esenciales para su sistema de agua.

Requisitos Esenciales.

Son relativamente simples los requisitos esenciales con que debe cumplir una tubería de agua, tales como :

1.- Fuerza y dureza.
2.- Durabilidad y larga vida en servicio.
3.- Economía en instalación y mantenimiento.
4.- Alta capacidad permanente de conducción de agua.
5.- Ductibilidad y adaptabilidad.
6.- Seguridad y elasticidad.
7.- Uniones a prueba de agua.

El tubo de acero responde mejor a cada uno de esos requisitos básicos, que los demás materiales usados actualmente para conducción de agua, por las siguientes razones :

1.- Una de las ventajas del tubo de acero sobre los demás materiales es su gran resistencia a la tensión; no se le aproxima ninguno de los demás materiales disponibles para tuberías de agua, en cuanto a que ofrece, con mucho, la mayor resistencia en proporción al espesor de las paredes. No hay substituto para la resistencia.

2.- Por cuanto respecta a durabilidad y larga vida, el tubo de acero supera a todos los demás tipos de materiales para conducción de agua. Los registros disponibles demuestran que hay casos de tubo de acero que ha estado en servicio por más de 50 años y sigue funcionando satisfactoriamente. - Con los grandes adelantos que se han realizado en las últimas décadas - por cuanto respecta a fabricación de acero y perfeccionamiento de recubrimientos, puede actualmente estimarse la vida útil de la tubería de acero en 100 años o más, conservadoramente.

3.- Generalmente el tubo de acero no cuesta más, y muchas veces cuesta menos en su adquisición e instalación; y es una importante ventaja la economía en mantenimiento que caracteriza a las tuberías de acero para agua.

4.- Todo sistema de tubería para agua necesita la máxima capacidad posible de conducción, pues la población que aumenta puede hacer pronto insuficiente la red, salvo el caso de que pueda confiarse en que no solamente tiene la mayor capacidad posible sino que la conservará cuando esté en uso. El tubo de acero debidamente protegido es prácticamente inmune a la corrosión y las incrustaciones, puede confiarse en que conservará su - capacidad. El amplio margen de seguridad que da la ingeniería empleada en el tubo de acero, es una ventaja más. Como resultado de lo anterior, puede aumentarse posteriormente la presión, si llega a aumentar la demanda de agua en el futuro, sin salirnos de los márgenes de seguridad.

5.- Casi la misma importancia tiene la ductilidad del tubo de acero, que es única comparada con los demás materiales. Esta singular característica con la que <u>sólo</u> cuenta el tubo de acero para agua, es lo que hace posible su uso en situaciones de terreno donde los demás materiales no pueden usarse, o pueden usarse sólo con dificultades o a mayor costo.

6.- La confiabilidad es posiblemente no una ventaja sino más bien una estricta necesidad en la línea de agua. Una vez que se ha instalado la tubería de acero, los ingenieros pueden confiar en que desempeñará su trabajo para el que se diseñó; esta confiabilidad no se concreta a capacidad uniforme, sino también a su resistencia para soportar un considerable número de situaciones inesperadas o de emergencia. Significa resistencia a los choques de agua y aluviones. Inclusive tiene la <u>elasticidad</u> necesaria para " dar de sí " lo suficiente al haber movimientos en la tierra; y es inmune a las vibraciones de la superficie.

7.- Un requisito de máxima importancia y que la tubería de acero llena satisfactoriamente es la necesidad de que las uniones sean absolutamente impermeables. Ninguna línea de agua puede funcionar bien y económicamente si sus uniones no son a prueba de filtraciones. Como todo ingeniero sabe, el desperdicio de agua puede resultar la falla más costosa en cualquier sistema de agua. En este aspecto es excelente el tubo de acero cuyas uniones, soldadas, mecánicas o con empaquetadura de hule son–

completamente impermeables y siguen siéndolo durante toda la vida de la línea.

Finalmente los líneas de tubo de acero le traen una bonificación en forma de mejores relaciones públicas, ventaja que no debe usted tomar a la ligera; la gente de su comunidad agradecerá el estar recibiendo mejor servicio a menor costo.

Acero .... Material Ideal.

Ningún otro material satisface todos los requisitos para bueno conducción: resistencia, largo vida, economía, alta capacidad permanente de conducción, ductilidad, confiabilidad y uniones totalmente a prueba de agua.

Tal vez la más importante característica para seleccionar un material para conducción de agua sea la resistencia sin el inconveniente de la rigidez; en este aspecto el acero supera a todos los demás materiales por combinar la máxima resistencia con la máxima ductilidad; la mínima resistencia a la tensión del acero que se usa normalmente para tubos de agua es de 60,000 libras por pulgada cuadrada. -

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Además de estas ventajas principales de la tubería de acero, ésta tiene otros muchos puntos complementarios de superioridad, inclusive la mayor variedad de medidas, espesores de las paredes y largos, que le permiten tener un tubo " hecho a la medida " para un determinado trabajo. Su manufactura a precisión, conforme a las normas de A.W.W.A., sus cuidadosas pruebas, le garantizan satisfacción. Y sus mayores longitudes combinadas a su peso considerablemente menor que el de otros materiales, mantienen los costos de transportación e instalación en un mínimo.

Los Resultados Hablan.

Cualquira que sea el interés básico de usted, la tubería de acero le da los mejores resultados :

1.- Al propietario, su estructura no porosa y sus uniones a prueba de fugas, significa que no se filtrarán las utilidades en forma de agua que gotea. No aumentarán las cuotas para desperdicio de agua. Debido a su resistencia a los choques y vibraciones, se eliminan las reclamaciones por fallas repentinas. Estos factores dejan mas satisfecho al cliente del proyecto, sin aumento en el costo.

2.- Al ingeniero, la gran variedad de diámetros, espesores de pared, uniones y niveles de resistencia, minimizan los problemas de diseño. El hecho de que el tubo de acero resiste una gran variedad de presiones vuelve a reducir dichos problemas. El factor de seguridad contra explosiones, del acero, es generalmente 3 ó mas, en tanto que este factor, en los materiales rígidos llega a bajar hasta 1½. Esto significa que una línea de acero diseñada para un flujo específico puede - en caso necesario - entregar mucha más agua con sólo aumentar la presión, pero conservando un factor razonable de seguridad. Y considerando que cada tramo de tubo de acero se prueba cuidadosamente en cuanto a su resistencia, el ingeniero puede tener la seguridad de que hizo una buena inversión.

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3.- Al contratista, las longitudes mayores disponibles en el tubo de acero tienen especial importancia, ya que se necesita de menos uniones al instalarlo. Por ejemplo, los tramos de 40 pies de tubo de acero de 48" de diámetro, diseñados para resistir más de 200 psi., sólo necesitan 132 uniones por milla, en tanto que si se usan tramos de 16 pies habrán de necesitarse 330 uniones por milla. Además, el tramo de 40 pies de tubo de acero de 48" pesa aproximadamente 7,000 libras, en tanto que un tramo de 16 pies de tubo de concreto de igual diámetro pesa unos 15,000 libras. Esto significa que el tubo de acero, no sólo necesita menos uniones para tenderlo, sino que además permite usar equipo más liviano para trabajarlo, con buena oportunidad de ahorrar algunos miles de dólares en los costos de instalación.

4.- Al ingeniero de operación, siendo el tubo de acero a prueba de agua e inastillable, le representa menores problemas de operación. Es imposible que se registren fallas repentinas y completas en una tubería de acero bien diseñada; esto elimina las costosas llamadas de emergencia para componer " roturas ", subsuelos inundados y excavaciones.

5.- Al usuario común, la línea de tubería de acero le representa no tener calles inundadas, no tener interrupciones en el servicio, pagar menos por consumo de agua, y ahorrar algo en sus impuestos. Y sus inversiones tienen doble protección, ya que puede diseñarse la línea para las actualidades necesidades y prever las futuras.

Por consiguiente, cualquiera que sea su interés en la conducción de agua, encontrará usted que el tubo de acero es lo ideal.

CONCLUSIONES.- El contenido de este instructivo puede resumirse así :

1.- La tubería de acero para servicio de agua satisface los más altos requisitos cuando se diseña bien, se instala bien y se protege, lo que garantiza su vida útil por muchas décadas. Bajo estas circunstancias, su costo de mantenimiento es cuando menos igual, y casi siempre menos, que el de cualquier otro tipo de tubo para agua.

2.- El tubo de acero posee una gran resistencia (de 30,000 a 50,000 psi., y resistencia a la tensión de 50,000 a 70,000 psi.,) capacidad de conducción permanente; durabilidad, economía y seguridad.

3.- El tubo de acero, en general, es adaptable, versátil, eficiente, uniforme, flexible, impermeable, elástico, inastillable, seguro, dúctil, fuerte, fácil de tender, no sufre rupturas repentinas, es fuerte como una viga, etc. Es -- practicamente el único tipo de tubería que se puede tender sobre la superficie o debajo de ella, con confianza. El tubo de acero es una necesidad moderna y la experiencia ha demostrado su importante aportación a la vida de nuestro país y del mundo.

" FABRICACION DE LA TUBERIA DE ACERO "

La materia prima a partir de la cual se fabrica el tubo es el acero, generalmente en rollos. El proceso se inicia introduciendo la materia prima por unas tijeras circulares cuya función es cortar las orillas de la lámina con el fin de obtener el exacto desarrollo del tubo y preparar las orillas del material para obtener una unión perfecta.

La materia prima casi preparada y todavía en rollo, está lista para el proceso de formación del tubo. Pasa primero a través de un sistema de rodillos niveladores cuya función es enderezar la placa y ajustarla a un plano horizontal. Inmediatamente pasa la lámina ya nivelada a través de una serie de rodillos formadores y moldeadores que, en frio, forman el tubo dándole la sección circular prevista y el diámetro deseado.

Una vez formado el tubo y en proceso siempre contínuo, pasa a través de una máquina de soldar completamente automática de 1,600 volts., que efectua una soldadura de alta calidad con un máximo de uniformidad y seguridad. Inmediatamente después de aplicada la soldadura se cortan los excesos de la misma, tanto exterior como interiormente, utilizando unos cortadores mecánicos, con lo cual se garantiza el acabado del producto.

En virtud de que la materia prima se ve alterada por el proceso de soldadura y -

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con el objeto de restituir a la misma sus propiedades de ductilidad asegurando al mismo tiempo la calidad de la unión, se le aplica un tratamiento térmico, con equipo eléctrico, a una temperatura mínima de 1,000° C. Posteriormente se enfria el tubo primero ambientalmente y en seguido utilizando enfriadores de agua y aceite.

Una vez enfriado el tubo pasa a través de un juego de roles rectificadores de diámetro los cuales garantizan la geometría final del producto, pasando de inmediato al corte transversal del tubo por medio de sierras de disco automáticos que cortan el tubo a las longitudes comerciales previstas.

Una vez efectuados estos procesos el tubo está terminado de fabricar y listo para entrar a la etapa de control de calidad.

El control de calidad se inicia numerando el tubo para su identificación posterior, y se somete a una primera inspección visual y con equipo de ultrasonido con lo cual se detectan posibles grietas en el material.

Posteriormente se cortan, con discos, los extremos del tubo, primero para garantizar la longitud exacta de los mismos y se utilizan los extremos cortados para, mediante una prensa, efectuar una prueba de aplastamiento, que permite observar el comportamiento del material y la soldadura al deformarse totalmente la sección del tubo.

Luego se somete a un lavado interior cada tubo con solventes especiales para eliminar impurezas y rebabas de la soldadura.

En estos condiciones el tubo se somete a una segunda inspección visual, ultrasónica y con Rayos X.

Se pasa ahora a preparar los extremos del tubo ya sea biselado o roscado para su última prueba de calidad que consiste en someter cada tubo a una prueba de presión hidrostática mayor a la presión de trabajo.

En estas condiciones y despues de un proceso estrictamente controlado, el producto está listo para su distribución y venta.

Con el procedimiento y control antes mencionado se fabrican en México por plantas mexicanas y con acero nacional tuberías que van de 114 mm. (4½") hasta 914 mm. (36") de diametro y con una gran varidad de espesores de pared. Por separado estamos incluyendo una tabla completa de especificaciones y características de la tubería lisa de fabricación nacional.

APLICACIONES

Los usos mas frecuentes para la tubería de acero y donde se encuentran las mayores ventajas para su selección son :

Líneas de Distribución.

Líneas de Descarga.

Drenajes.

Sifones.

Tubos en plantas de bombeo.

Tubos para plantas de fuerza.

Tuberías a Presión.

Líneas Subterráneas.

Lineas bajo carreteras o ferrocarriles.

Tuberias auto soportadas sobre pantanos o ríos.

Tubos para dragado.

Gráficas comparativas de las principales caracteristicas de las tuberias de acero, cobre y plástico.

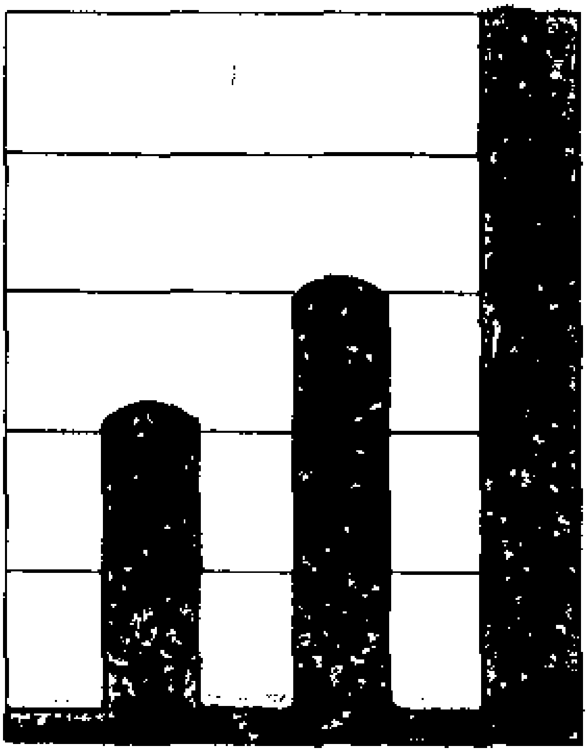
(Fuente: AISCI - ASM - AISI)

COMPARACION DE LA RESISTENCIA AL IMPACTO ENTRE LAS TUBERIAS DE PLASTICO, COBRE Y ACERO

COMPARACION DE LA RESISTENCIA A LA COMPRESION ENTRE LAS TUBERIAS DE PLASTICO COBRE Y ACERO

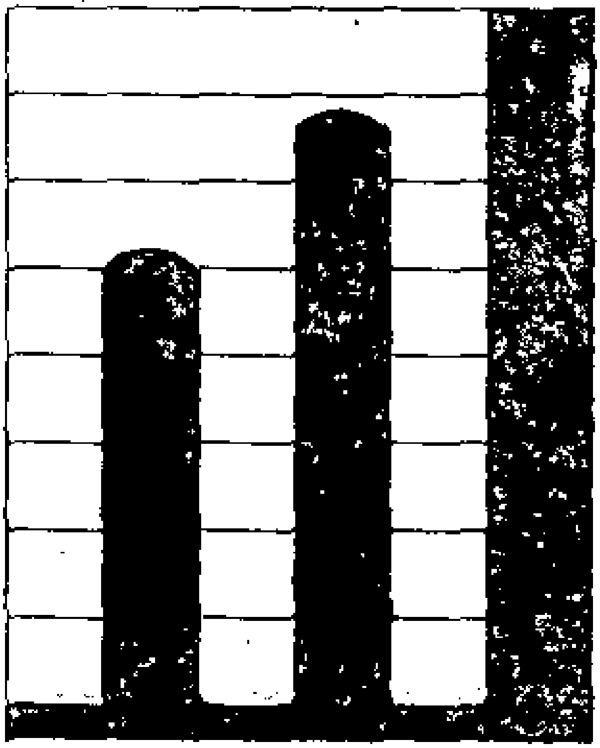
COMPARACION DEL COEFICIENTE DE EXPANSION ENTRE LAS TUBERIAS DE COBRE Y ACERO CON EL CONCRETO

COMPARACION DE LA RESISTENCIA A LAS TEMPERATURAS ENTRE LAS TUBERIAS DE COBRE Y ACERO

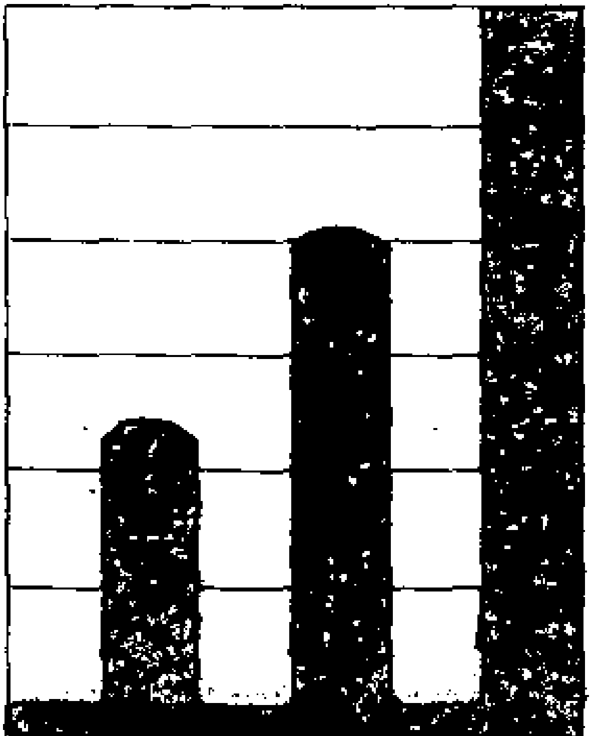


Graficas comparativas de las principales caracteristicas de las tuberias de acero, cobre y plástico.

COMPARACION DE LA RESISTENCIA A LA TENSION
ENTRE LAS TUBERIAS DE COBRE Y ACERO



COMPARACION DE LA RESISTENCIA A CARGAS EXTERNAS
ENTRE LAS TUBERIAS DE COBRE Y ACERO



PROCEDIMIENTOS GENERALES PARA TENDIDO DE TUBERIAS DE ACERO PARA CONDUCCION DE LIQUIDOS

Localización.

Daremos por un hecho la localización de la línea; ya que no forma parte del tema que estamos tratando.

Preparación del Terreno.

En el terreno elegido, se procederá a excavar la cepa que recibirá la línea, utilizando para esto el equipo adecuado dependiendo del tipo de terreno. La profundidad de la cepa normalmente es de 1.50 mts., mas el diámetro de la tubería a tender. Se cuidará que el material, producto de la excavación, se aumente siempre en un lado de la cepa, dejando el otro lado para recibir el tubo y como área de trabajo.

El fondo de la cepa se procurará dejar en condiciones tales que permita el apoyo de la tubería en condiciones adecuadas y lo mas uniforme posible. En terrenos rocosos o con mucha piedra, deberá prepararse una cama para el tubo con arena o tierra blanda que garantice un apoyo uniforme a la tubería.

Recepción de Material.

El tubo se recibe generalmente en longitudes de aproximadamente 12 mts. Normal mente los tubos se envian al campo debidamente pintados con pintura anticorrosiva en toda su longitud excepto en los extremos que deberán estar preparados para la unión soldada, es decir biselados apropiadamente dependiendo del grueso de la pared, y libres de pintura, óxido o cualquier impureza.

Tendido y soldado de la línea.

En estas condiciones los tubos se distribuyen a lo largo de la línea.

Con ayuda de un tractor de pluma lateral se posicionan los tubos sobre caballetes de madera a una altura mínima de 30 cms. del terreno natural, en tal forma que permita el acceso del soldador en todo el perímetro de la junta.

Con ayuda de un alineador por la parte interior del tubo y un alineador (canastilla) por la parte exterior se colocan los extremos del tubo para iniciar el proceso de soldadura.

La junta deberá quedar preparada en tal forma que se garantice el alineamiento - y dejando una separación entre tubos de 1/16 de pulgada.

En estas condiciones se inicia el proceso de soldadura de la junta con los siguientes pasos :

1.- Fondeo.

Dos soldadores inician esta etapa de la parte superior del tubo hacia la parte inferior, terminando el fondeo en la parte baja de la junta. Esta primera-etapa de soldadura es la mas importante ya que una buena aplicación del fondeo garantizará la eficiencia de la unión. La soldadura deberá depositarse utilizando electrodo de gran penetración que permita aplicarse en cualquier posición y que garantice la total unión de la pared del tubo pero que además no sobrepase la pared interior, con objeto de conservar integro la capacidad del tubo. Por especificacion la soldadura no podrá sobresalir mas de 1/32" de la pared interior.

2.- Paso Caliente.

Esta etapa comprende dos procesos el primero es remover parte de la soldadura aplicada en el fondeo utilizando la misma máquina soldadora pero con la polaridad invertida y un alto amperaje. Esta operación permite sanear la soldadura de fondeo y eliminar la escoria que pudo quedar atrapada en el fondeo debido a la condición de aplicación en la parte mas cerrada del bisel. El segundo paso consiste en aplicar un cordón de soldadura en toda la junta ya con la polaridad directa de la maquina y con alto amperaje que permita eliminar residuos de escoria. Se aplica tambien con dos soldadores simultaneamente iniciando el cordón en la parte superior de la junta para terminarlo en la parte inferior. Se emplean electrodos de la serie E 60 - 10 y de 1/8" de diámetro.

3.- Relleno de la junta.

En estas condiciones y previa limpieza de la soldadura se procederá, con cordones sucesivos, a terminar la soldadura de la junta. El último cordón aplica do no deberá sobresalir más de 1 30 de la pared exterior del tubo.

En estas condiciones estará terminada la junta y se procederá a inspeccionarse usando radiografías o gamagrafías.

Si el resultado de la inspección radiográfica es satisfactorio se procederá a limpiar la superficie a los lados de la junta y se aplicará la pintura anticorrosiva en esa zona.

Dependiendo de las condiciones del terreno y del diametro de la tubería se procederá a hacer las juntas necesarias para completar una longitud de línea de aproximadamente 3 kilometros. A esta línea soldada se le llama " LINCADA ".

Antes de proceder a bajar la tubería a la cepa se procederá a aplicar la protección adecuada que evite la corrosión del material.

Una vez tendidas en la cepa dos líneas de tubería debidamente protegida se procederá a efectuar la soldadura que una las dos líneas. El procedimiento es semejante al descrito anteriormente sólo habrá necesidad de hacer una ampliación a la cepa en el lugar de la junta en tal forma que permita efectuarse la soldadura en condiciones convenidas, terminando en el sitio la pintura y la protección contra la corrosión.

Una vez tendida y terminada la línea se procede a rellenar la cepa compactando unicamente la parte superficial aprovechando los propios tractores.

Antes de poner en servicio la línea deberá limpiarse interiormente utilizando un etapa de soldadura es la mas importante ya que una buena aplicación del fondeo garantizará la eficiencia de la unión. La soldadura deberá depositarse utilizando electrodo de gran penetración que permita aplicarse en cualquier posición y que garantice la total unión de la pared del tubo pero que además no sobreposa la pared interior, con objeto de conservar integra la capacidad del tubo. Por especificacion la soldadura no podra sobresalir mas de 1/32" de la pared interior.

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Antes de poner en servicio la línea deberá limpiarse interiormente utilizando un -

cilindro de hule (diablo) el cual tendrá un diametro igual al diámetro interior de la tubería y se hará correr a lo largo de la misma utilizando agua y aire a presión. Este tapón detectará también alguna falla en la línea como exceso de soldadura o deformaciones del tubo. Para poder localizar el tapon dentro de la tubería se le pone un isótopo con lo cual y con ayuda de un contador de radiaciones es facilmente localizable, y podrá repararse el defecto localizado al atascarse el tapón.

Personal y equipo utilizado

3 Tractores de pluma lateral.
10 Máquinas soldadoras con motor de combustión interna.
1 Biseladora de oxi - acetileno.
1 Cortador de oxi - acetileno.
2 Fondeadores.
2 Soldadores de paso caliente.
6 Soldadores.

Rendimiento estimado en tubería de 254 mm. de diametro.	155 Juntas / 10 horas
Longitud de la línea . (aproximadamente).	2 Kilometros.

" CORROSION "

Cuando el término corrosión se aplica a las tuberías de acero, se entiende portal el deterióro que sufre ésta por acción galvanica y/o electrolítica. Las primeras tuberías de acero fueron instaladas, generalmente sin recubrimiento protector y normalmente sin considerar las condiciones del medio en el cual se iba a cobrar. En algunos casos se colocó la tubería en medios subterráneos (bajo tierra) no compatibles con un metál ferroso; presentándose el fenómeno de corrosión y ocasionando problemas de mantenimiento. Esta situación ha conducido a que la generalidad de las personas consideran que el acero (o en general los compuestos ferrosos) son más suceptibles a la corrosión que cualquier otro material. Sin embargo esta suceptibilidad ocurre sólo cuando cualquier tubería de acero es expuesta a suelos y aguas de naturaleza corrosiva, cuando se aplica una protección permanente a la tubería de acero su vida útil queda asegurada.

El problema de la corrosión en tuberías de acero, pueden ser eliminado, teniendo presentes dos consideraciones básicas :

1.- La necesidad de Protección Interior.

2.- La necesidad de Protección Exterior.

1.- Protección Interior.

La American Water Works Association, ha aprobado dos tipos de revestimientos, uno realizado con esmalte a base de alquitrán de hulla (coal -

tar enamel), y otro con cemento mortero para revestimiento interior de tubería de acero para agua. La función primaria del revestimiento en una tubería es proporcionar y mantener una gran capacidad hidráulica de flujo. La capacidad de flujo es mantenida evitando el desarrollo de tuberculos de moho, y- proporcionando una superficie lisa dentro de la tubería. Estos materiales de - reventimiento aplicados de acuerdo a los stándars de la AWWA, proporcionan coeficientes de flujo para la ecuación de Hazen - Williams (C) de 140.

2.- Protección Exterior.

Antes de desarrollarse métodos eficientes para el control de la corrosión, era práctica común añadir un recubrimiento de acero a las paredes del tubo para tener una cierta tolerancia de corrosión. Sin embargo ésta no es una solución práctica para el problema.

Investigaciones dirigidas por la Oficina Nacional de Stándars, ha demostrado claramente que todos los metales ferrosos se corroen, esencialmente en la misma proporción dentro del mismo medio. Además estas investigaciones han demostrado que la corrosión ataca un acero enterrado en el suelo, en forma de pequeñas cavidades. Por lo tanto, una tolerancia de corrosión, aumentando - arbitrariamente el espesor de las paredes del tubo, a lo mas, retrasa solo temporalmente la aparición del problema, pero no proporsiona la solución a largo plazo que se desea.

Muchos factores influyen en la corrosividad de los suelos bajo tierra y estos facto res están ampliamente discutidos en el AWWA Manual M 11. Sin embargo los factores mas sencillos e importantes que pueden ser facilmente obtenidos es la resistividad de los suelos. La siguiente siguiente tabla proporciona la probabilidad de corrosión de acuerdo a la resistividad del terreno :

Resistividad (omhs cm3)	Probabilidad de Corrosión
0 - 1,000	Muy Alta
1,000 - 2,000	Alta
2,000 - 5,000	Media
5,000 - 10,000	Baja
Arriba de 10,000	Muy Baja

RECUBRIMIENTOS

El método las antiguo que se ha empleado para combatir la corrosión, es el de la aplicación de recubrimientos de muy diversos tipos. En la actualidad, disponemos de una gran gama de recubrimientos, cada uno de ellos con propiedades y funciones específicas, por lo que estamos en posibilidad de seleccionar el que mejor se adapte a nuestras necesidades. En el tendido de líneas de conducción, se observa el empleo de tratamientos sucesivos con pinturas primarias, esmaltes de base bituminosa, especialmente de alquitrán de hulla, aplicación de fieltros de refuerzos, etc.

El buen éxito de la aplicación de un recubrimiento, depende, en primer lugar, de una perfecta adhesión entre el recubrimiento y la superficie metálica. Es de capital importancia efectuar una concienzuda limpieza de la tubería con el objeto de dejarla libre de materias extrañas como son : aceites, grasas, herrumbre, etc. En una palabra, toda materia que pueda evitar un contacto íntimo entre recubrimiento y metal. Para este fin se hace uso de rasquetas, cepillos de alambre, máquinas rotatorias de limpieza o bien, limpieza con chorro de arena que es, con mucho, el método más efectivo.

Una vez limpia la tubería se procede a la aplicación de una pintura primaria, cuya función consiste en ser el puente de unión entre la tubería y el recubrimiento. Estas pinturas primarias se adhieren fácilmente al metal y proporcionan una superficie, a la cual se adhiere contenacidad el esmalte caliente. Si se tratara de aplicar el esmalte a la tubería sin la previa operación a que nos estamos refiriendo, el esmalte caliente no llegaría a humectar totalmente la superficie metálica, disminuyendo notablemente sus propiedades adhesivas.

Los recubrimientos más comunmente empleados para la protección de líneas de conducción subterráneas, son los llamados esmaltes, fabricados con bases bituminosas. Debido a que el éxito en la aplicación de un recubrimiento depende en gran parte de su efectividad para detener el paso de la humedad, son preferibles aquellos materiales que tengan un bajo promedio de absorción de agua; siendo uno de esos materiales el alquitrán de hulla.

Los recubrimientos a base de asfalto, por lo general, tienen una buena resistencia eléctrica cuando se aplican, pero debido a la absorción de agua, esta resistencia

... 28

disminuye tiempo después del tendido de la línea en suelos húmedos.

El empleo, cada vez más amplio, de los recubrimientos a base de alquitrán de hulla, con la casi total exclusión de los esmaltes asfálticos, puede atribuirse a las características de este tipo de recubrimientos como son, su baja absorción de agua su estabilidad química, el mantenimiento de su resistencia eléctrica, su resistencia al ataque de ácidos y álcalis débiles, etc. Estos recubrimientos generalmente contienen rellenos minerales, y se aplican comunmente en caliente. Como complemento de los esmaltes, se emplean fieltros de refuerzo elaborados a base de fibra de vidrio.

Los fieltros de fibra de vidrio tienen la gran ventaja de que pueden ser saturados con el esmalte caliente, con el cual forman una sola unidad, de la misma manera que las varillas de acero pasan a ser parte integral de una losa de concreto, con la ventaja de mejorar su resistencia a golpes, vibraciones, tensiones, esfuerzos naturales del suelo, flujo en frío, etc.

Otro tipo de recubrimientos son los llamados " mastiques " que son fabricados a base de materiales bituminosos con un alto porcentaje de material de " carga ".- Esta generalmente consiste en arena ú otro material inorgánico semejante. Se aplican en caliente y existen reportes de que son bastante efectivos para contrarrestar la corrosión y muestran gran resistencia a las tensiones del suelo. Sin embargo, su empleo no se ha extendido, debido a que se requieren instalaciones especiales para su aplicación y a su relativo alto costo.

Una vez aplicados los recubrimientos, se procede a probar la tubería con el objeto de reparar cualquier falla ó imperfección que exista en el recubrimiento, antes de bajar la tubería a la zanja. Para este fin se hace uso de instrumentos eléctricos llamados detectores de fallas en los cuales se emplean potenciales de 10 a 12 mil volts y corrientes máximas de 10 miliamperes para evitar peligros al personal que los maneja.

Es de suma importancia considerar que ál aplicar un recubrimiento es prácticamente imposible obtener un cien por ciento de continuidad, debido a muchas causas, habrá pequeñas descontinuidades en el recubrimiento. Para proteger esas descontinuidades en el recubrimiento, se utiliza la protección catódica, con la cual el recubrimiento se aproxima lo más posible a la perfección.

Sin embargo, debemos tomar en cuenta que a mayor número de descontinuidades en el recubrimiento, tendremos mayor costo de protección catódica; de allí la importancia de asegurar una buena aplicación del recubrimiento.

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PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

COMPLEMENTO II

ING. RAUL GRANADOS

JULIO, 1979

Palacio de Minería Calle de Tacuba 5, primer piso. México 1, D. F.

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 pasos. 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 pueda 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.

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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

ING. JOSE LUIS SANCHEZ MARTINEZ

JUNIO, 1979.

Palacio de Minería   Calle de Tacuba 5,   primer piso.   México 1, D. F.

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

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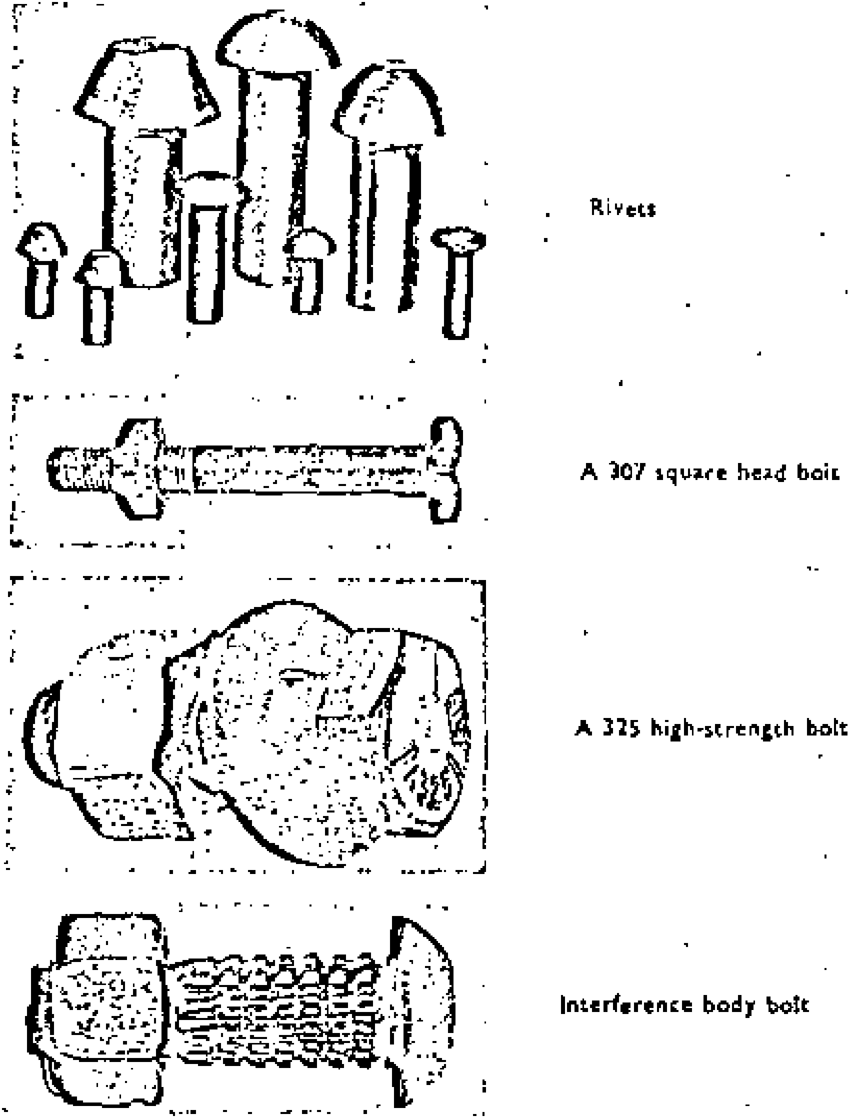


Fig. 18.1 Mechanical fasteners. (Courtesy of Bethlehem Steel Corp.)

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.

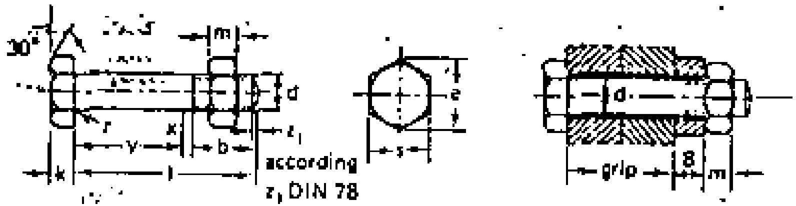
En este sentido, las especificaciones del AISC fijan una serie de casos concretos en que los tornillos A307 no deben usarse.

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

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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.

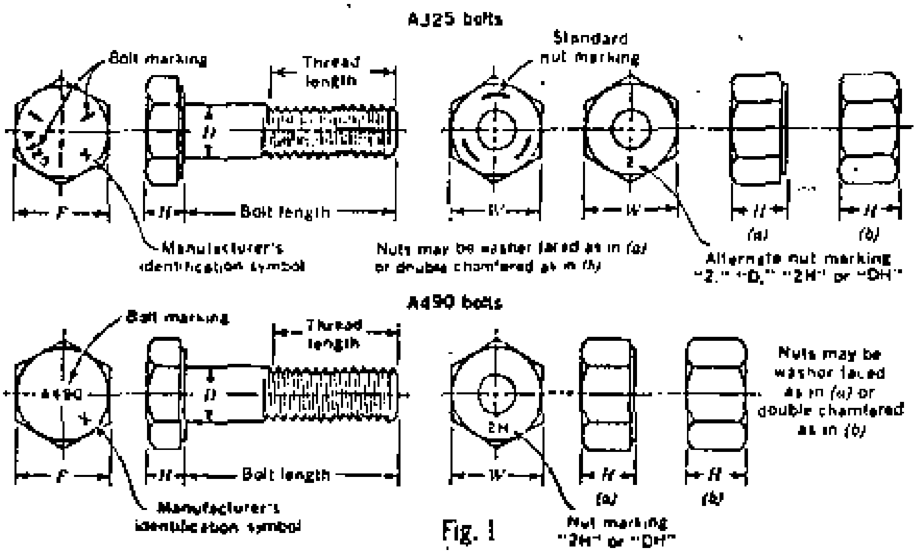

Fig. 1

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*
½	⅞	5/16	1	⅞	31/64
⅝	1 1/16	25/64	1¼	1 1/16	39/64
¾	1¼	15/32	1⅜	1¼	47/64
⅞	1 7/16	35/64	1½	1 7/16	55/64
1	1⅝	39/64	1¾	1⅝	63/64
1⅛	1 13/16	11/16	2	1 13/16	1 7/64
1¼	2	25/32	2	2	1 7/32
1⅜	2 3/16	27/32	2¼	2 3/16	1 11/32
1½	2⅜	15/16	2¼	2⅜	1 15/32

SPECIFICA
DATA

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° cómo 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				
				Washers	
	Type 1 Bolts	Type 2 Bolts[a]	Nuts	Quenched and Tempered	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

TORNILLOS

A 490

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	38

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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.

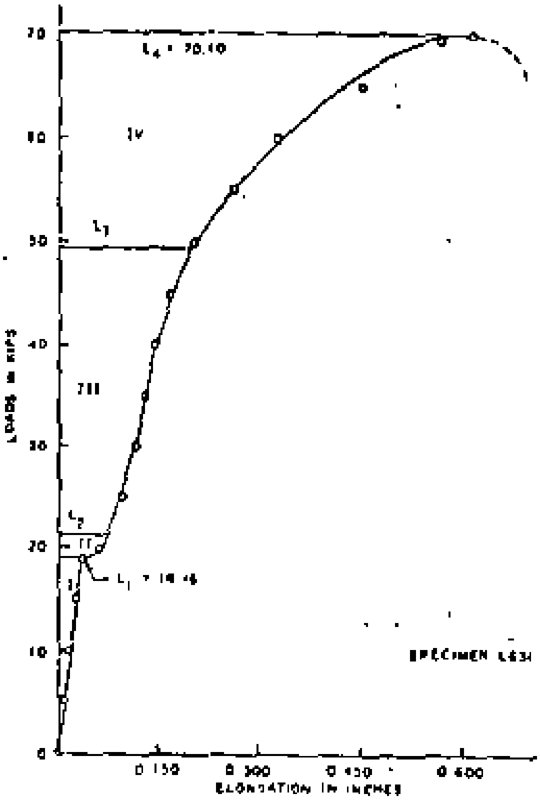

FIG. 6.—TYPICAL LOAD-JOINT ELONGATION RELATIONSHIP FOR SPECIMENS

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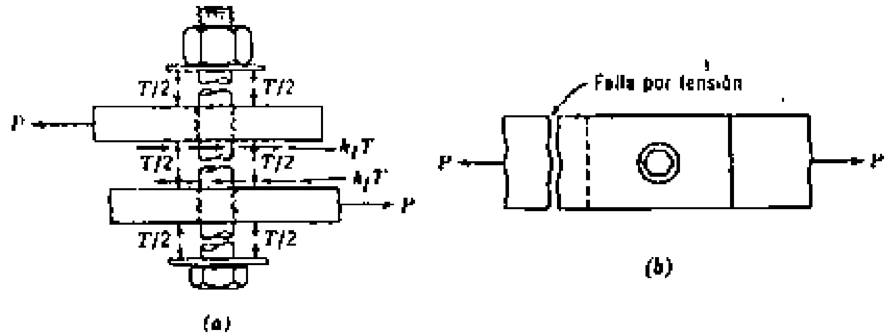
Teniendo en cuenta el comportamiento mencionado se distinguen dos tipos de juntas con tornillos de alta resistencia: las juntas de fricción y las juntas de aplastamiento.

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 equivaldría a la falla, si bien, los coeficientes de seguridad 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.



(a)

(b)

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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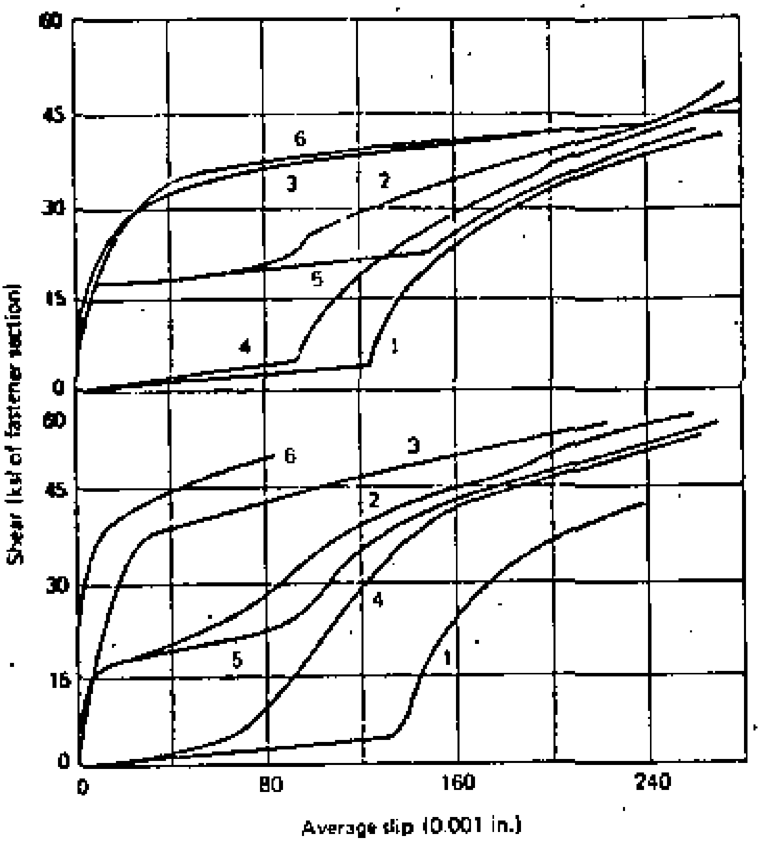

Legend

Bolts: $\frac{3}{4}$" diameter

Specimens 1 & 4: bolts with zero tension

Specimens 2 & 5: bolts with tension of 36,000 lb per bolt

Specimens 3 & 6: riveted joints

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

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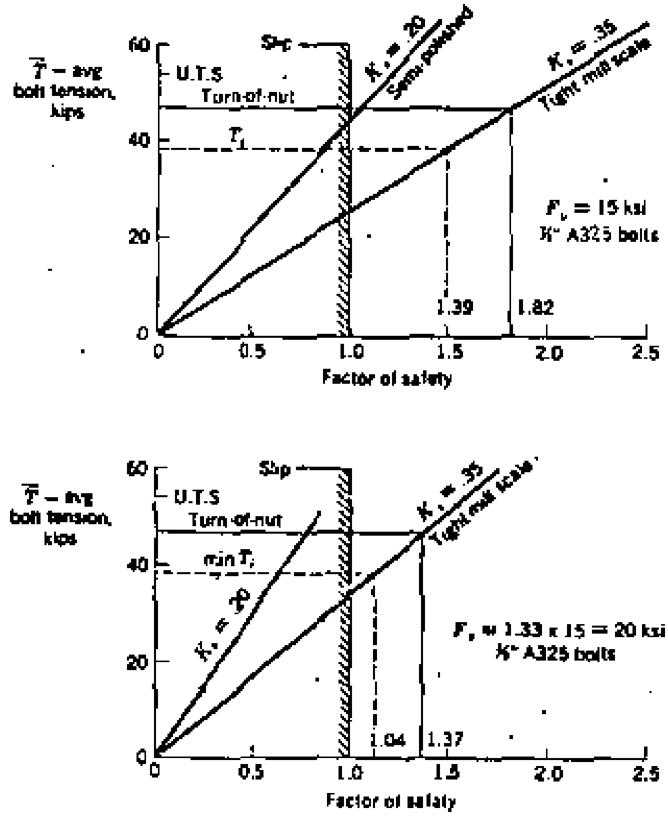

Fig. 18.16 Factor of safety against slip.

Fact, p. 629

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	11.6	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.

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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[a]

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

[a] 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.

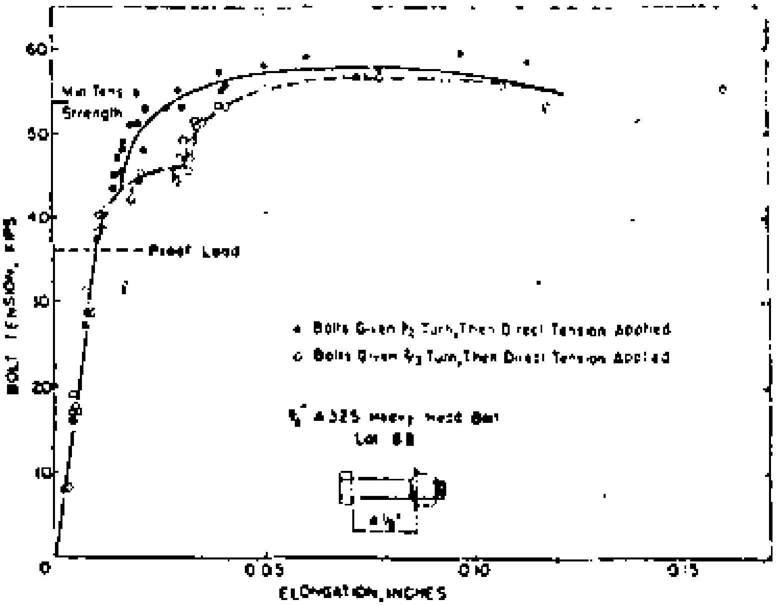


FIG. 6.—RESERVE TENSILE STRENGTH OF TORQUED BOLTS

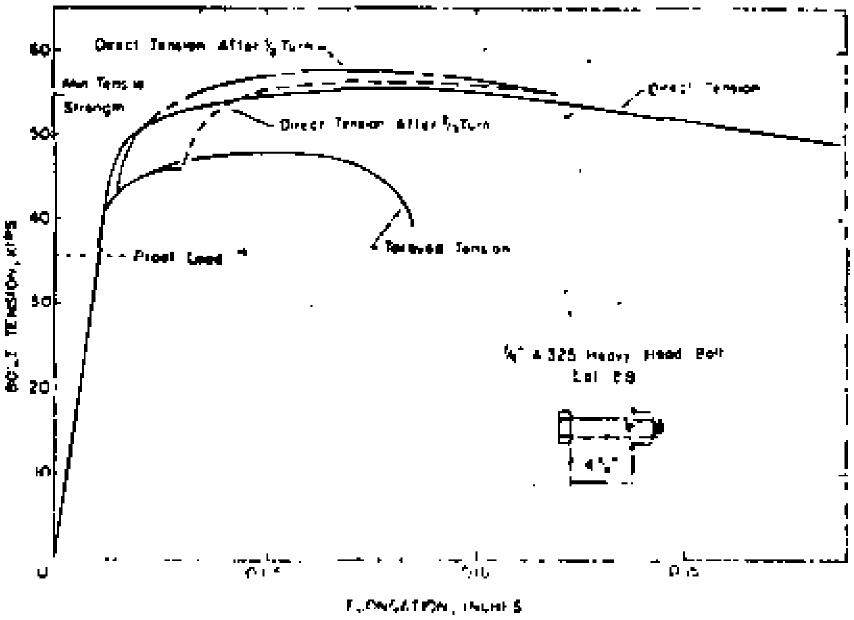


FIG. 7.—COMPARISON OF LOAD-ELONGATION RELATIONSHIPS

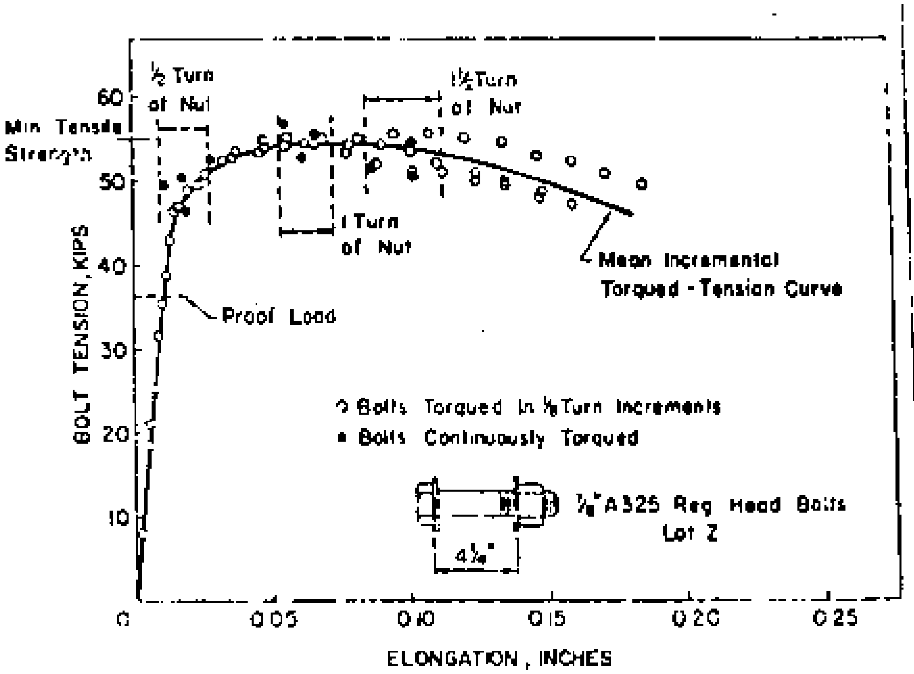


FIG. 8.—COMPARISON OF CONTINUOUSLY AND INCREMENTALLY TORQUED BOLTS

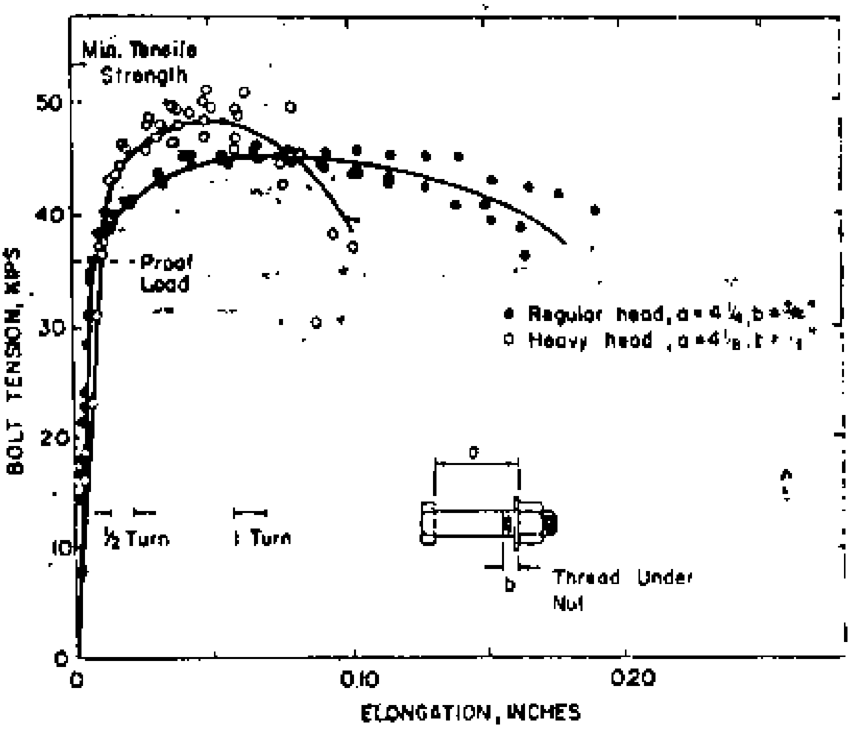


FIG. 13.—EFFECT OF THREAD LENGTH UNDER THE NUT

Rumpf, ASCE

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.

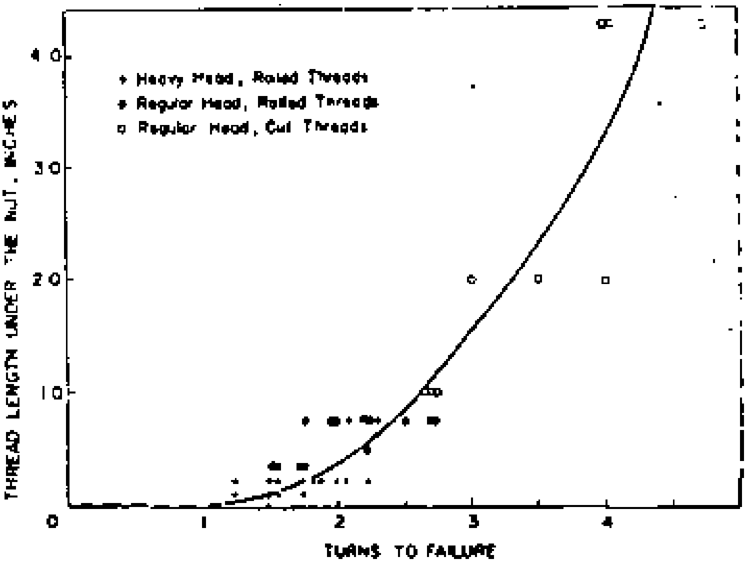
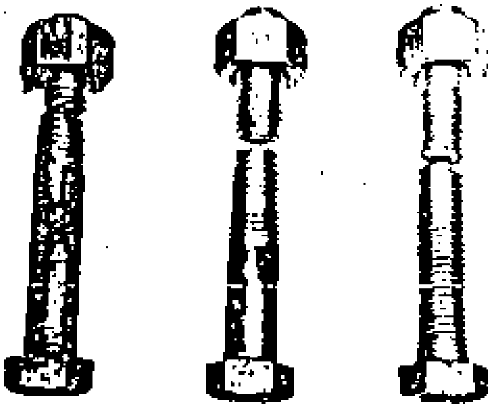


FIG. 11.—EFFECT OF THREAD LENGTH ON ROTATION CAPACITY



Rumpf ASCE

1.16.3 Long G[illegible]s

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]
≤⅞	⅛	0	$\frac{3}{16}$	$1\frac{1}{2}d - \frac{1}{16}$
1	$\frac{3}{16}$	0	¼	$1\frac{7}{16}$
≥1⅛	¼	0	$\frac{5}{16}$	$1\frac{1}{2}d - \frac{1}{16}$

[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]
½	⅞	¾
⅝	1⅛	⅞
¾	1¼	1
⅞	1½[c]	1⅛
1	1¾[c]	1¼
1⅛	2	1½
1¼	2¼	1⅝
Over 1¼	1¾ × Diameter	1¼ × Diameter

[a] For oversized or slotted holes, see Sect. 1.16.5.4.

[b] All edge distances in this column may be reduced ⅛-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 1¼-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]	
≤⅞	$\frac{1}{16}$	⅛	¾d	0
1	⅛	⅛		
≥1⅛	⅛	$\frac{3}{16}$		

[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 oversize, in inches (2)	Plate thickness, 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	0.329	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	64.1
B64	4/16	3/8	Data Unattainable	
B71	1/16	1/2	0.313	60.0
B72	2/16	1/2	0.300	66.6
B73	3/16	1/2	0.287	69.0
B74	4/16	1/2	0.240	66.0

[a] L61-L64 and B61-B64: 3/4-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		Minimum Side Dimension	Mean Thickness	Slope or Taper in Thickness
			Min.	Max.			
½	1¹⁄₁₆	¹⁷⁄₃₂	0.097	0.177	1¾	⁵⁄₁₆	1:6
⅝	1⁵⁄₁₆	²¹⁄₃₂	0.122	0.177	1¾	⁵⁄₁₆	1:6
¾	1¹⁵⁄₃₂	¹³⁄₁₆	0.122	0.177	1¾	⁵⁄₁₆	1:6
⅞	1¾	¹⁵⁄₁₆	0.136	0.177	1¾	⁵⁄₁₆	1:6
1	2	1¹⁄₁₆	0.136	0.177	1¾	⁵⁄₁₆	1:6
1⅛	2¼	1¼	0.136	0.177	2¼	⁵⁄₁₆	1:6
1¼	2½	1⅜	0.136	0.177	2¼	⁵⁄₁₆	1:6
1⅜	2¾	1½	0.136	0.177	2¼	⁵⁄₁₆	1:6
1½	3	1⅝	0.136	0.177	2¼	⁵⁄₁₆	1:6
1¾	3⅜	1⅞	0.178[b]	0.28[b]			
2	3¾	2⅛	0.178[b]	0.28[b]			
Over 2 to 4 Incl.	2D—½	D + ⅛	0.24[c]	0.34[c]			

[a] Dimensions in inches. (Tolerances as noted in Table 1-A.)
[b] ³⁄₁₆ in. nominal.
[c] ¼ 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 ⅞ of the bolt diameter from the center of the washer.

Table 1-A Washer Dimension Tolerances (inches)

Dimension	Washer Size	
	To 1½ in. Nominal Bolt Size, Incl.	Over 1½ in. Nominal Bolt Size
Nominal diameter of hole	−0; +¹⁄₃₂	−0; +¹⁄₁₆
Nominal outside dimensions	−¹⁄₃₂; +¹⁄₃₂	−¹⁄₁₆; +¹⁄₁₆
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

SPECIFICATIONS
AISC

TABLE 1.23.3

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
$\leq \frac{7}{8}$	$d + \frac{1}{16}$	$d + \frac{3}{16}$	$(d + \frac{1}{16}) \times (d + \frac{1}{4})$	$(d + \frac{1}{16}) \times 2\frac{1}{2}d$
1	$1\frac{1}{16}$	$1\frac{1}{4}$	$1\frac{1}{16} \times 1\frac{5}{16}$	$1\frac{1}{16} \times 2\frac{1}{2}$
$\geq 1\frac{1}{8}$	$d + \frac{1}{16}$	$d + \frac{5}{16}$	$(d + \frac{1}{16}) \times (d + \frac{3}{8})$	$(d + \frac{1}{16}) \times 2\frac{1}{2}d$

[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
½	11/16
⅝	⅞
¾	1
⅞	1⅛
1	1¼
1⅛	1½
1¼	1⅝
1⅜	1¾
1½	1⅞

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 radíca 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).

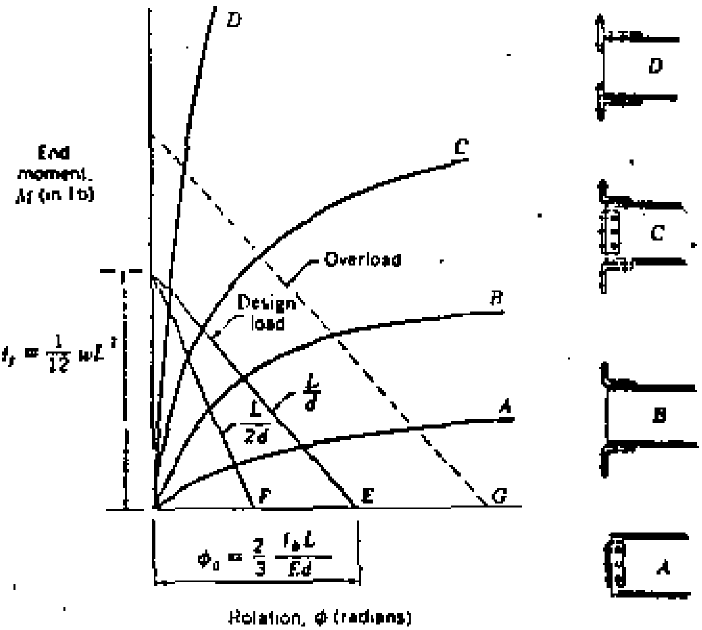


Fig. 18.14 Typical moment-rotation curves and beam-lines.

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:

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

$(M = 0)$ $\phi_0 = \frac{wL^3}{24EI}$ (simple beam end slope)

46

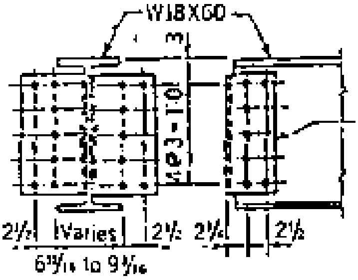
of the connection is maintained. Table II-A5 gives a shear value of 212 kips for eight 7/8″φ A325-X bolts: for seven bolts the shear will be 212 × 7/8 = 186 kips. The angle thickness required for eight bolts is 9/16″. In the interest of economy this may be revised, using $t_{min} = R \div (F_v \times L \times 2)$, 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 2¼″-2½″ 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 1⅛″. This gives a minimum width of leg 2¼″ + 2½″ + 1⅛″ = 5⅞″ 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:	1⅜″
	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 1⅛″ for 7/8″φ bolts. Thus, the minimum angle leg width for the outstanding leg will be 3 1/16 + 2½ + 1⅛ = 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′-2½″. (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 + 7/16) + 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 (2½″ gage + 1⅛″ edge distance) = 9 3/16″. The gage chosen may be anywhere between these two values and is the option of the detailer.

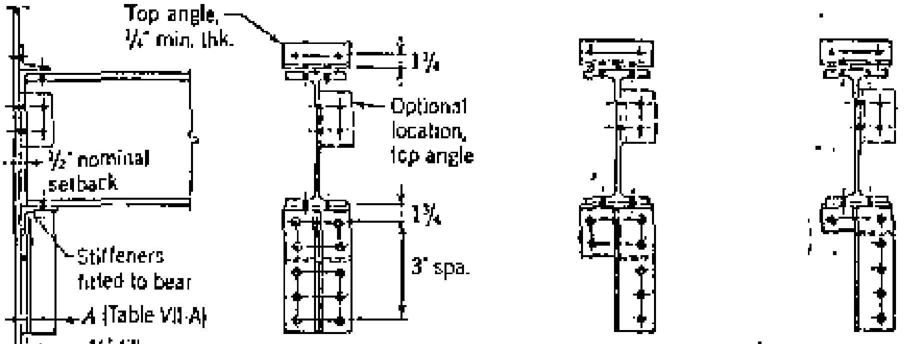


Detail for Example (c)
Angle material: $F_y = 36$ ksi
Beam material: $F_y = 50$ ksi

STIFFENED SEATED BEAM CONNECTIONS

Bolted or Riveted

TABLE VII



Type A

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

Type B

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

Type C

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.

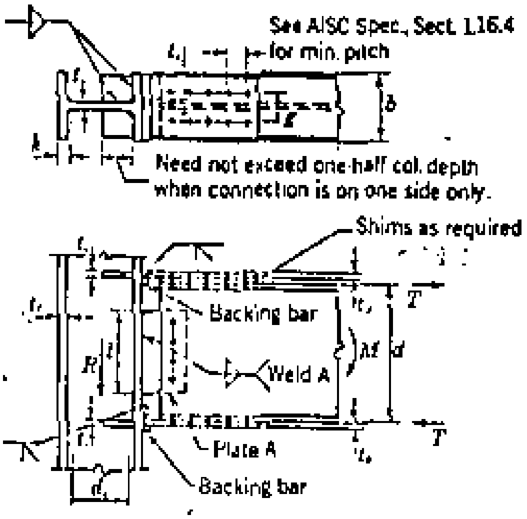
To permit selection of the most economical seated beam connection, the beam reactions should be shown on the contract drawings. If they are not shown, the connections should be selected to support half the total uniform load capacity shown in the beam load tables for the given shape, span, and steel 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

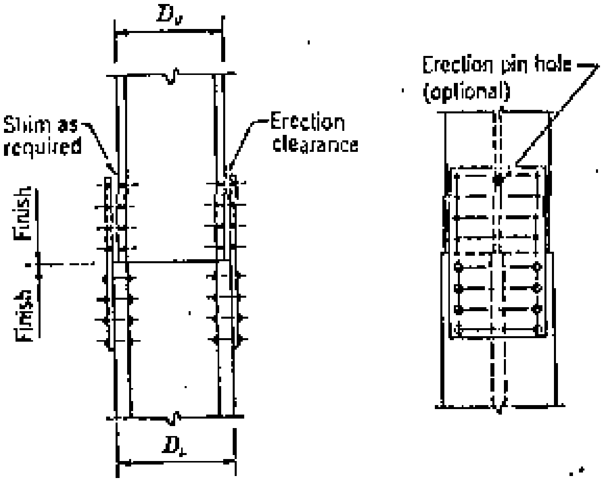
Many framing systems are designed as Type 1 (rigid-frame) and the connections must be designed to develop the inherent frame moments. The following example illustrates the design of a moment connection that may be used in rigid-frame construction and the method shown is recommended for the design of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



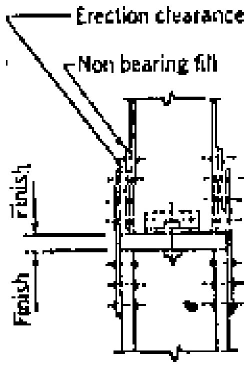
The moment is assumed to be resisted by the flange plates shop welded to the column and field fastened to the beam flanges. The shear is assumed to be transferred to the column by a vertical plate shop welded to the column and field fastened to the beam web.

	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 $= \frac{T}{r_v}$	

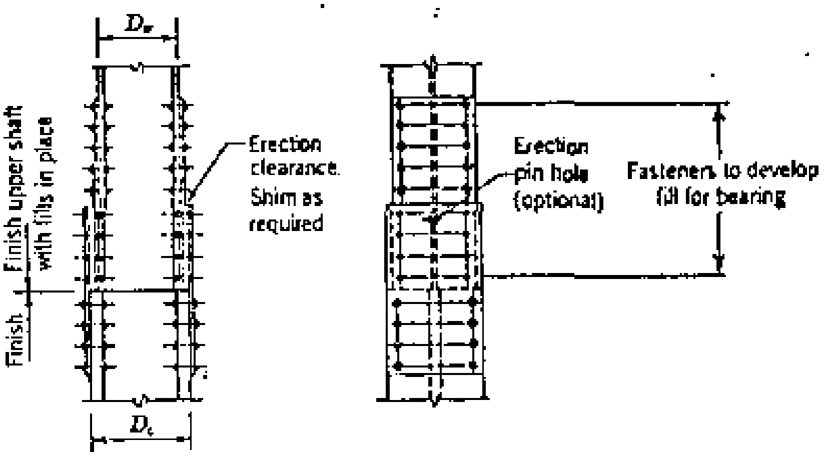
SUGGESTED DETAILS
Column splices
Riveted and bolted



DEPTH OF D_U AND D_L
NOMINALLY THE SAME



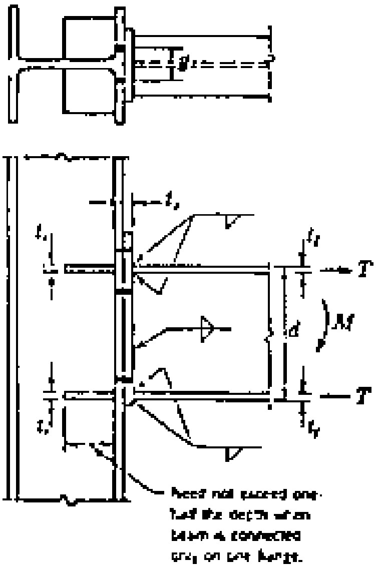
BUTT PLATE



DEPTH D_U NOMINALLY
2 IN. LESS THAN D_L

Note: Erection clearance = ⅛ in.

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: $S = \frac{1440}{24} = 60$ in.^{3}

   W 16 × 40 has a section modulus of 64.6 > 60 in.^{3} — pg. 2 - 10

2. Check flange force:

$$T\ (W\,16 \times 40) = \frac{1440}{16.0 - 0.503} = 92.9 \text{ kips}$$

Allowable flange force (W 16 × 40)
= 7.0 × 0.503 × 24
= 84.5 kips < 92.9 n.g.

∴ Try W 16 × 45: $S = 72.5$ in.^{3} > 60 in.^{3}

SOLDADURA

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 SLAG O ELECTROGAS

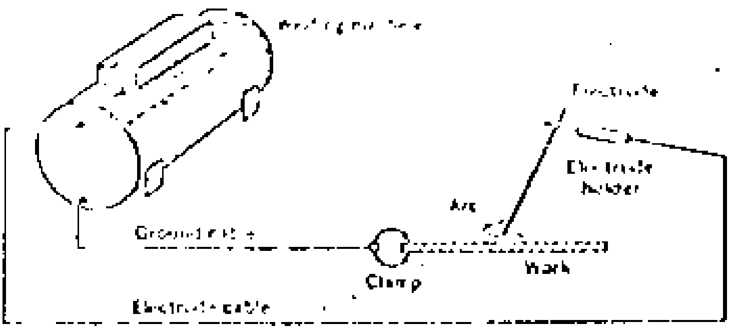


Fig. 14.1 The welding circuit.

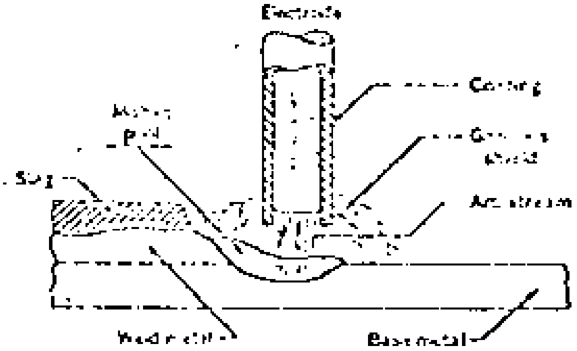


Fig. 14.3 Shielded arc-welding process.

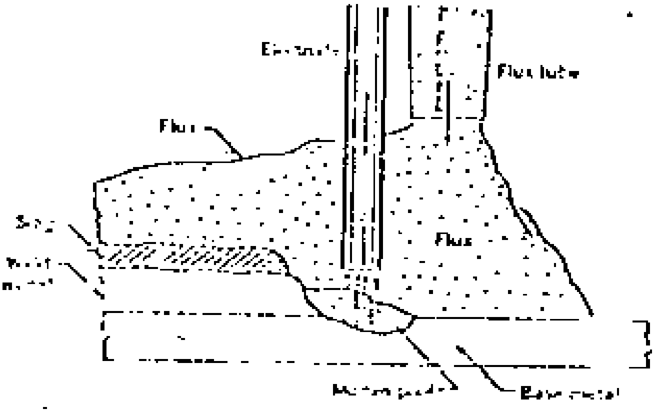


Fig. 14.6 Submerged arc-welding process.

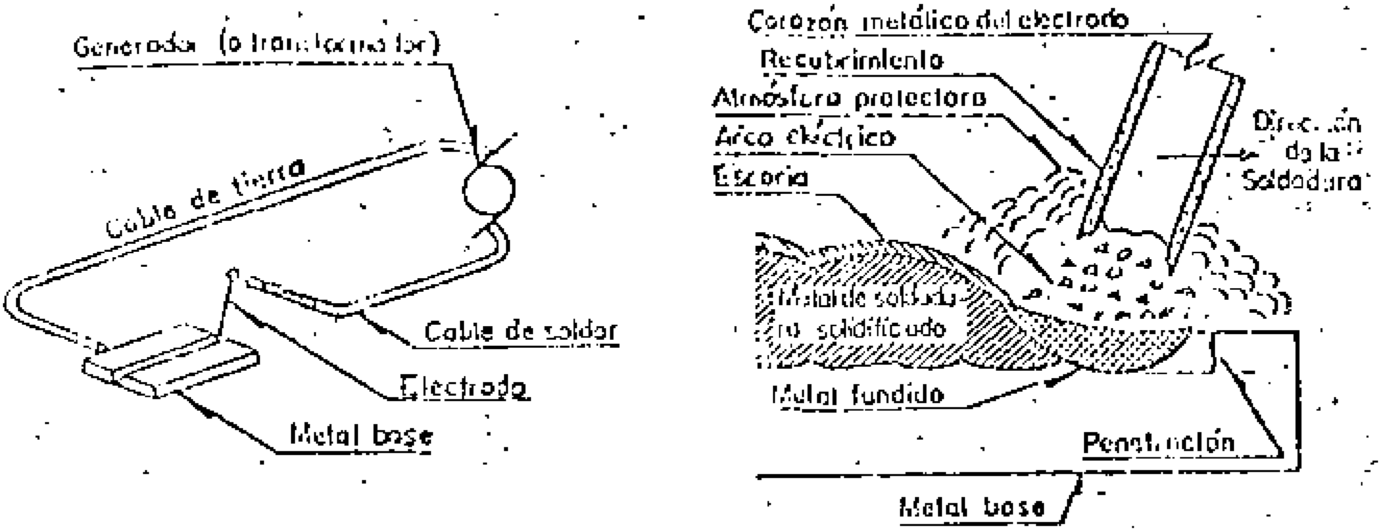


Fig 32

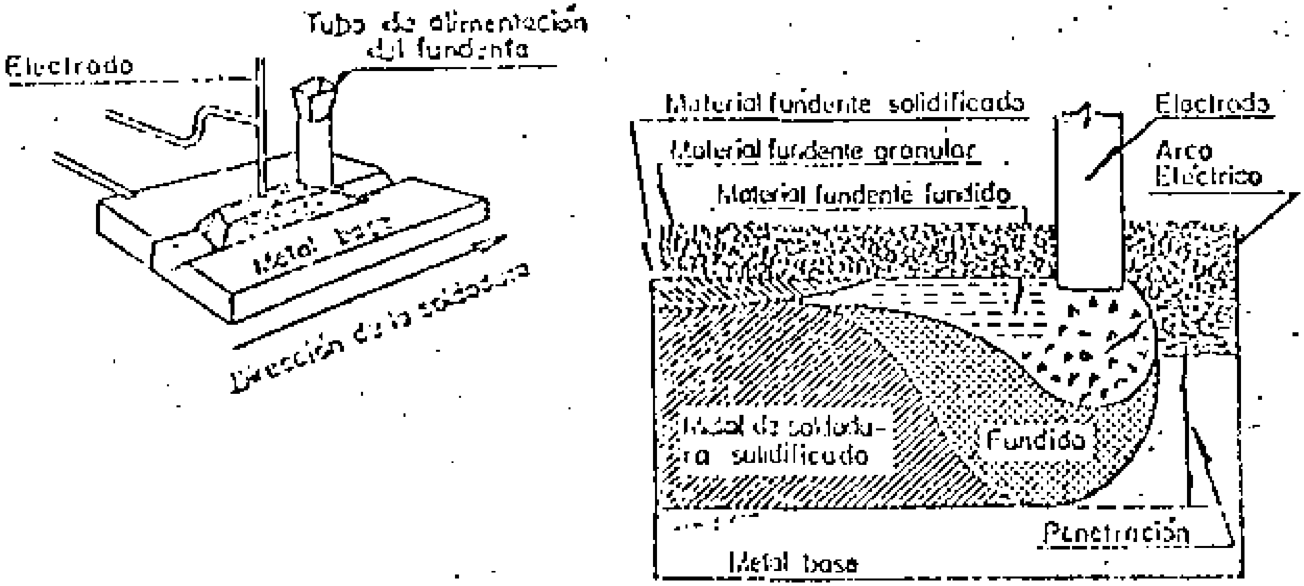


Fig 33

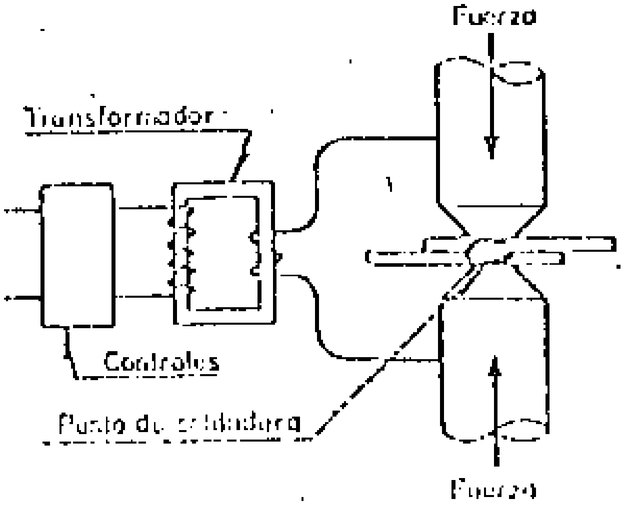


Fig 34

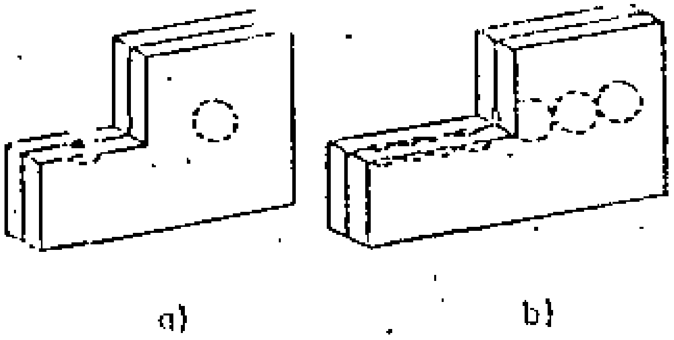

a) b)

Fig 35

The Self-Shielde
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.

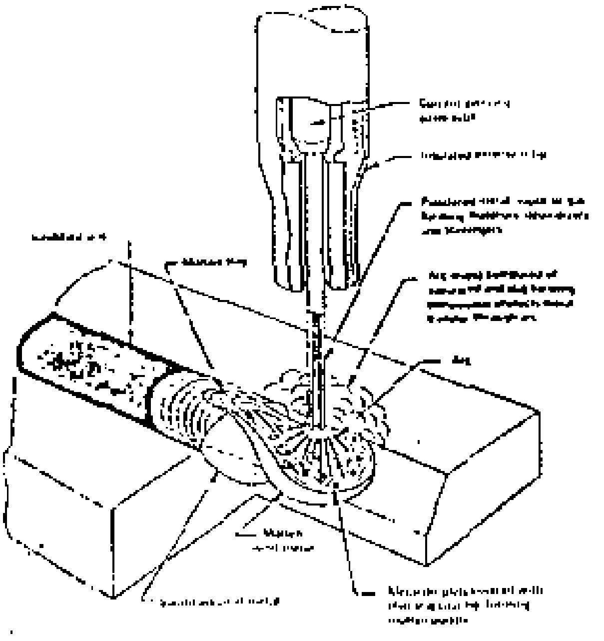


Fig. 5-5. Principles of the self-shielded flux-cored arc-welding process. The electrode may be viewed as an "inside-out" construction of the stick electrode used in shielded metal-arc welding. Putting the shield-generating materials inside the electrode allows the coiling of long, continuous lengths 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.

55

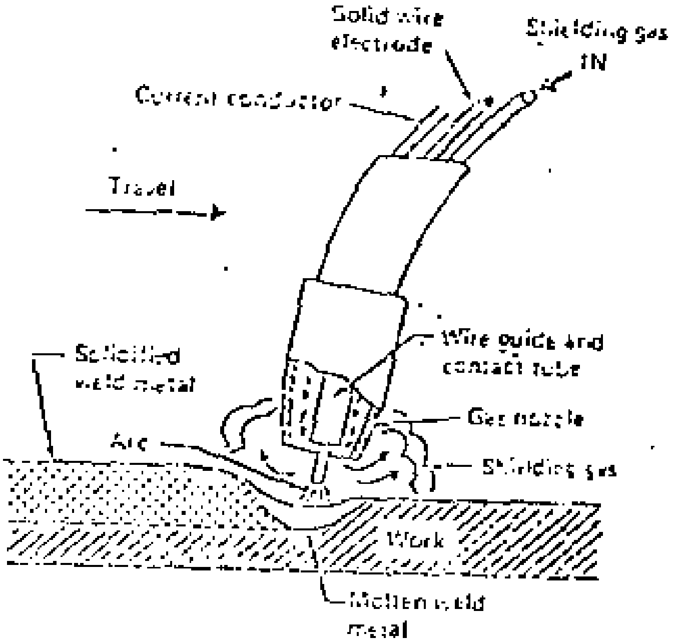


Fig. 5-13. Principle of the gas metal arc process. Continuous solid-wire electrode is fed to the gas-shielded arc.

56

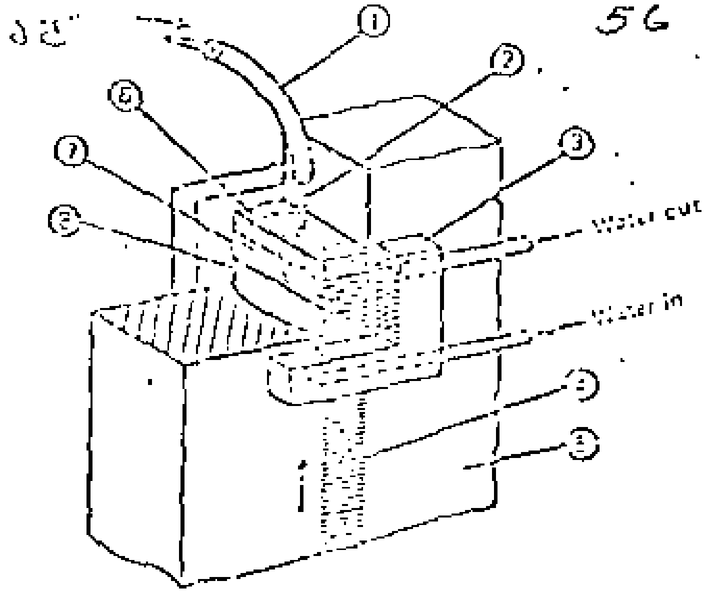


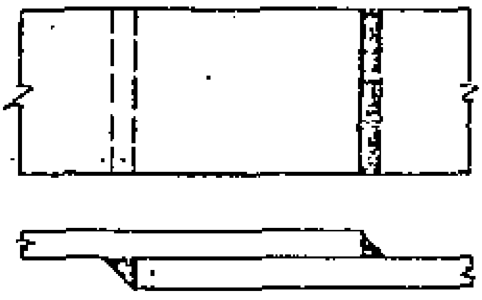
Fig. 5-21. Schematic sketch of electroslag welding: (1) electrode guide tube, (2) electrode, (3) water-cooled copper shoes, (4) finished weld, (5) base metal, (6) molten slag, (7) molten weld metal, (8) solidified weld metal.

II. TIPOS DE JUNTAS

- a) a tope
- b) traslape
- c) ente
- d) de esquina
- e) de borde

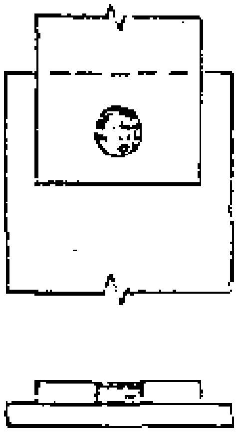
III. TIPOS DE SOLDADURAS

- a) soldadura de filete
- b) soldadura de penetración
  - b_1) penetración completa
  - b_2) penetración incompleta
- c) soldadura de tapón
- d) soldadura de ranura

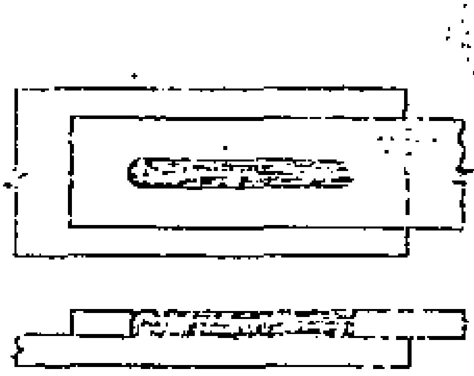


SOLDADURA DE FILETE

SOLDADURA DE PENETRACIÓN



SOLDADURA DE TAPÓN

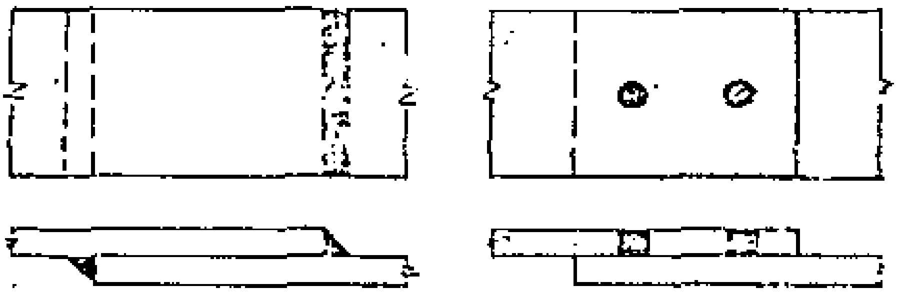


SOLDADURA DE RANURA

a1. SOLDADURAS DE FILETE

a2. SOLDADURAS DE PENETRACIÓN

a. JUNTAS A TOPE



b1. SOLDADURAS DE FILETE

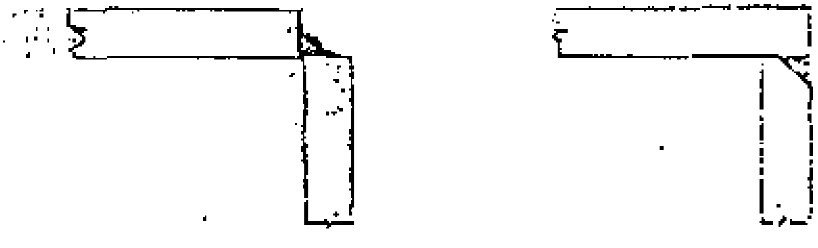
b2. SOLDADURAS DE TAPÓN

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

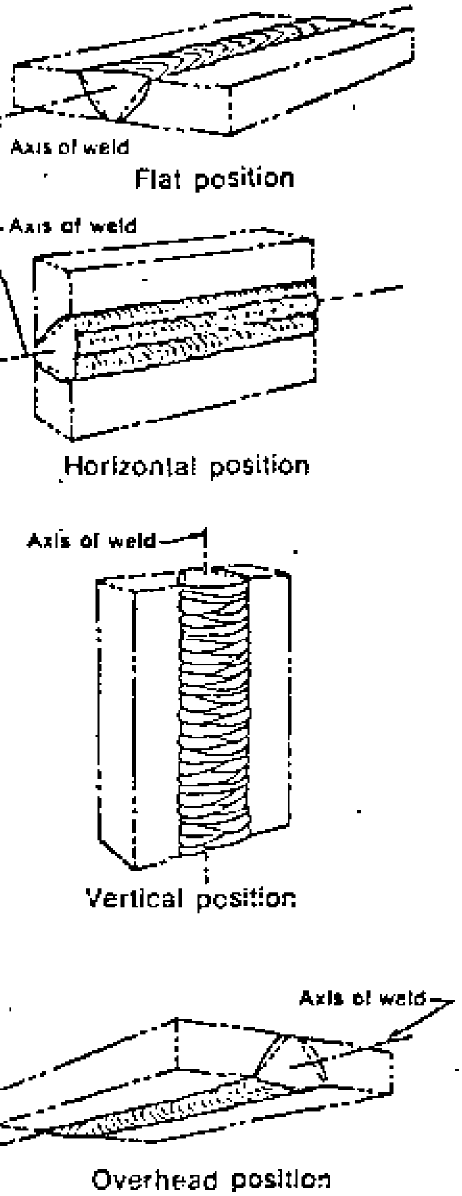


Fig. 2—Positions of welding for groove welds

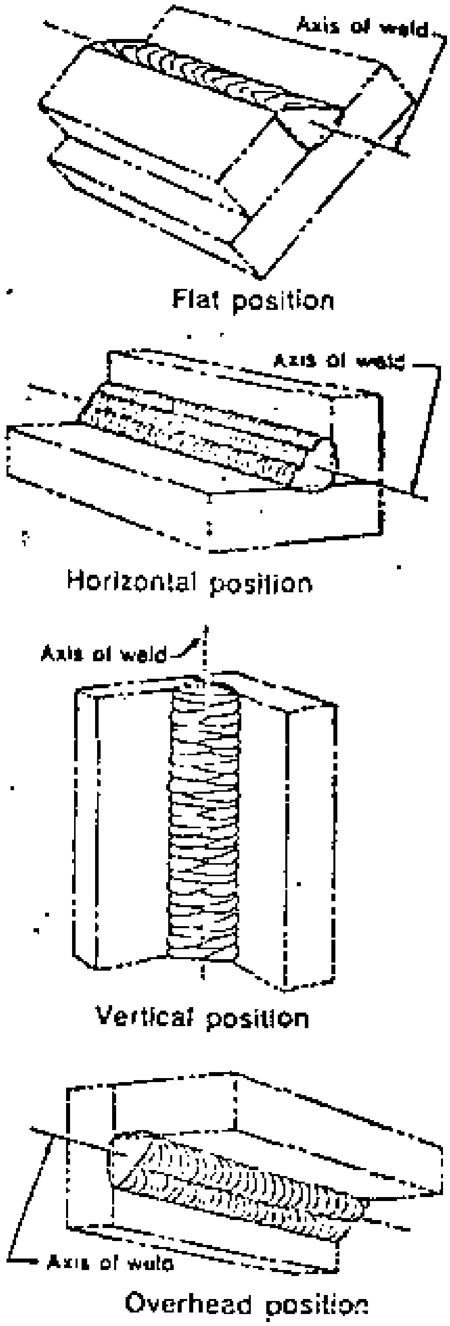
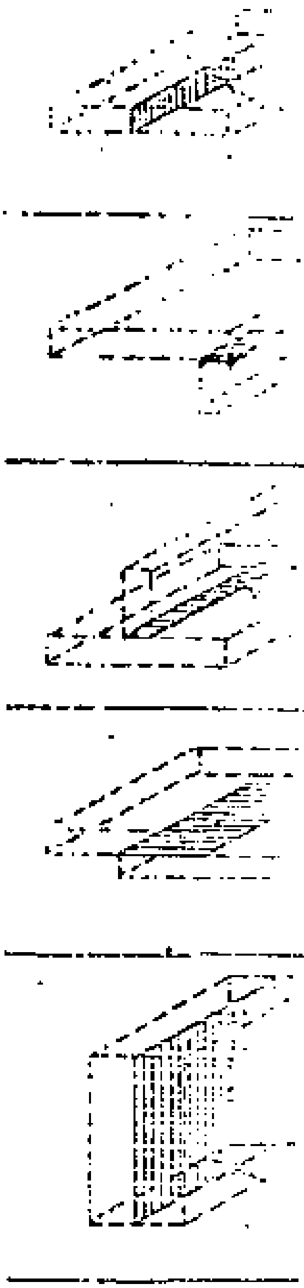


Fig. 3—Positions of welding for fillet welds



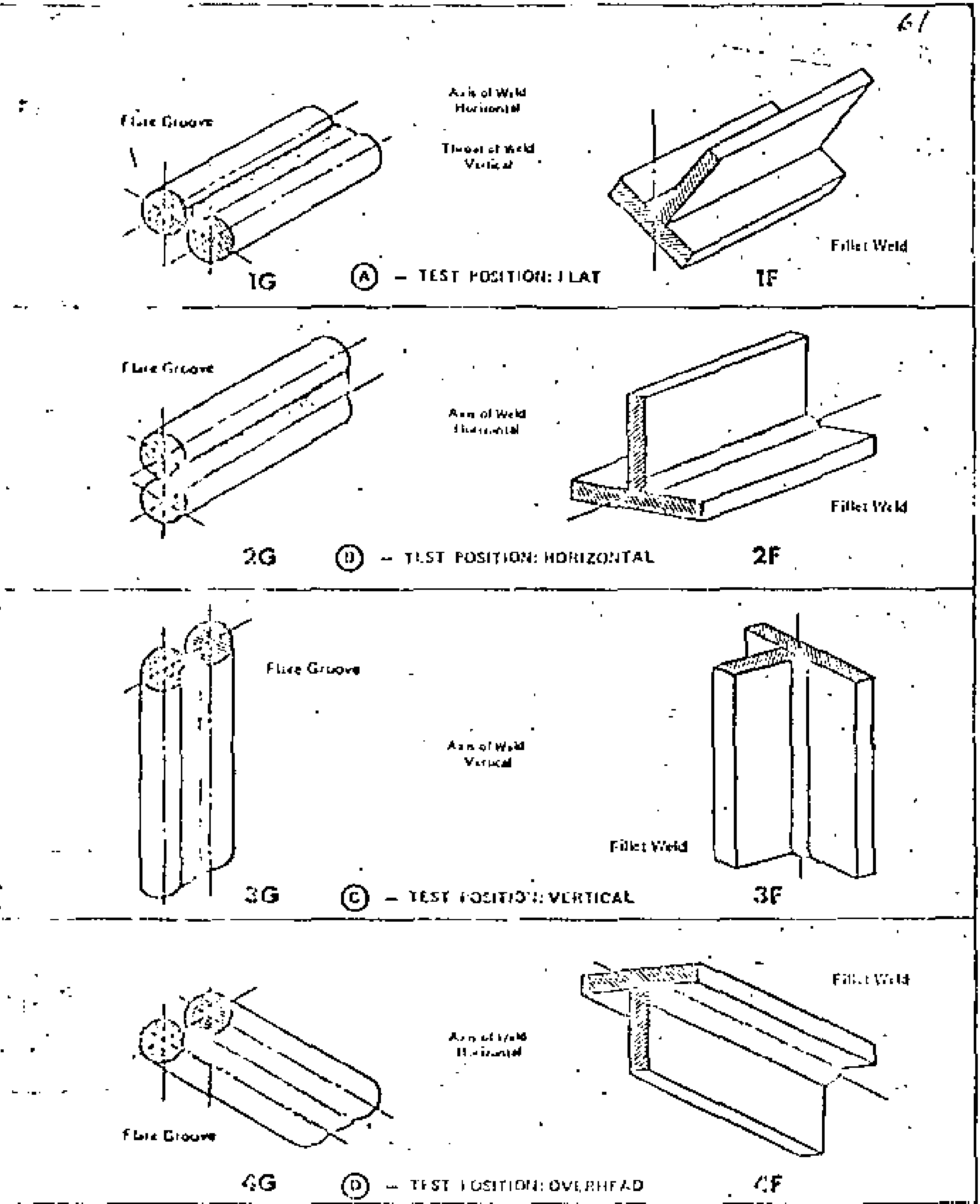
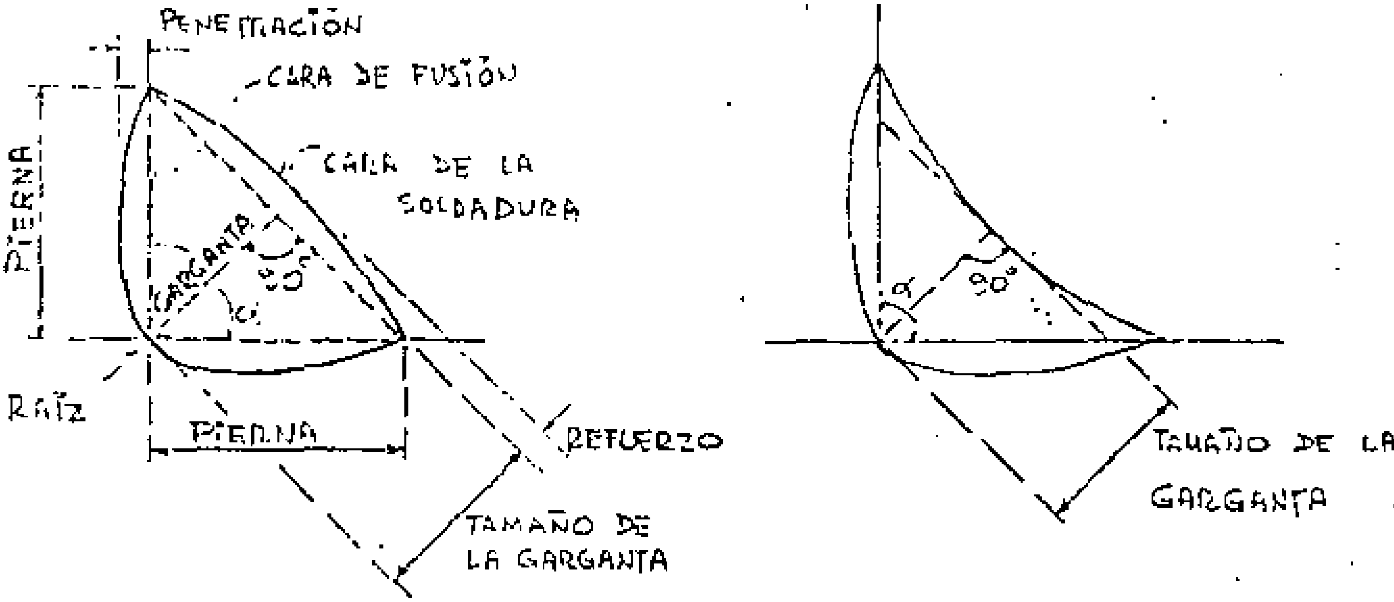


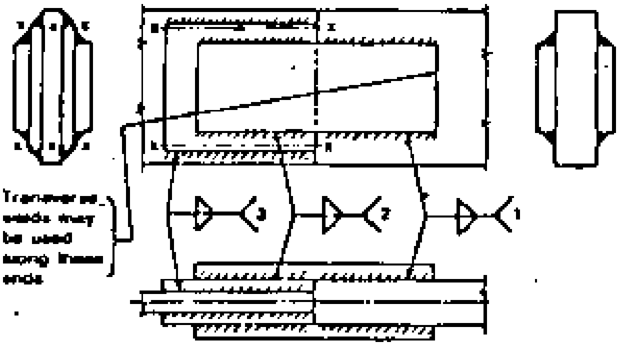
Fig. 6.2.4.2 — Indirect butt splice test positions for flare groove welds. (Positions for fillet welds are for information only.)

V. SOLDADURAS DE FILETE

- a) secciones transversales
- a^1) características
- a^2) secciones aceptables
- a^3) 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° ≤ α ≤ 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).

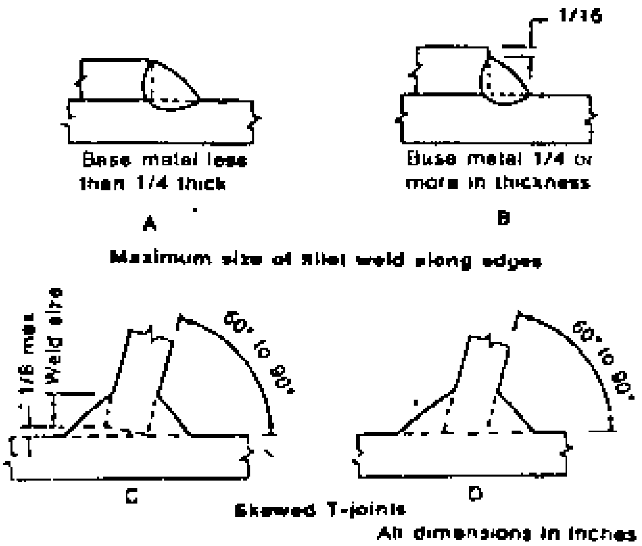
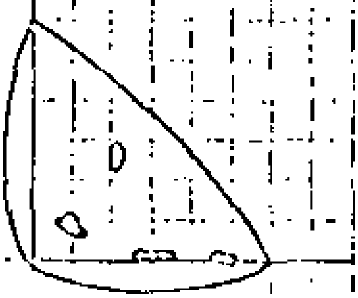


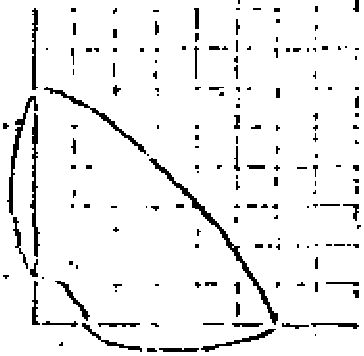
Fig. 2.7.1—Details for fillet welds.

POROSIDAD

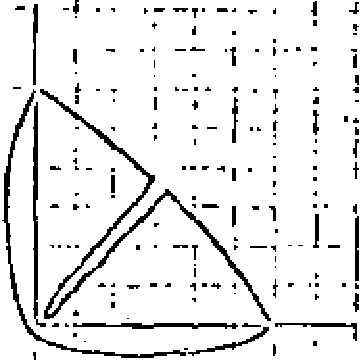


INCLUSIONES DE ESCORIA

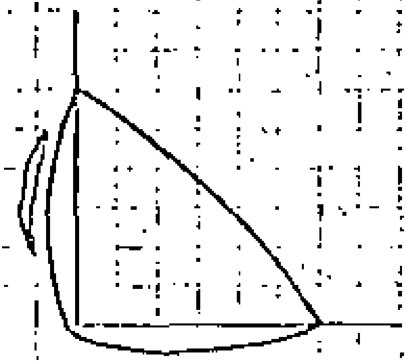
FUSIÓN INCOMPLETA



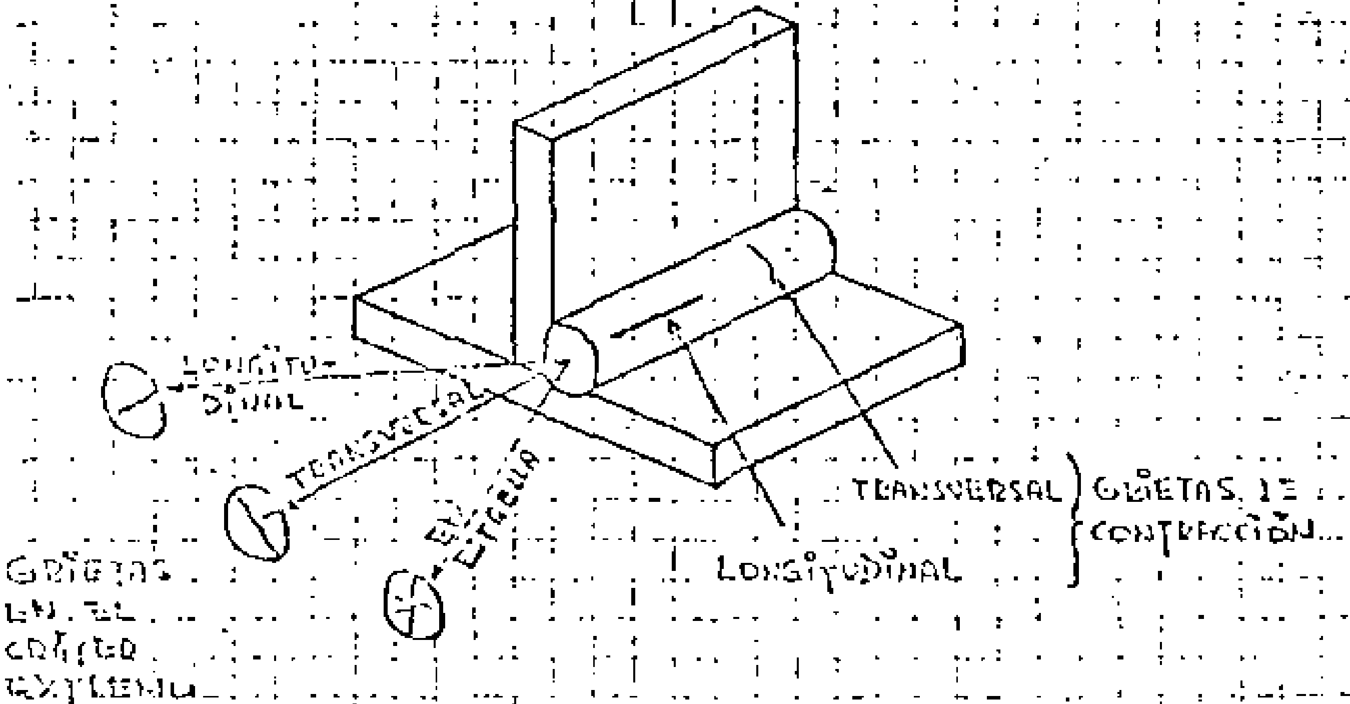
FALTA DE PENETRACIÓN



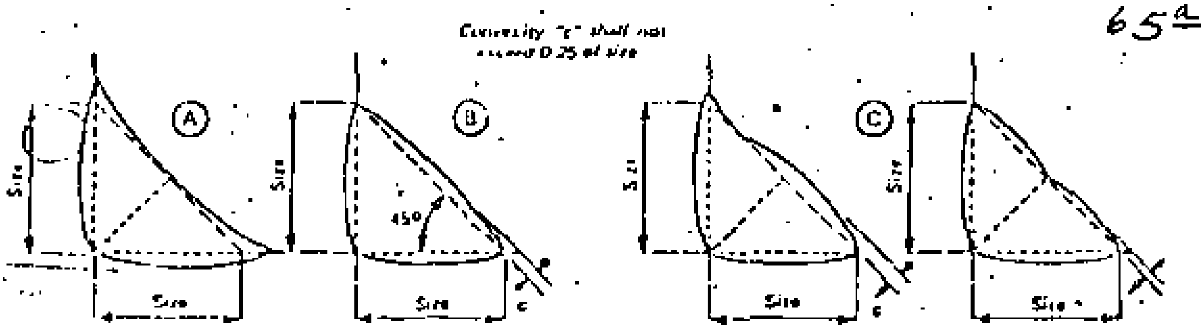
GRIETA LONGITUDINAL



GRIETA EN EL METAL BASE

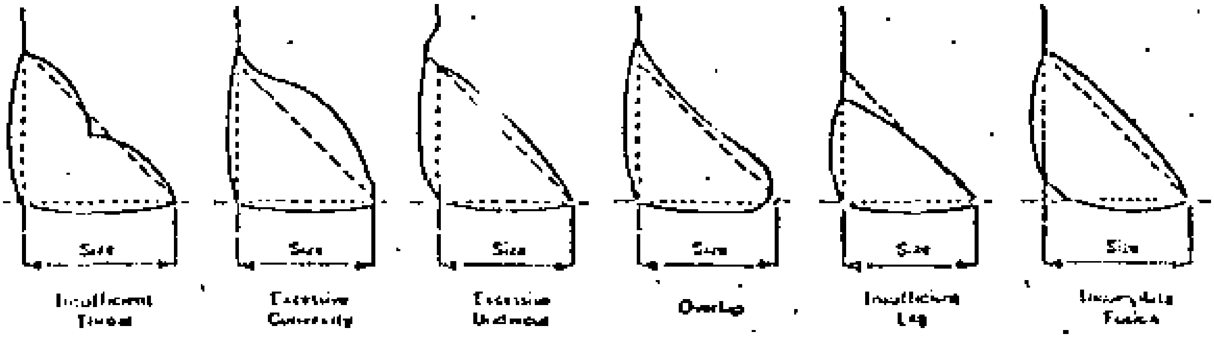


65a



Desirable Fillet Weld Profiles

Acceptable Fillet Weld Profiles



Insufficient Throat

Excessive Convexity

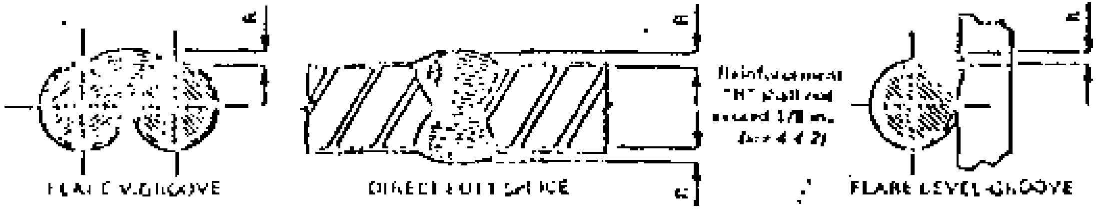
Excessive Undercut

Overlap

Insufficient Leg

Incomplete Fusion

(D) Unacceptable Fillet Weld Profiles

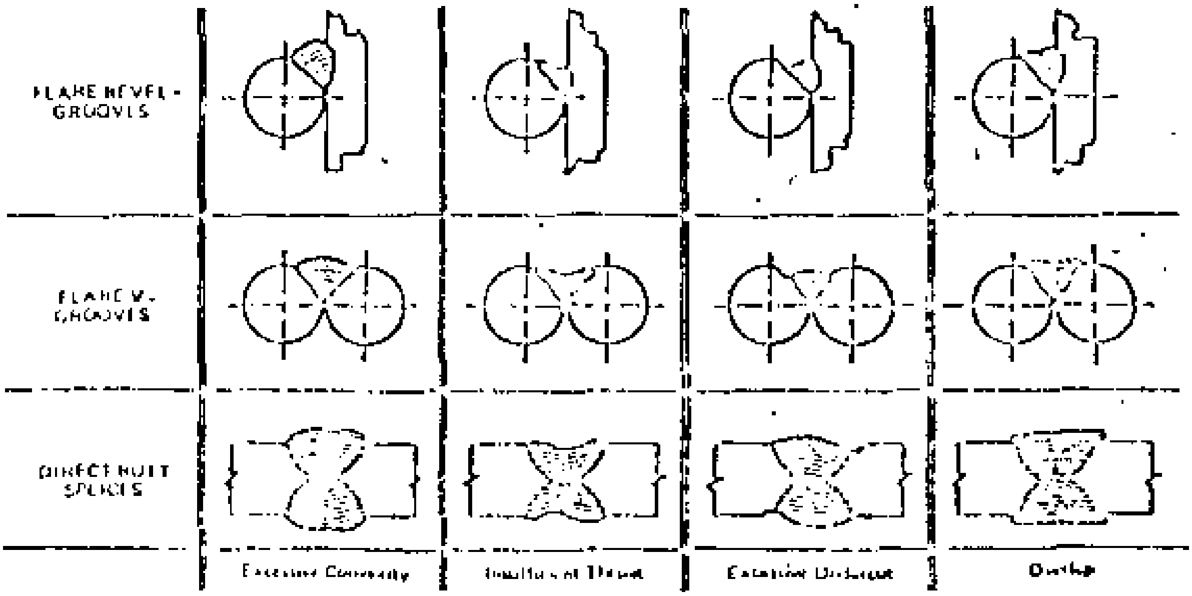


FLARE V-GROOVE

DIRECT BUTT SPLICE

FLARE BEVEL-GROOVE

(E) Acceptable Groove Weld Profiles



Excessive Convexity

Insufficient Throat

Excessive Undercut

Overlap

(F) Unacceptable Groove Weld Profiles

Fig. 4.4 — Acceptable and unacceptable weld profiles

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Tamaño mínimo de soldaduras de filete.

TABLE 1.17.2A

MINIMUM SIZE FILLET WELD

Material Thickness of Thicker Part Joined (Inches)	Minimum* Size of Fillet Weld (Inches)
To ¼ inclusive	⅛
Over ¼ to ½	3/16
Over ½ to ¾	¼
Over ¾	5/16

* Leg dimension of fillet welds.

AIS

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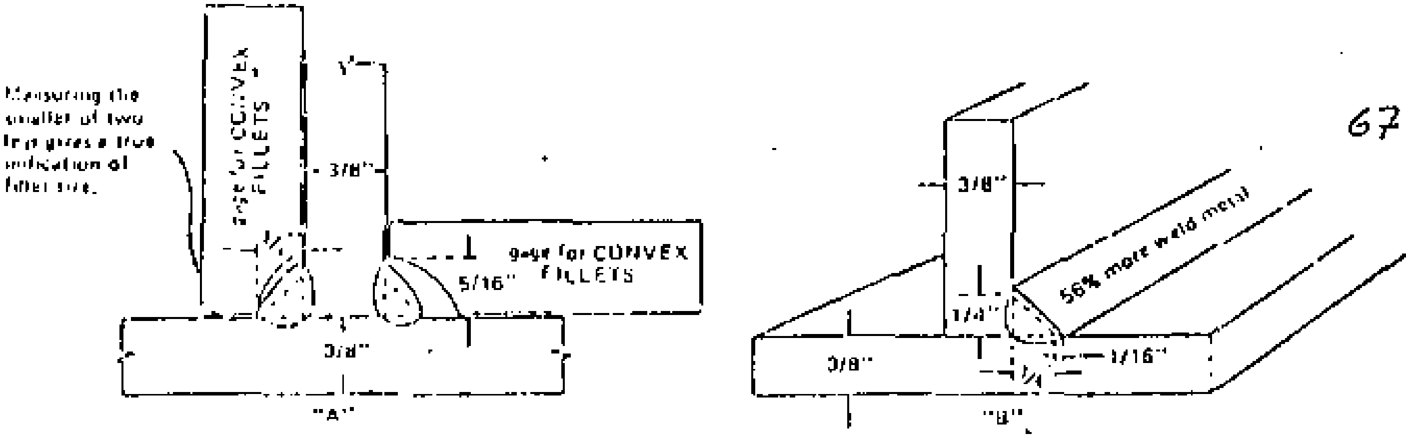
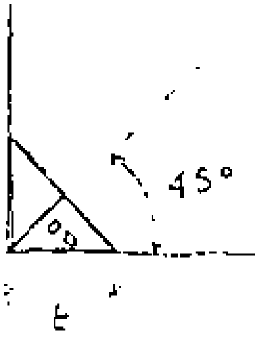


Fig. 11-12. Underwelding is a violation of specifications and cannot be tolerated, whereas overwelding is costly and serves no useful purpose. If 5/16-in. fillet welds were specified in "A", these welds would be undersize. If 1/4-in. fillet welds were specified, these welds would be overwelded. If 1/16 in. were added to both legs, as in "B", the weld volume would increase 56% and increase the cost of welding.

Resistencia de soldaduras de filete:

Fillet Welds		
Shear on effective area v	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	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	

AISC



$g = t \cos 45°$ = garganta efectiv

$P_{ad} = v \cdot 1 \cdot g$

$P_{ad} = 0.707\, t\, v$

Resistencia = $P_{ad} \cdot L$

L = longitud incluyendo retornos

En soldaduras de arco sumergido se puede considerar omo garganta efectiva el tamaño, para soldaduras de enos de 3/8". Para soldaduras de más de 3/8" se puede usar la garganta teórica + 0.11".-

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

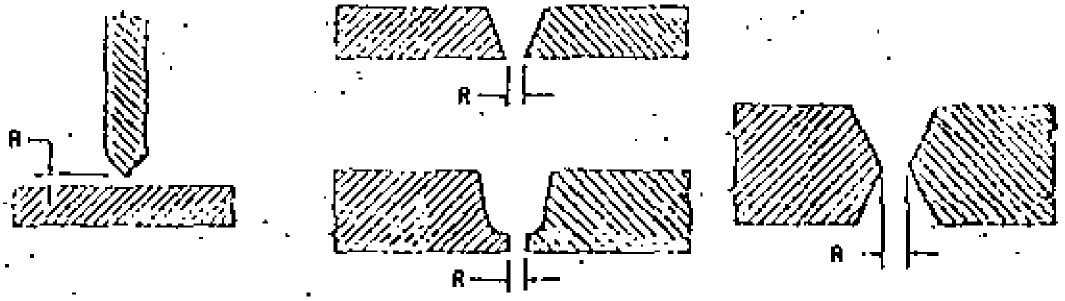
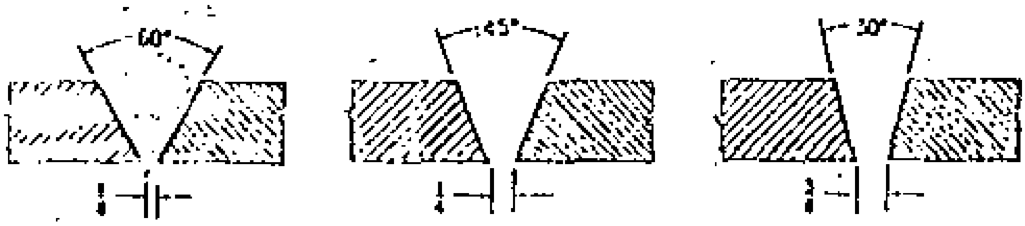


FIGURE 2



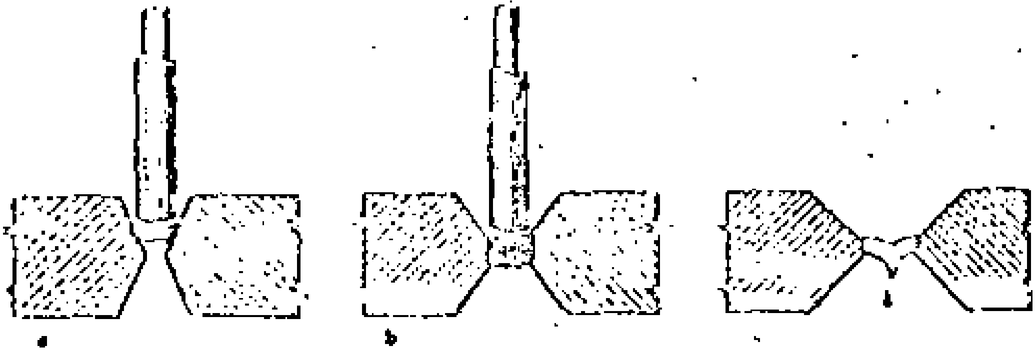
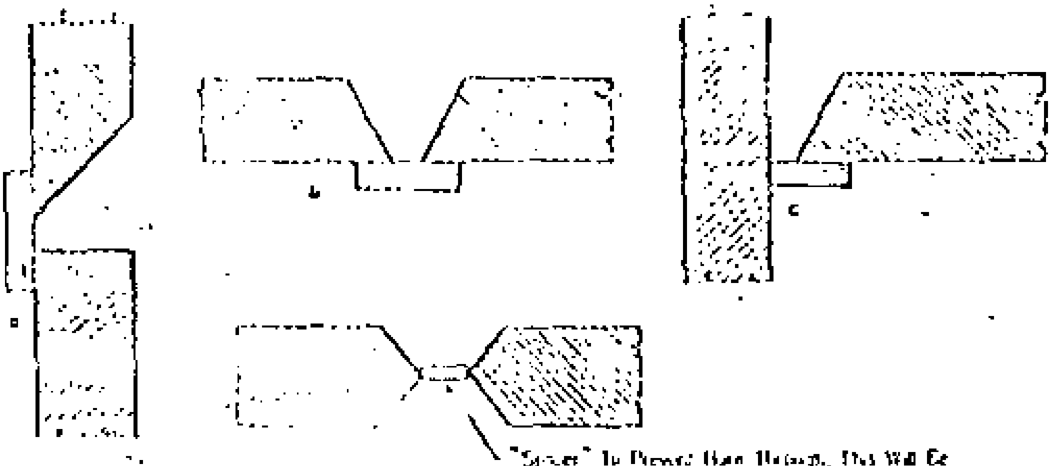


FIGURE 3



"Spacer" To Prevent Burn Through, This Will Be Gouged Out Before Welding Second Side

FIGURE 4

FIGURE 6

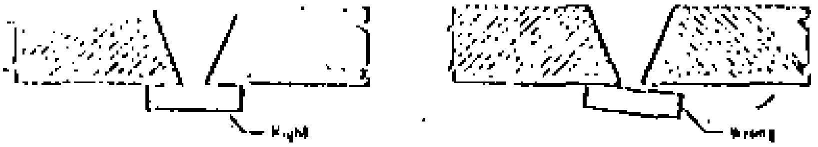


FIGURE 7

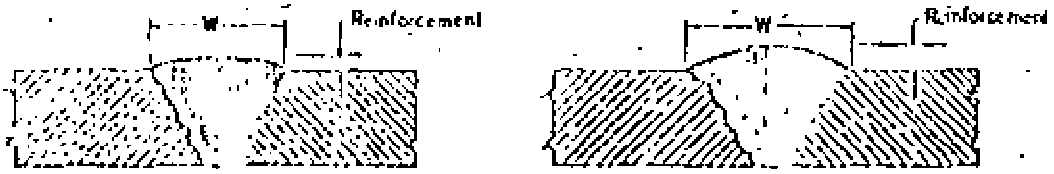


FIGURE 8

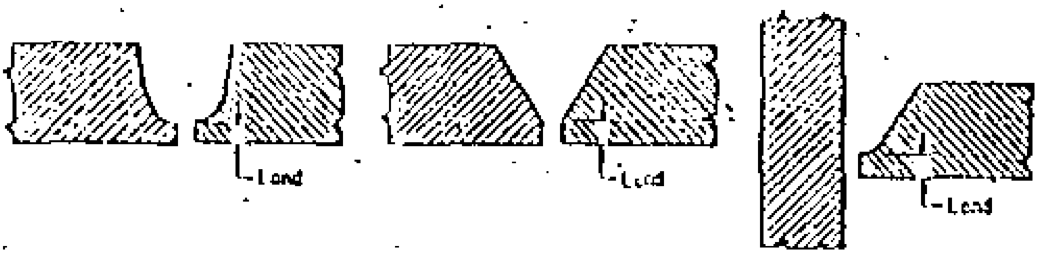


FIGURE 9

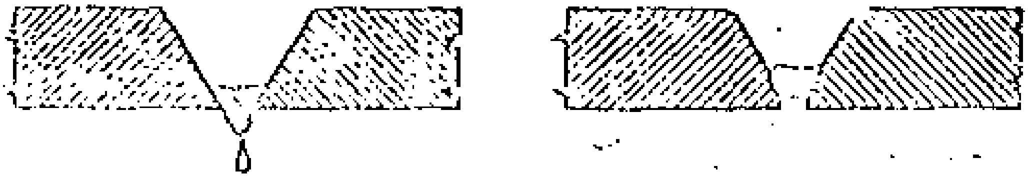


FIGURE 10

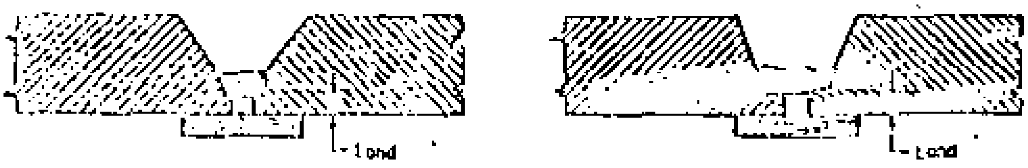


FIGURE 13

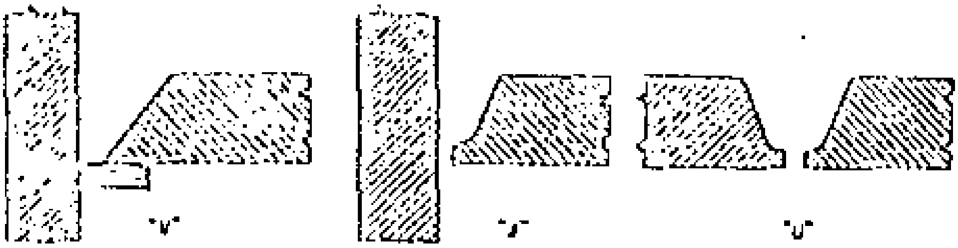


FIGURE 14

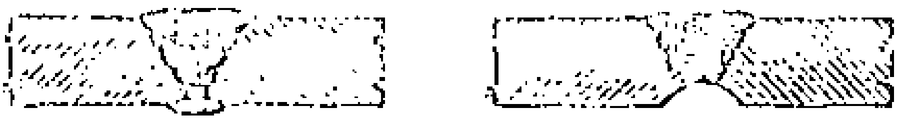
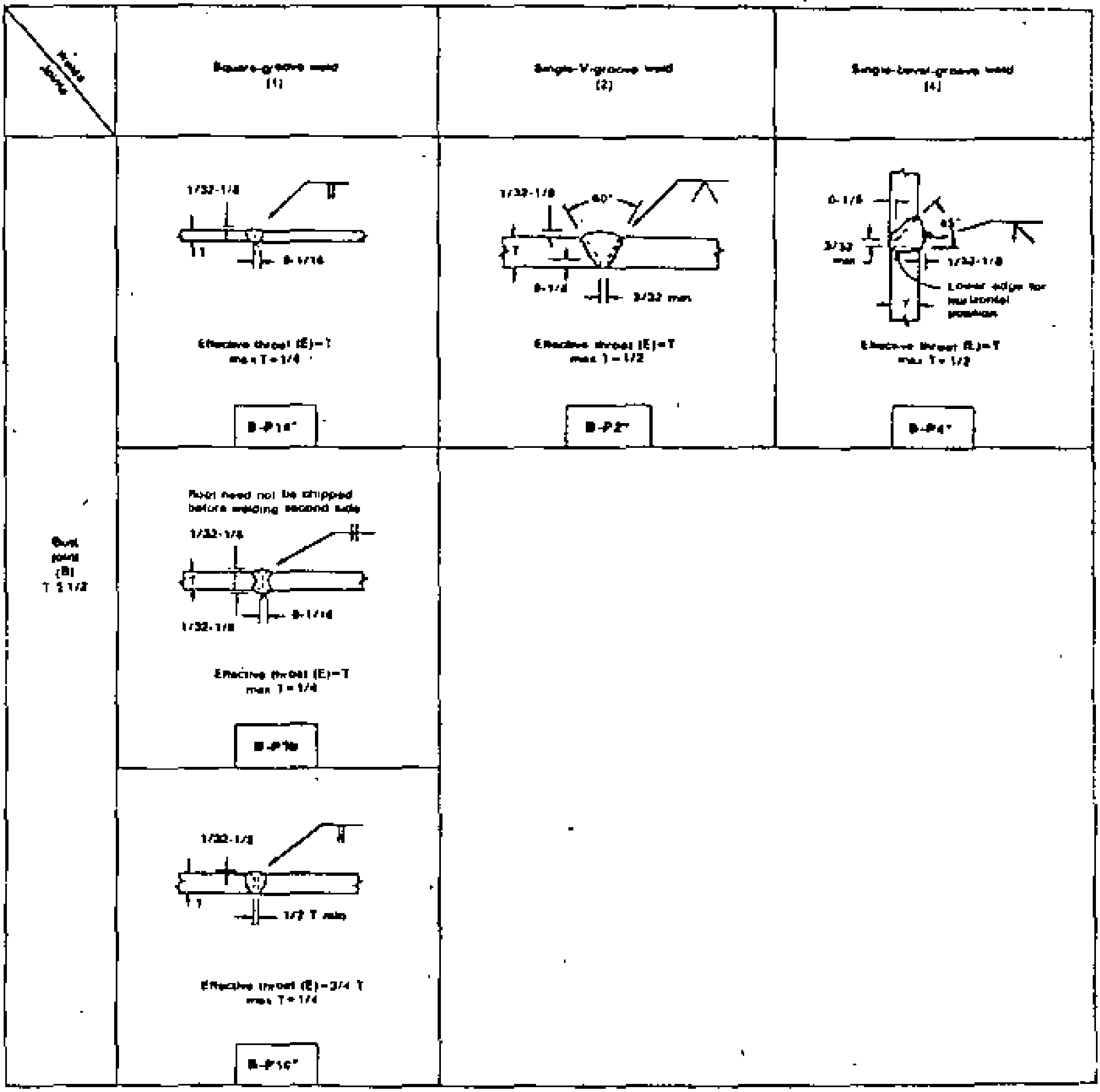


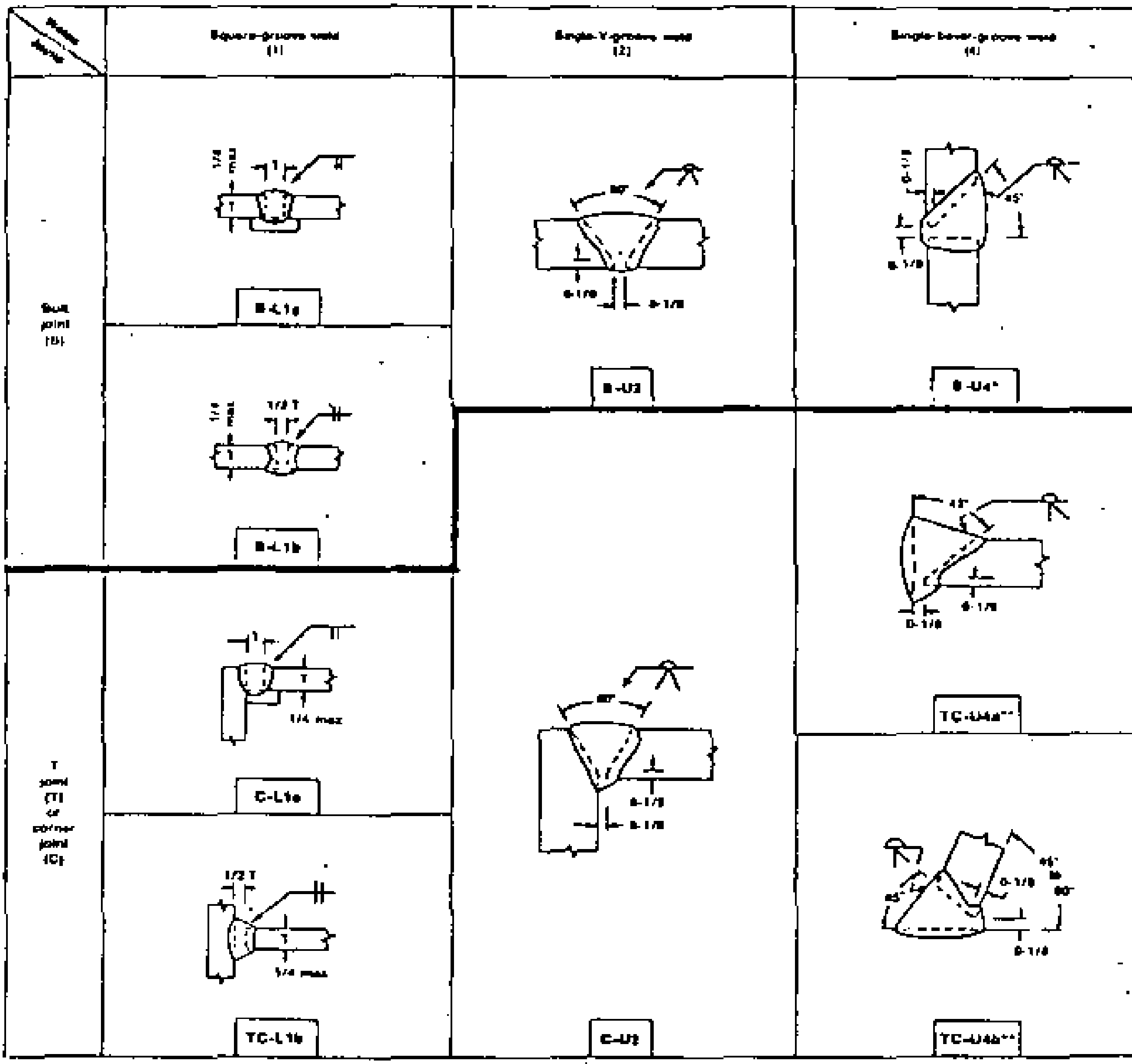
FIGURE 15



† 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.



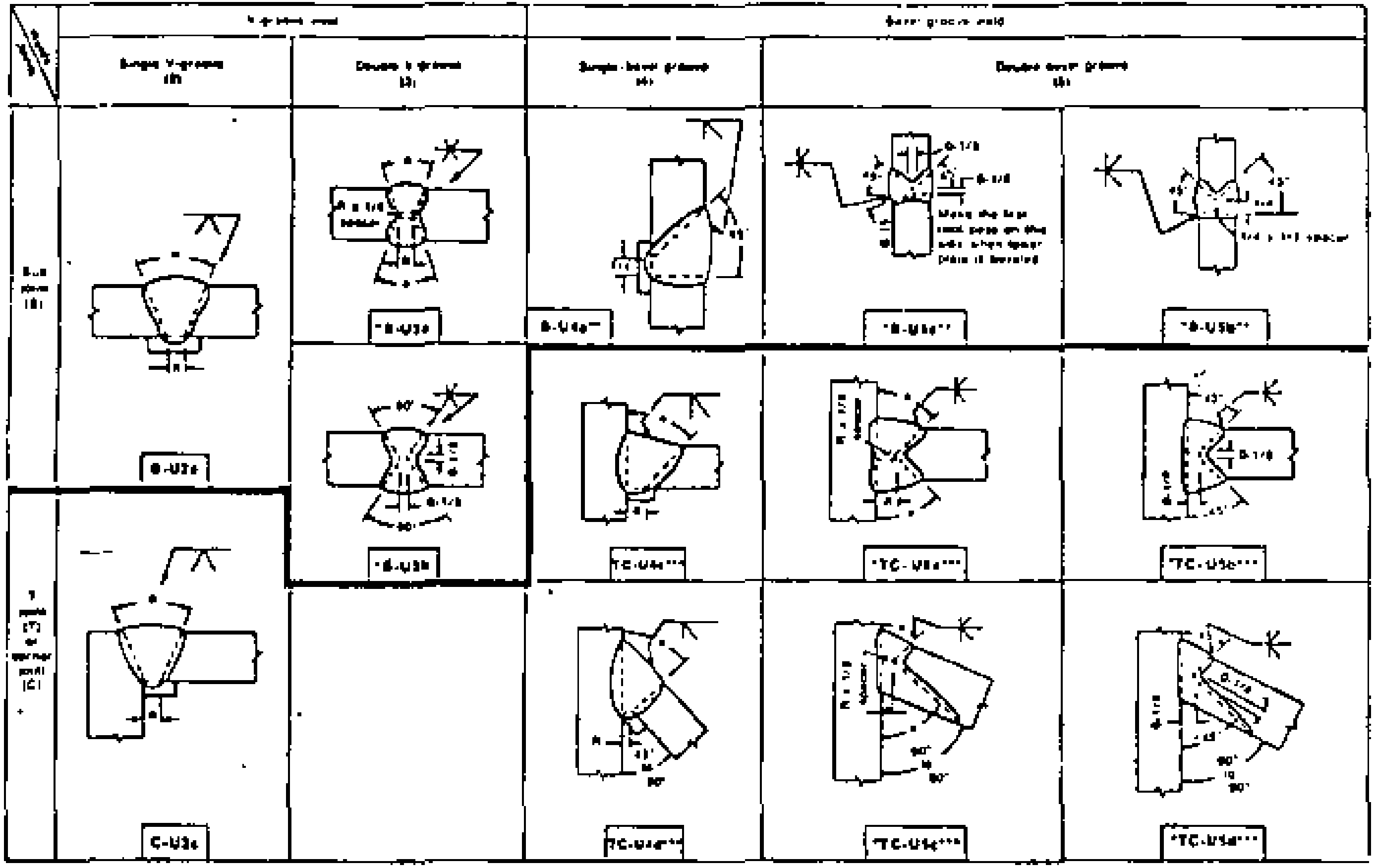
All dimensions in inches.

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, 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 thickn 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 cha 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 th is (L) and unlimited thickness (U)*



Limitations for joints
B-U2a, B-U3a and C-U2a

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

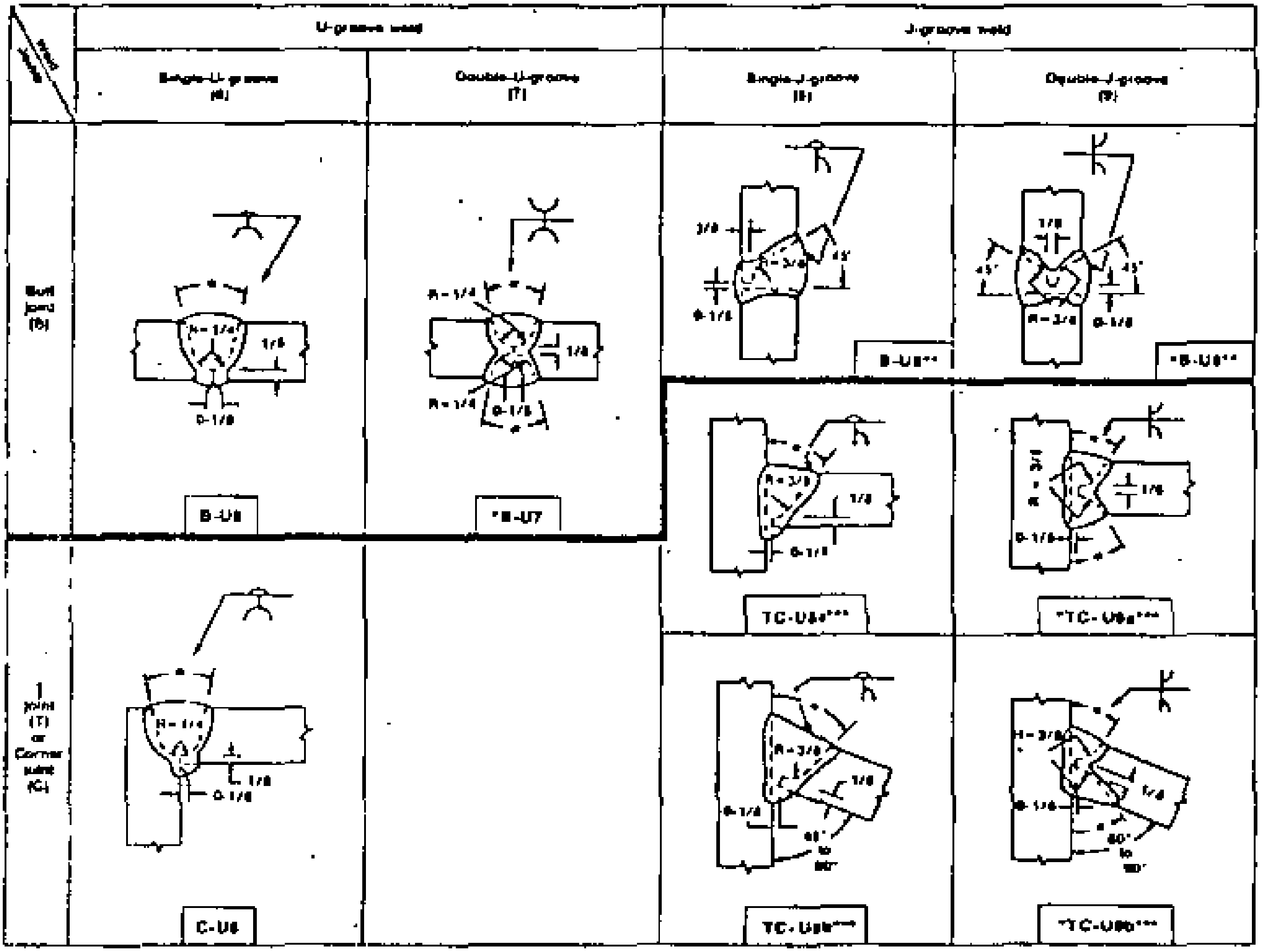
α	R	Permitted welding positions
45°	1/4	All positions
30°	3/8	Flat and overhead only

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 (U).



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.

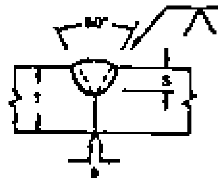
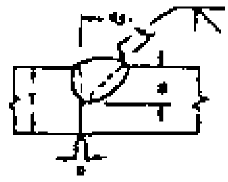
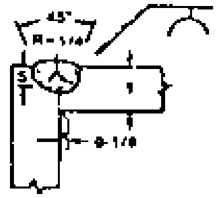
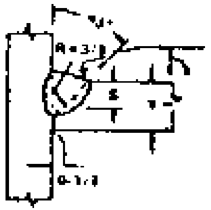
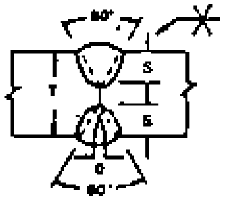
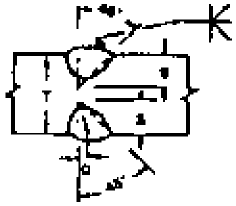
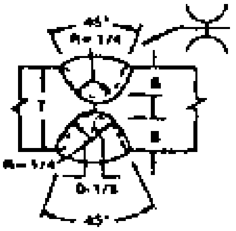
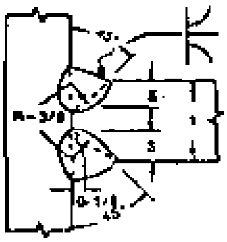
1. Gouge roots of joints without backing before welding other side (See 4.10.8).
2. See 2.9.2 for allowable variation of dimensions and 3.3.4 for workmanship tolerances.
3. If fillet welds are used in buildings to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not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

Welds / Joints		V-groove weld	Bevel-groove weld	U-groove weld	J-groove weld
		Single-V-groove weld (2)	Single-bevel-groove weld (4)	Single-U-groove weld (6)	Single-J-groove weld (8)
Butt (B) T (T) or corner (C) joint	Minimum root face of joint shall be 1/8 in.	 Effective throat (E)=S** BC-P2*	 Effective throat (E)=S—1/8** ***BTC-P4*	 Effective throat (E)=S** BC-P6*	 Effective throat (E)=S** ***BTC-P8*
		Double-V-groove weld (3)	Double-bevel-groove weld (5)	Double-U-groove weld (7)	Double-J-groove weld (9)
		 Effective throat (E)=S** B-P3	 Effective throat (E)=S—1/8** ***BTC-P5*	 Effective throat (E)=S** B-P7	 Effective throat (E)=S** ***BTC-P9*

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 melting.

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[f]	

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 ≥45°	Depth of chamfer minus $\frac{1}{8}$-inch
		≥60°	Depth of chamfer
Gas metal arc or flux cored arc	All	≥60°	Depth of chamfer
	Horizontal or flat	<60° but ≥45°	Depth of chamfer
	Vertical or overhead	<60° but ≥45°	Depth of chamfer minus $\frac{1}{8}$-inch
Electrogas	All	≥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	$\frac{5}{16}R$
Flare-V-groove	All	$\frac{1}{2}R$*

* Use $\frac{3}{8}R$ for Gas Metal Arc Welding (except short circuiting transfer process) when $R \geq 1$ inch.

La distancia entre piezas que han de soldarse de filete, no será mayo 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 } For electrodes 3/16 in. and under, except 5/32 in. and under for classi-
OH = Overhead } fications 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	Silicon	Nickel	Chromium	Molybdenum	Vanadium
7014, E7015 7016, E7018 7024, E7028	1.25*	0.90	0.30*	0.20*	0.30*	0.08*
5010, E6011 5012, E6013 5020, E6027	No chemical requirements					

* The sum total of all elements with the asterisk shall not exceed 1.60 per cent.

[a] For obtaining the chemical composition, dc, straight polarity only, may be used where ac, both polarities, is specified.

ILA COMPARATIVA DE ELECTRODOS PARA SOLDAR

SEGUN VARIOS FABRICANTES

ESPECIFICACION AWS	A.O. SMITH	AGA ARTIC	CHAMPION	ELLIS	GENERAL ELECTRIC	HOBART	LINCOLN	P & H	WESTING HOUSE
E-6010	SW 14	FERROMATIC 10	DIABLO AZUL	6010	W 610 A	10	FLEET WELD 5	AP 100	XL 610
E-6011	SW 10	FERROMATIC 11	DIABLO AZUL ALTERNO	6011	W 611 A	335	FLEET WELD 35	ACI	ACP 611
E-6012	SW 11 SW 12	FERROMATIC 12	DIABLO GRIS No. 2	6012	W 612 A	12	FLEET WELD 7	PFA 612 P	FP 6012 FP 1417
E-6013	SW 15 SW 16	FERROMATIC 13	DIABLO LIGERO	6013	W 613 A	13	FLEET WELD 47	AC 613	SW 613 SW 7 M
E-7018	SW 21	CELLOCORD 70	DIABLO AZUL 45	7018	W 718 A	[illegible]	SHIELD ARC 85	CM 4	AP MO
FIERRO VACIADO	SW 5	SETEC ARC 17		435	W 41	HARCAST	FERROWELD	HARCAST	CASTING WELD
RECUBRIMIENTOS DUROS	SW 305 B	CITO-MANGAN	DIABLO DE MANGANESO	700		[illegible] MANGANOL	MANGAN WELD	HARMO MANGA	
	SW 111 B			721		V MANGANIK	MANGAN WELD AC	HARNI MANGA	
	D WELD B	SUEMEX 250		370	W 35	TUFANHARD 350	ABRASO WELD	HARTOP BROWN	HARDEN TOUGH 350
	D WELD E	SUEMEX 450	DIABLO DURO	360	W 11	TUFANHARD 400	FACEWELD 1	HARTOP RED	HARDEN TOUGH 450
	D WELD F	SUEMEX 600	DIABLO RESISTENTE	370	W 35	TUFANHARD 600	FACEWELD 12	HARTOP YELLOW	HARDEN TOUGH 550

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				
End Color / Spot 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		

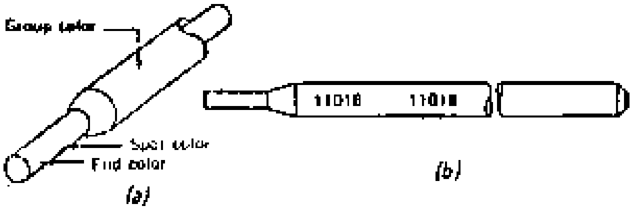


Fig. 4-1. (a) National Electrical Manufacturers Association color code method to identify an electrode's classification; (b) American Welding Society imprint method.

Starting in 1964, AWS new and revised specifications for covered electrodes required the classification number be imprinted on the covering, as i Fig. 4-1(b). However, some electrodes can be man factured faster than the imprinting equipment ca mark them and some sizes are too small to be legibl marked with an imprint. Although AWS specifies a imprint, the color code is accepted on electrodes i 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 E6015 and E6016										
End Color / Spot 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	...
E8018-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 b consulted before conducting any tests.

Radiographic requirements are shown in Tabl 4-9. Grade I has fewer and smaller porosity tha Grade II. The radiographic standards can be foun 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	70,000	57,000	22
E7011-X			22
E7015-X			25
E7016-X			25
E7018-X			25
E7020-X			25
E7027-X			25
E8010-X	80,000	67,000	19
E8011-X			19
E8013-X			16
E8015-X			19
E8016-X			19
E8018-X			19
E8016-C3 E8018-C3	80,000	68,000 to 80,000	24
E9010-X	90,000	77,000	17
E9011-X			17
E9013-X			14
E9015-X			17
E9016-X			17
E9018-X			17
E9018-M	90,000	78,000 to 90,000	24
E10010-X	100,000	87,000	16
E10011-X			16
E10013-X			13
E10015-X			16
E10016-X			16
E10018-X			16
E10018-M	100,000	88,000 to 100,000	20
E11015-X	110,000	97,000	15
E11016-X			
E11018-X			
E11018-M	110,000	98,000 to 110,000	20
E12015-X	120,000	107,000	14
E12016-X			
E12018-X			
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 4-13. 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 F61-XXXX[c] F62-XXXX[c] F63-XXXX[c] F64-XXXX[c]	62,000 to 80,000	50,000	22[d]	Not required 20 ft/lb at 0°F 20 ft/lb at −20°F 20 ft/lb at −40°F 20 ft/lb at −60°F
F70-XXXX F71-XXXX[c] F72-XXXX[c] F73-XXXX[c] F74-XXXX[c]	72,000 to 95,000	60,000	22[e]	Not required 20 ft/lb at 0°F 20 ft/lb at −20°F 20 ft/lb at −40°F 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	50,000	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 4-11. 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				0.035	0.03	0.15	0.50
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				
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 minimum mechanical-property requirements.

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

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 4-15. AWS A5.20-69 Impact-Property Requirements for Flux-Cored Arc-Welding Weld Metal

AWS Classification	Minimum V-Notch Impact Requirement [a]
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

[a] 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	0.80 to 1.40	0.30 to 0.50	0.025	0.035							
E70S-2	0.06		0.40 to 0.70							0.05 to 0.15	0.02 to 0.12	0.05 to 0.15
E70S-3	0.06 to 0.15		0.45 to 0.70									
E70S-4	0.07 to 0.15		0.65 to 0.85									
E70S-5	0.07 to 0.19		0.30 to 0.60									0.50 to 0.90
E70S-6	0.07 to 0.15	1.40 to 1.85	0.80 to 1.15									
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 0.20 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 x 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).

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

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 4-21. 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 0.50	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 0.20 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 (0.062), 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
ECuA1-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 Chemical requirements for the nickel base electrodes are based on deposited weld metal analysis

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		Aluminum, percent
										Each	Total	
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
ER5183	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 33.

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 continuous 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	0.75 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	...	...	...	0.60	...	...	...	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 2.0	...	...	...	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 0.50	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 version 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	0.60	...	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	0.8 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 4.75	...	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	0.60 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.

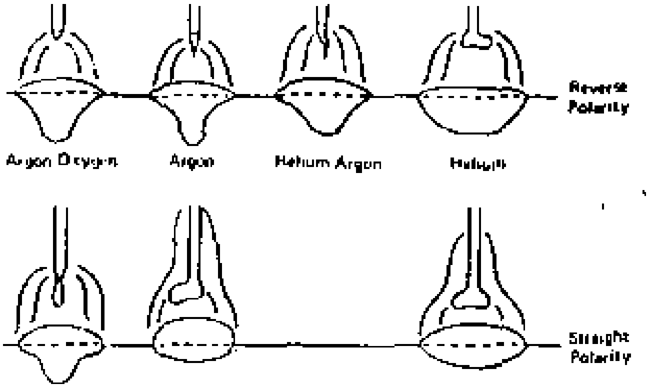


Fig. 4-2. Electrode tip shape, bead contour, and penetration patterns for various shielding gases

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 anu 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 mus' 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.

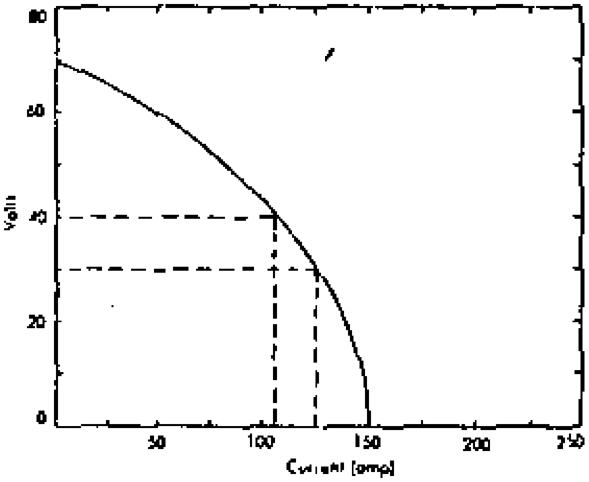


Fig. 4-3. Typical output curve for a variable-voltage power source, adjusted for minimum current variation.

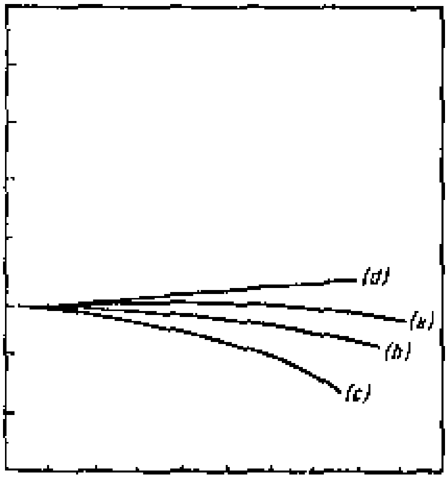


Fig. 4-4. Typical output curves for a constant voltage power source

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. Thi problem, however, has been solved by designir better transient characteristics in the welder and 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

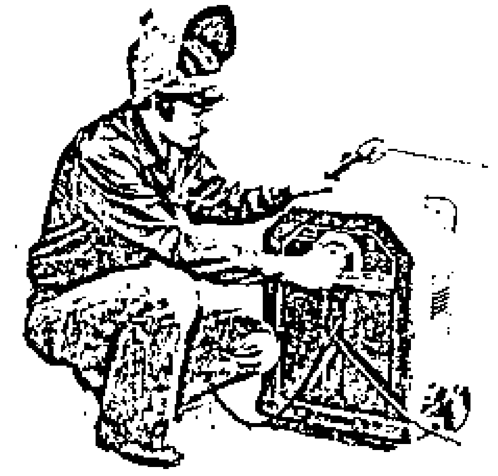


Fig. 4-5. A typical small AC transformer welder for light-duty and limited-service welding

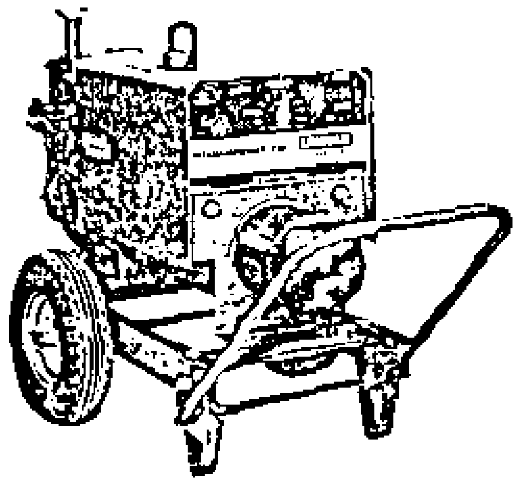


Fig.4-6. A typical engine-driven power source that supplies AC current for welding or power for lights and tools.

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	200-1750

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

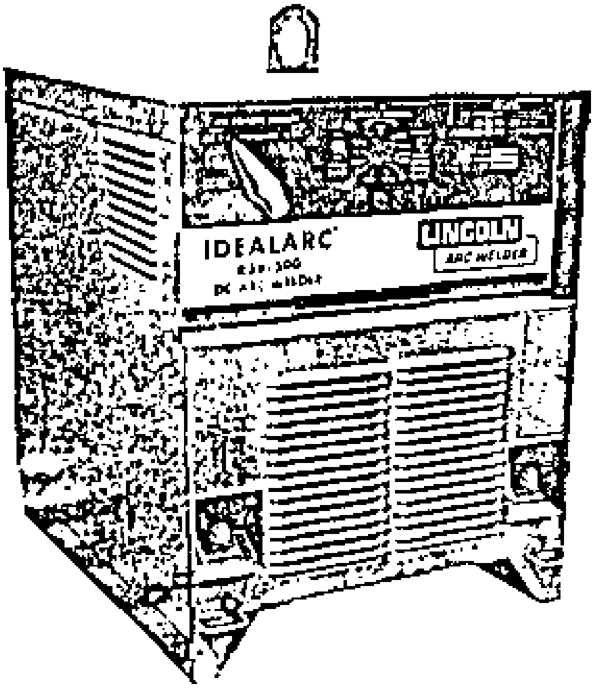


Fig. 4-7. A typical industrial type AC three-phase input, DC output variable voltage welder. The heavy duty welders are available in a wide range of sizes, see Table 4-36.

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.

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	60-850	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	60- 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

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

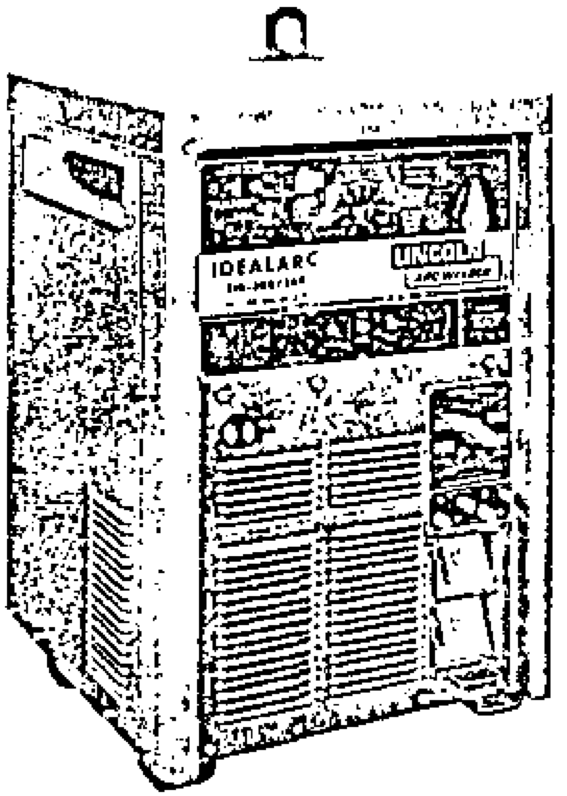


Fig. 4-8. An AC-DC transformer-rectifier welder designed for gas tungsten-arc welding.

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.

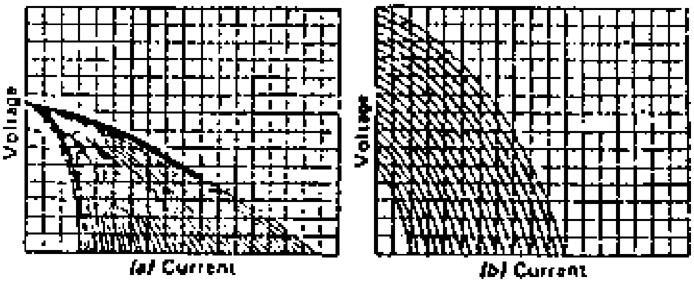


Fig. 4-9. Output for a DC generator welder having adjustments in both the series and shunt fields. Output curves produced by adjusting the series field are shown in (a); curves produced by adjusting the shunt field are shown in (b).

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

produces an output change as shown in Fig. 4-9(a), and is sometimes called the "current" control.

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).

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.

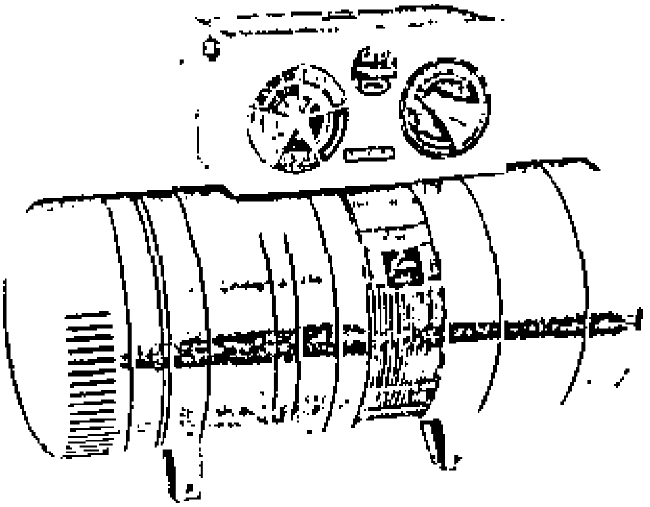


Fig. 4-10. A typical motor generator welder.

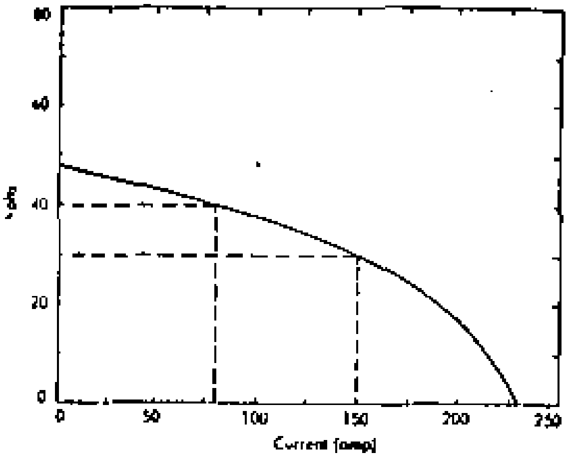


Fig. 4-11. Typical output curve preferred for vertical and overhead shielded metal-arc welding.

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.

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	80	. . .	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.

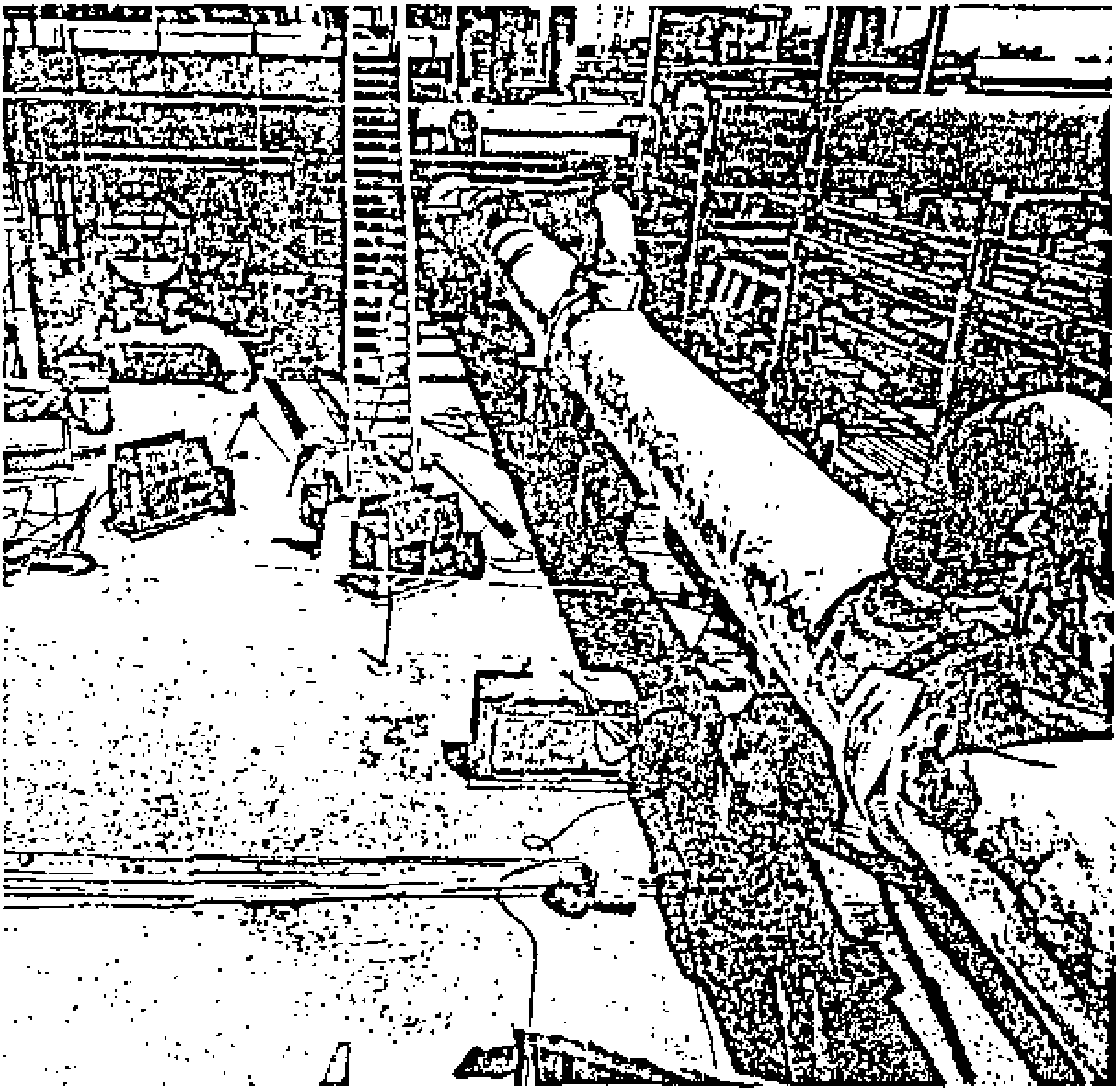
There is one best way for every welding job. Sometimes it is AC; sometimes it is DC. For one job, sensitive control may be required for maximum efficiency. For another, certain types of controls may be unnecessary. A welder should be selected, therefore, according to the job to be done.

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. 4-5 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 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.

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.

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

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*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 0.30-0.50
51XX	Cr 0.70-1.15
E51100	C 1.00; Cr 0.80-1.15
E52100	C 1.00; Cr 0.90-1.15
61XX	Cr 0.50-1.10, Va 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.

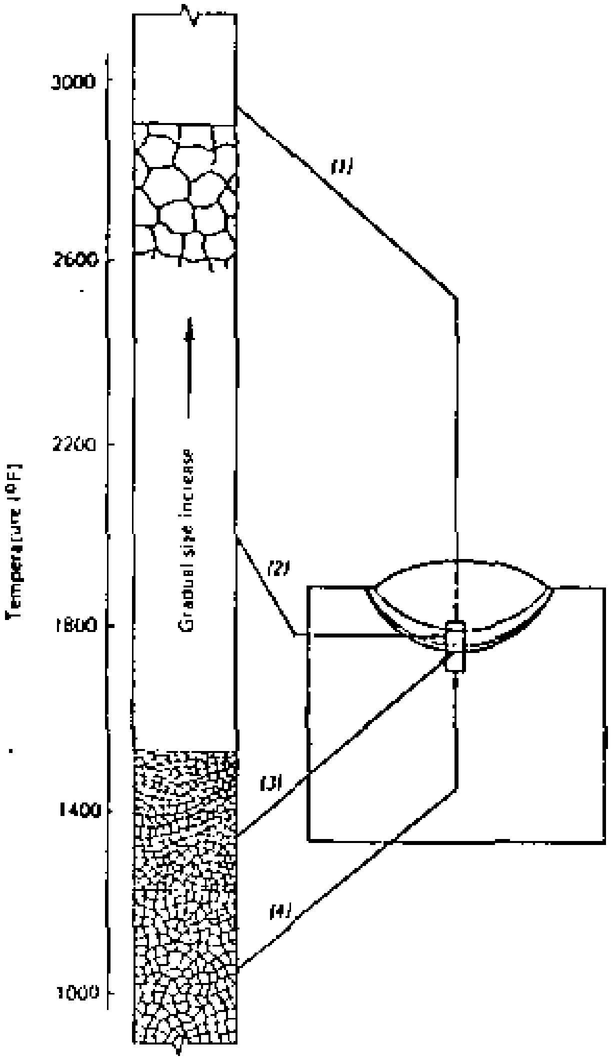

Fig. 6-2. Effect of welding heat on hardness and microstructure of an arc-welded 0.25% carbon steel plate. The schematic diagram represents a strip cut vertically through the weld shown. Significance of the four numbered zones are: 1. Metal that has been melted and resolidified. Grain structure is coarse. 2. Metal that has been heated above the upper critical temperature (1525°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°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

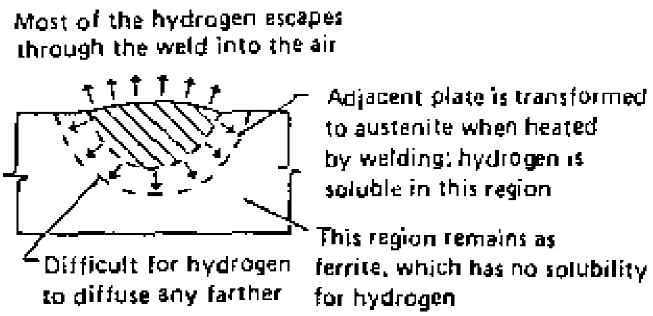

Fig. 6-3. Austenitic heat-affected zone of a weld has high solubility for hydrogen. Upon cooling, the hydrogen builds up pressure that can cause underbead cracking.

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 that appear on the plate surface adjacent to the weld are called "toe cracks."

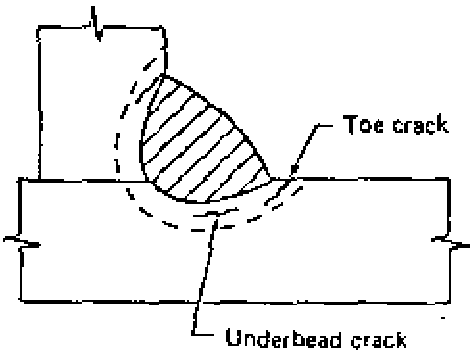

Fig. 6-4. Underbead cracking and toe cracks caused by hydrogen pickup in heat-affected zone of plate

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 on 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

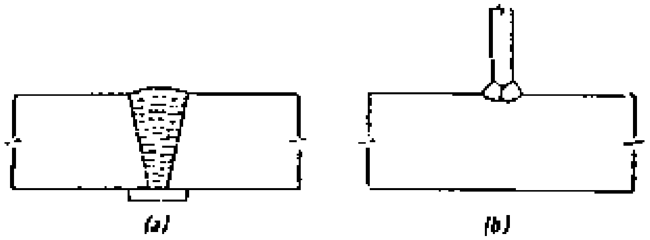

Fig. 6-5. A groove-welded butt joint in thick plate (a) requires a higher preheat, because of joint restraint, than a fillet-welded joint of a thin member and a thick plate (b). See Section 2.3 for the minimum size weld required by AWS.

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 (Fi 6-5).

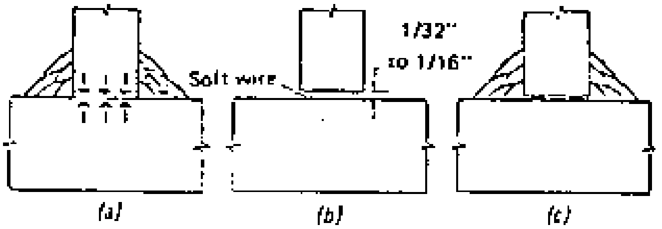

Fig. 6-6. In a restrained joint in thick plates (a), all shrinkage stress must be taken up in the weld. Separating the plates with soft wires (b) allows the plates to move slightly during cooling. The wires flatten (c) and remove most of the stress from the weld metal.

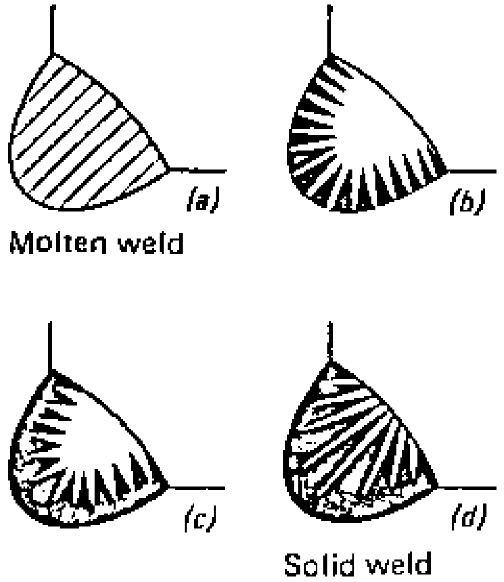

Fig. 6-7. A molten fillet weld (a) starts to solidify along the sides ne to the plate (b). Solidification proceeds as shown in (c) and (d).

The Effect of Joint Restraint

If metal-to-metal contact exists between thic 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 th weld, as illustrated in Fig. 6-6(a). This restraint ma cause the weld to crack, especially in the first pa on the second side of the plate.

Joint restraint can be minimized by providing space of 1/32 to 1/16 in. between the two membe to allow movement during cooling. Such spaces gaps can be incorporated by several simple mean

1. Soft steel wire spacers may be place between the plates, as in Fig. 6-6(b). Th wire flattens out as the weld shrinks, shown in Fig. 6-6(c). (Copper wire shoul not be used because it may contaminate th weld metal).
2. Rough flame-cut edges on the plate. Th peaks of the cut edge keep the plates apar yet can deform and flatten out as the wel shrinks.
3. Upsetting the edge of the plate with a heav center punch. Results are similar to those the flame-cut edge.

Provision for a space between thick plates to b welded is particularly important for fillet welds.

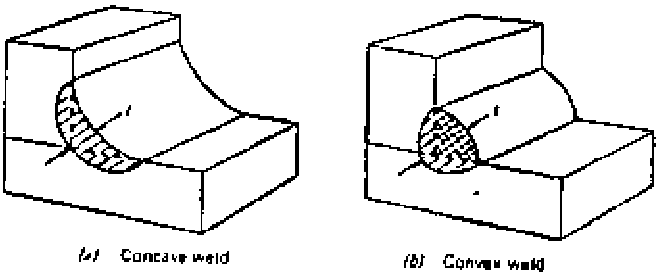

Fig. 6-8. The leg size and the surface of a concave fillet weld (a) may be larger than that of a convex bead (b), but its throat, t, may be considerably smaller.

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.

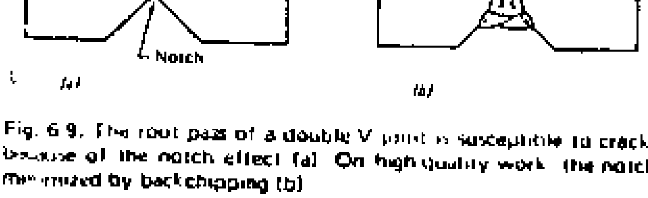

Fig. 6-9. The root pass of a double V joint is susceptible to cracking because of the notch effect (a). On high quality work, the notch is minimized by backchipping (b)

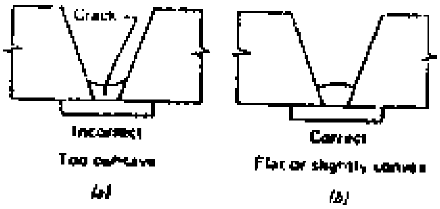

Fig. 6-10. A concave root pass (a) may crack because tensile stresses exceed the strength of the weld metal. A slightly convex root-pass bead (b) helps prevent cracking

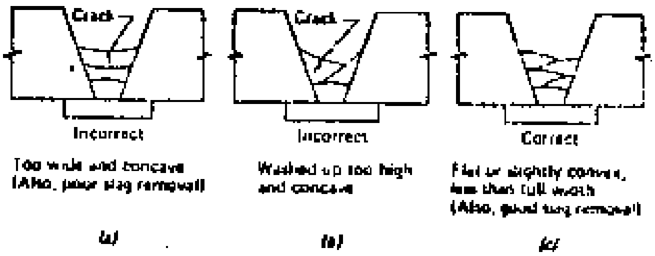

Fig. 6-11. Wide, concave passes (a and b) in a multiple pass weld may crack. Slightly convex beads (c) are recommended

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.

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-

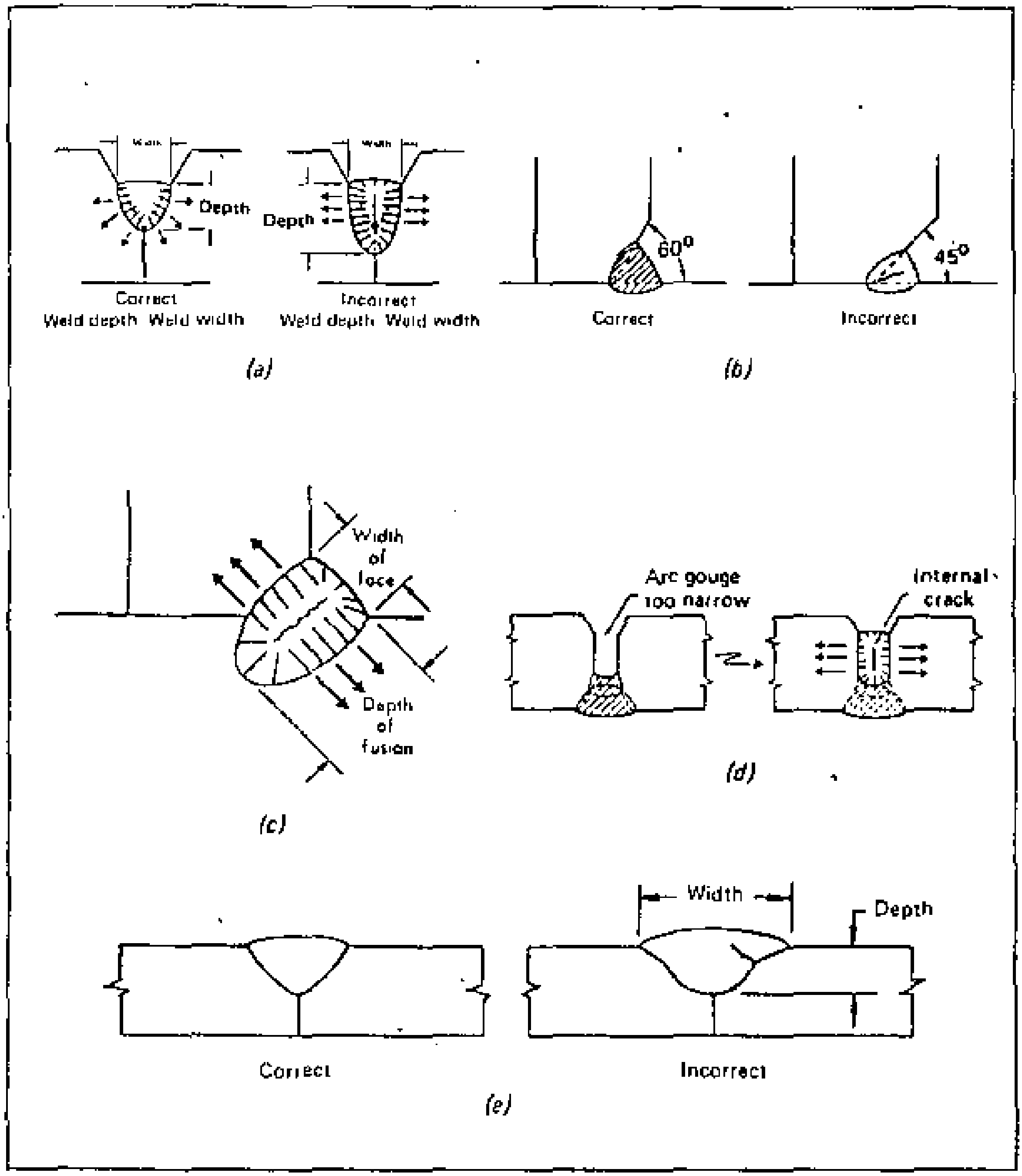

Fig. 6-12. Internal cracking can occur when weld penetration is greater than width. Correct and incorrect proportions are shown in (a), (b), and (c). Arc gouging a groove too narrow for its depth can cause a similar internal crack (d). Cracks can also occur when depth is too shallow (e). Width of a weld 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.

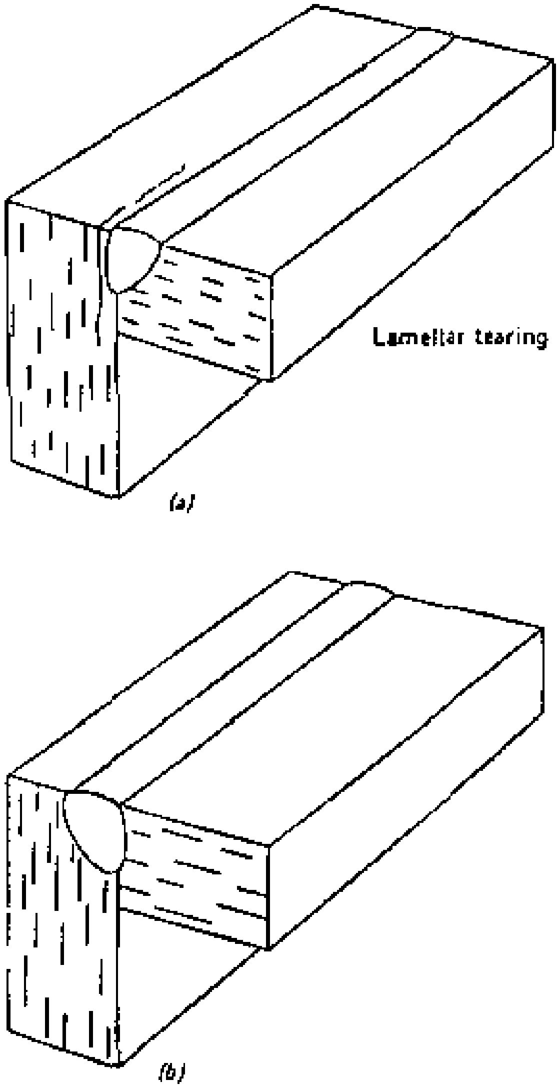

Fig. 6-13. Lamellar tearing (a) and a suggested solution (b).

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, Barty, 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.

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.

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	0.070	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
1071	0.18-0.23	0.60-0.90	0.040	0.050
1022	0.18-0.73	0.70-1.00	0.040	0.050
1023	0.20-0.75	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
1048	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
1076	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
1085	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

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
1060	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)

A36 ASTM GRADE and Descriptive Information	Mechanical Properties			Material Shape	Thickness Group Or Grade	Chemical Requirements (Ladle) Percent						
	Tensile Strength (ksi min.)	Yield Point (ksi min.)	Elongation in 2 in. % min			C Max.	Mn† Max.	P Max.	S Max.	Si †	Cu Min.	V Min.
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	21		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		over 1-1/2 to 2-1/2incl	0.26	0.80 - 1.20	0.04	0.05	0.15 - 0.30	0.20*	
	58 to 80	36	21		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		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	21		over 3/4" to 1-1/2" incl	0.27	0.60 - 0.90	0.04	0.05		0.20*	
	58 to 80	36	21		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 (electric resistance or seamless) (only chemistry limit is phosphorous)	60 min.	35	**		B			**				
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	**		over 3/4 to 1-1/2 incl	0.22	1.25		0.05			
(other alloying elements may be added) If Cmax 0.15, Mn$_{max}$ can be raised to 1.40	63 min	42	24		over 1-1/2 to 4" incl	0.22	1.25		0.05			
	70 min	50	**	Struc Shapes	I	0.22	1.25		0.05			
	67 min	46	**		II	0.22	1.25		0.05			
	63 min	42	24		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	**		over 3/4" 1-1/2" incl	0.22	.85 - 1.25	0.04	0.05	0.30	0.20	0.02
	63 min	42	24		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		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	**		II	0.22	.85 - 1.25	0.04	0.05	0.30	0.20	0.02
	63 min	42	24		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		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		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			0.27	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)
			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	1.65	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	Plates And Bars	to 4" incl	70 min	50	21	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	-	-	-
		over 4" to 5" incl	67 min	46	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	-	-	-
		over 5" to 8" incl	63 min	42	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	-	-	-
	Shapes	Group 1,2,3,4	70 min	50	19	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
		Group 5	67 min	46	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	-	-	-
						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 .0015-.005
		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	0.01-0.08		-	B .002-.006
		over 2 1/2" to 4" incl	105 to 135	90	17														

A572: Alloy content shall be in accordance with one of the following –

(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 only in combination with 0.15 min Si shall be restricted to plate or bar thickness of 1/2" max. and to shapes of Table A, Group I of Spec A6.
(5) Si (0.40 max) for shapes and plates to 1 1/2"; for grade 42 plates over 1 1/2" (0.15 – 0.30 max).

† Where two figures are given this is a min and 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 these 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.*

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* 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	138	176	any	any
350°F	15	21.5	43.5	73.5	109.5	151	any	any
400°F	13	19	40	65	93	127	166	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 keyhol 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.

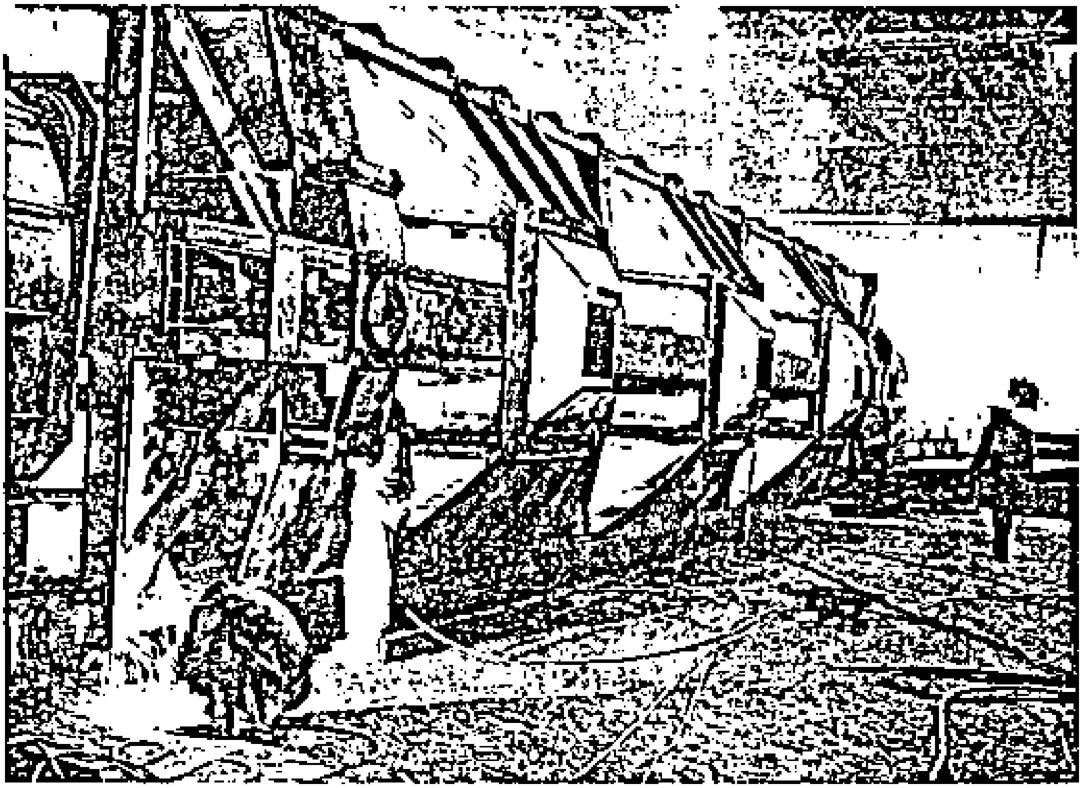
Where molybdenum is added to base metals to increase the resistance to creep at elevated temperatures, the electrode deposit must have a similar amount of molybdenum.

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 – 600	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	500 – 600
8620	100 min	200 – 300	250 – 350
8630	200 – 300	250 – 350	400 – 600
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

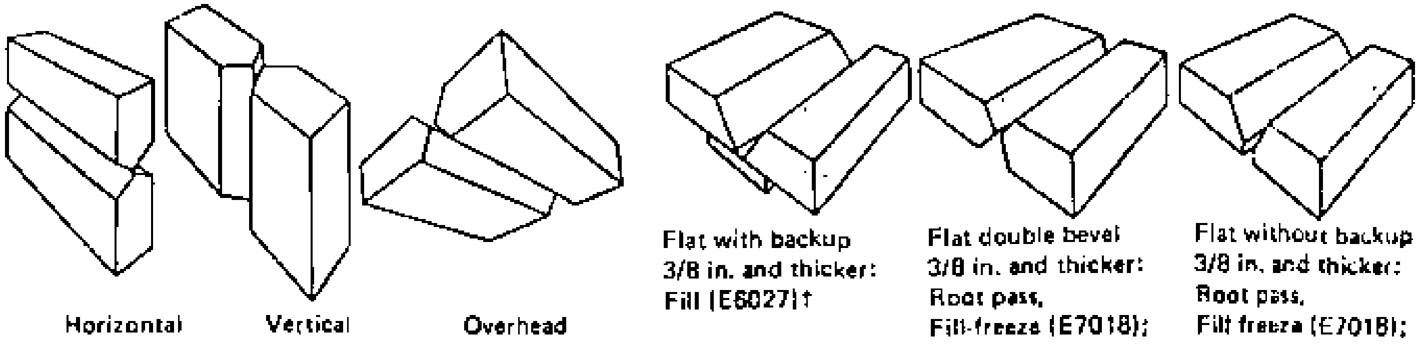
Choice of electrode is straightforward when welding high-strength or corrosion-resistant steels. Here, choice is generally limited to one or two electrodes designed specifically to give the correct chemical composition in the weld metal. But most arc welding involves the carbon and low-alloy steels for 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	26	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	66,000	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	160 – 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	280 – 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	300 – 500	375 – 475	375 – 470	400 – 525*

*These values do not apply to the E7028 classification.

FILLET AND CORNER WELDS'

Fillet welds over 10 to 12 in. in length on 3/16-in. or thicker plate

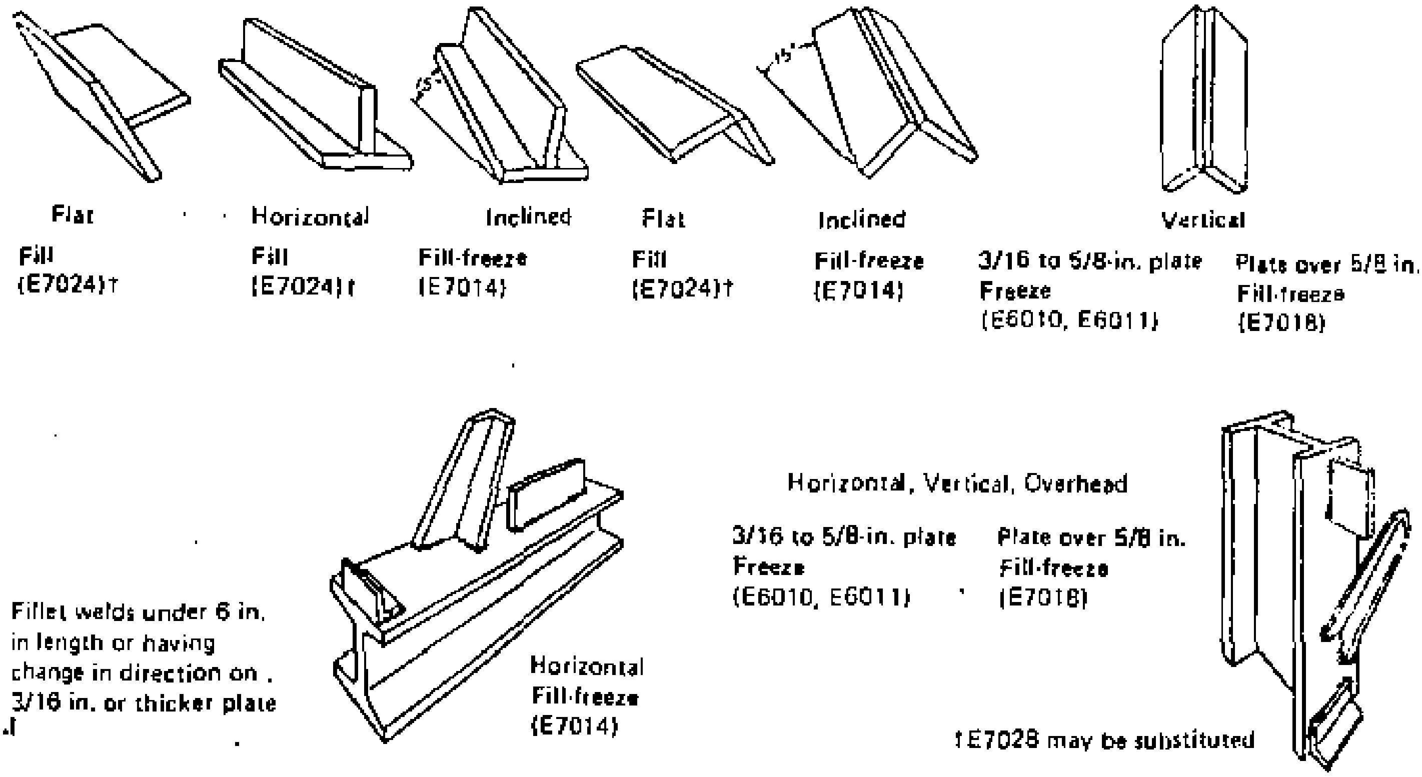


Fig. 6-15. Guide to selection of electrodes for fillet and corner welds.

SHEET METAL JOINTS

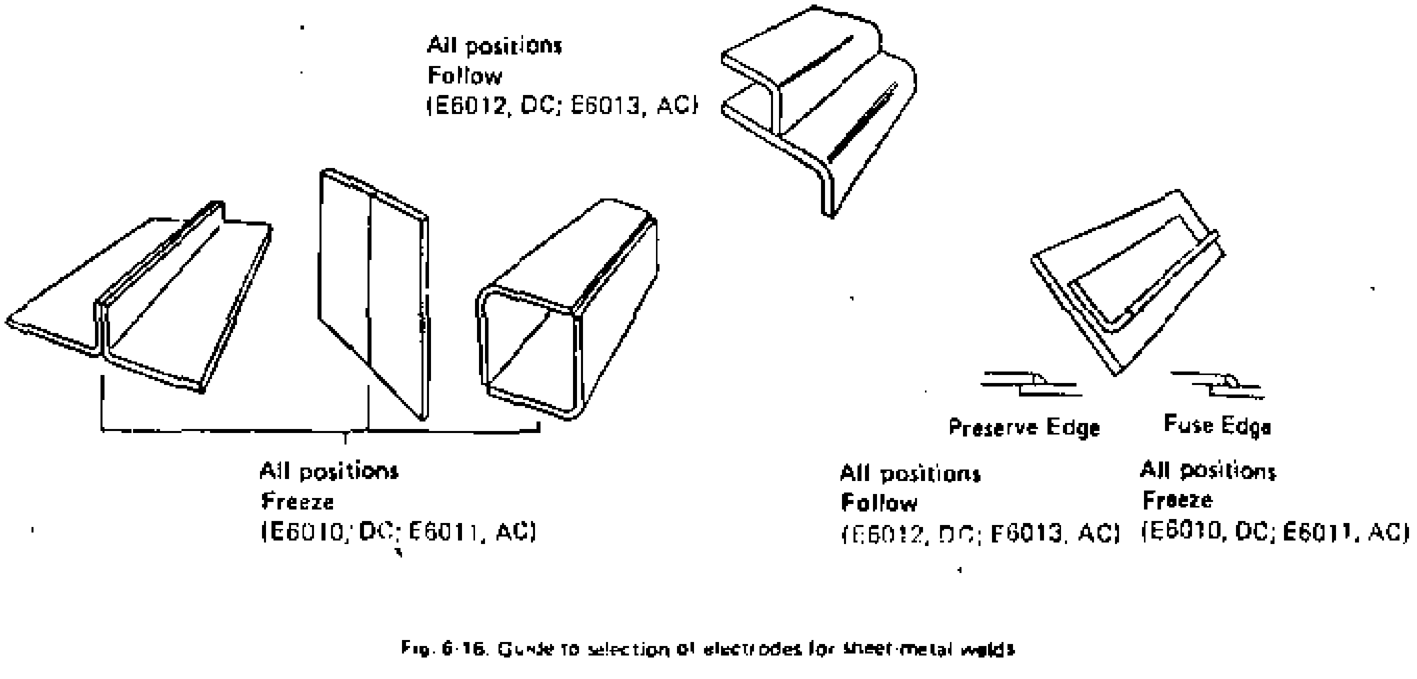


Fig. 6-16. Guide to selection of electrodes for sheet-metal welds

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

Continue

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-C
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 – vessel plate	55 & 60	E7018 or E7028
		65 & 70	E7018 or E9018-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
F369-73a	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 E8010 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, using a technique similar to those described for first-pass vertical-up welds.

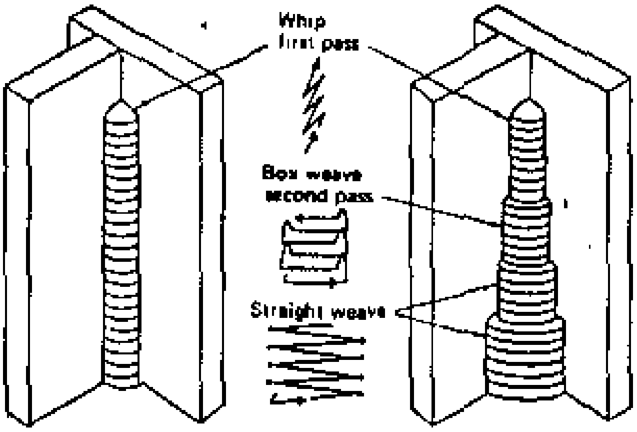


Fig. 6-17. Technique for vertical welding with fast-freeze electrodes.

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.

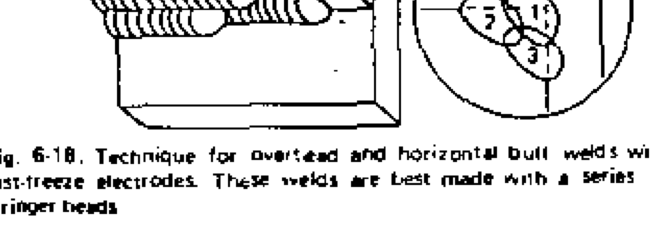


Fig. 6-18. Technique for overhead and horizontal butt welds with fast-freeze electrodes. These welds are best made with a series of stringer beads.

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. Do not exceed the center of the range if the weld is to be of X-ray quality.

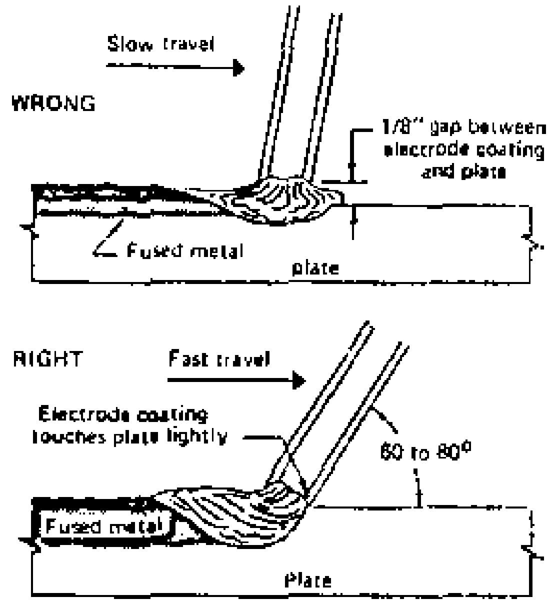


Fig. 6-19. Technique for flat welds with fast-fill electrodes. An incorrect technique is included for comparison.

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.

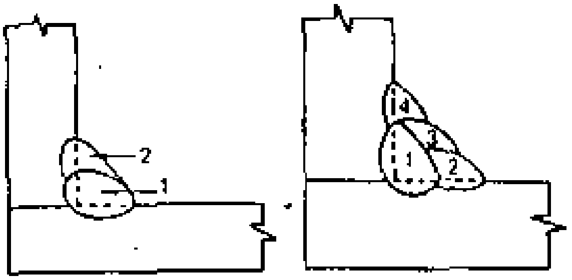


Fig. 6-20. Technique for multi-pass horizontal fillet welds with fast-fill electrodes. Beads should be deposited in the order indicated.

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

Nature of Moisture Pickup	Drying Temperatures	
	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-pa welding of thin-gage sheet metal in fla, 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.

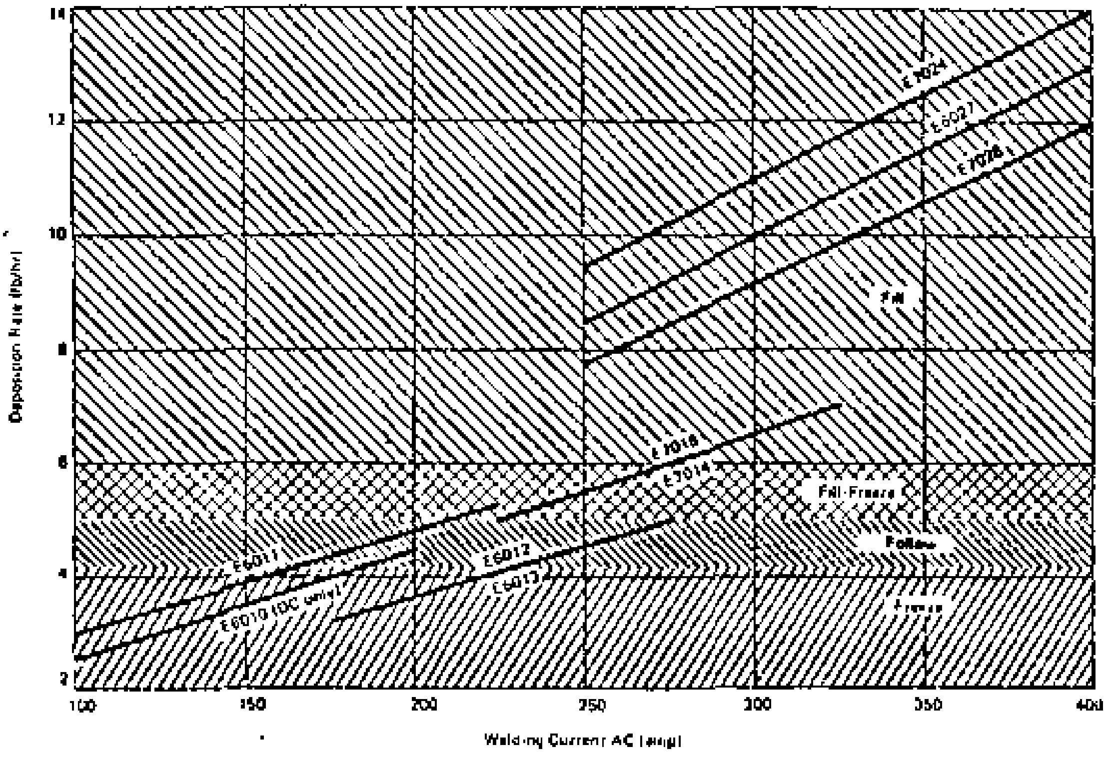


Fig. 6-21. Deposition rates for various mild steel electrodes

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	102,000	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 42, 45 V45	Note 1
	V50, 55 AW Ten AW 441, 440 AWX 50, 55 Alz Dynalloy 60 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 High Strength B, D Armco LTM	E7018 or E7028
	C 60, 65 V 60, 65 High Strength A	E8018-C3
	Lo-Temp Armco LTM VNT Super Lo Temp	E8018-C1
	C 70	E8018-B2
	SSS 100, 100A, 100B HY80, HY100 OTC	E11018-M
Bethlehem Steel Corporation	V42, 45, 50, 55 RQC 50N Mayari R, R 50 Mod. Mn Mn-V A441	E7018 or E7028
	V60, 65 Mayari R 60	E8018-C3
	RQC 60 Q & T	E8018-C1
	RQC 90 RQ100, 100A, 100B	E11018-M
Inland Steel Company	INX 42, 45	Note 1
	INX 50, 55 Hi Man Tri Steel Cor-Ten A, B	Note 7 E7018 or E7028
	INX 60, 65 Hi-Steel Cor-Ten C	E8018-C3
	INX 70	E8018-B2
Jones & Laughlin Steel Corporation	JLX 42, 50	Note 1
	JLX 50, 55 Jalten 1, 2, 3 Cor-Ten A 50CC, 55CC Hi-C Ti	E7018 or E7028
	JLX 60, 65, 60CC, 65CC	E8018-C3
	JLX 70, 70CC	E8018-B2
	Jalloy S90, 100 V-AN 80	E11018-M
Kaiser Steel Corporation	Kaisaloy 42-CV, 45-CV	Note 1
	Kaisaloy 50-CV, 55-CV Kaisaloy 45FG, 50CR, 50MW, 50MV	E7018 or E7028
	Kaisaloy 60SQ, 60CV	E8018-C3
	Kaisaloy 70MB	E8018-B2
Lukens Steel Company	Lukens 45, 50 Lukens A440, A441 Cor-Ten A LT-75N	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 NAX-Fine Grain NAX Hi Mang NAX High Tensile GLS-441	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 MAX High Tensile	E7018 or E7028
	Republic 50, 60, M 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 EX-Ten 60, 65 Man-Ten	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 Yoloy HS, HSX Yo-Man	E8018-C3 Note 7
	Yoloy S	E8018-C1
	YSW-70	E8018-B2

For notes, refer to 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.

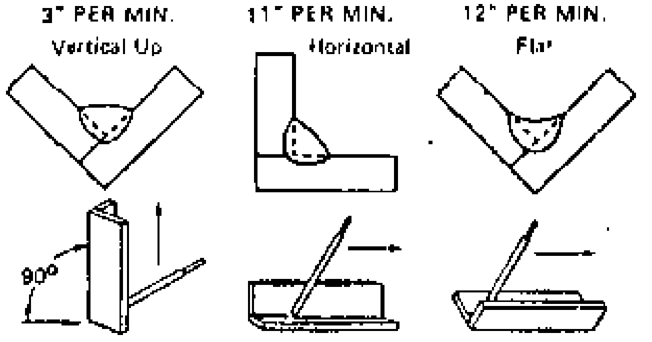


Fig. 6-22. Variations in welding speed with different joint positions

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-

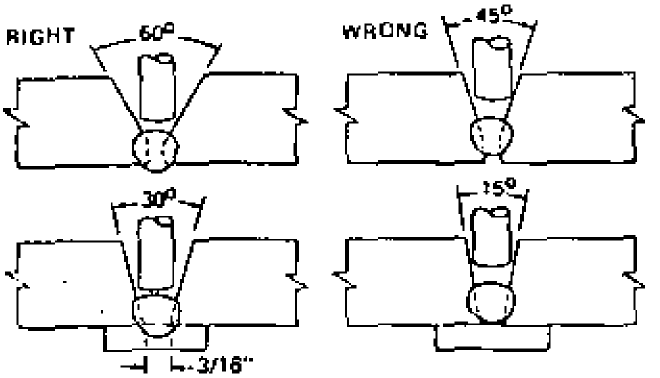


Fig. 6-23. Correct and incorrect bevels for good bead shape and adequate penetration.

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 burnthrough 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 land are practical when the seal bend cost is offset by easier edge preparation and the gap can be limited to about 3/32-in.

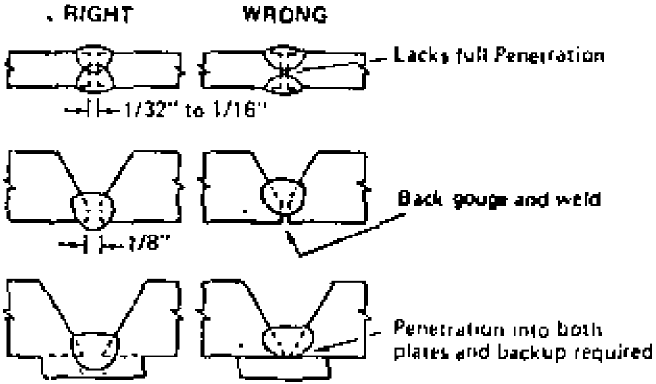


Fig. 6-24. Correct and incorrect gaps for proper penetration

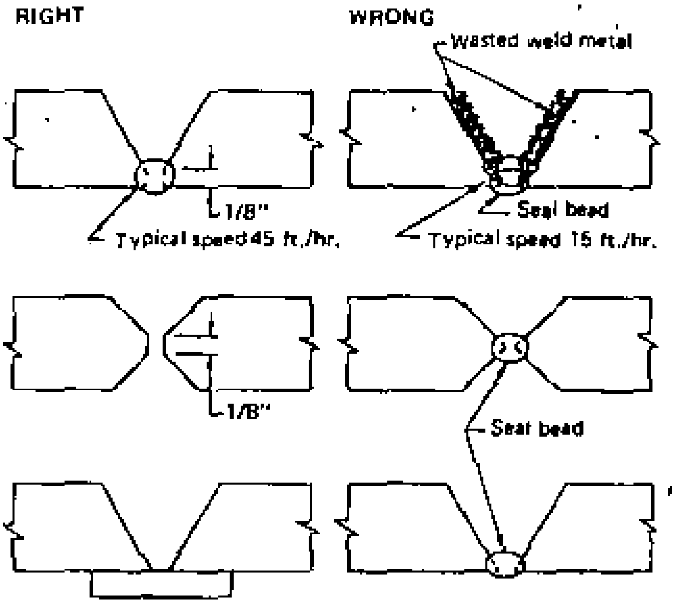


Fig 6-25. Proper joint geometry for thick-plate welding.

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 6/32-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)

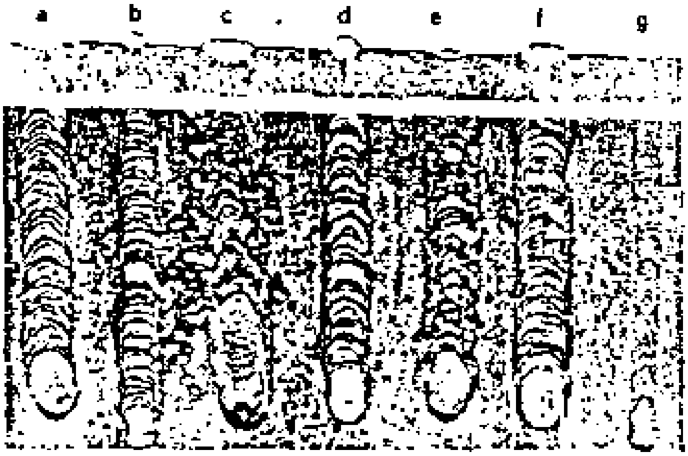


Fig. 6-26. Effect of welding variables on bead characteristics. Proper current, travel speed, and arc length (a). Current too low (b). Current too high (c). Arc length too short (d). Arc length too long (e). Travel speed too slow (f). Travel speed too fast (g).

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.

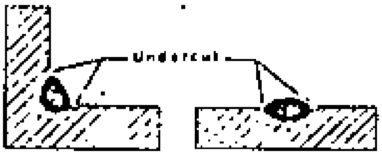


Fig. 6-28. Undercut in a weld. The effect is undesirable from the appearance standpoint and may weaken the joint.

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

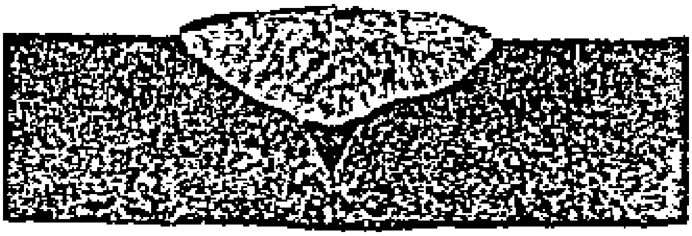
Most porosity is not visible. But severe porosity can weaken the weld. The following practices minimize porosity:

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

Porosity

Surface Holes

Poor Fusion



Shallow Penetration

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.

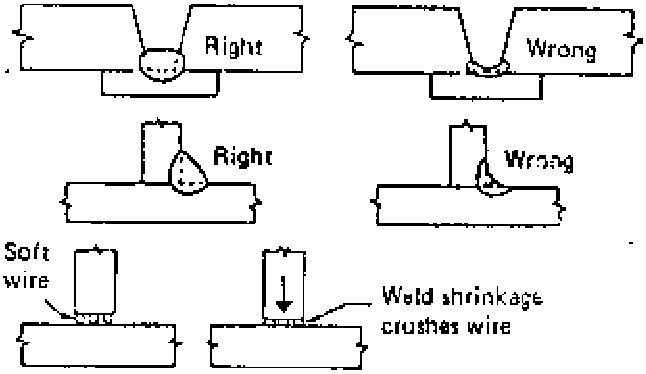


Fig. 6-30. Factors in controlling weld cracking. Illustrated are correct and incorrect joint geometries and bead shapes and a technique to permit stress relaxation in an otherwise rigid joint.

Most cracking is attributed to high-carbon or alloy content or high-sulfur content in the base metal. To control this type of cracking:

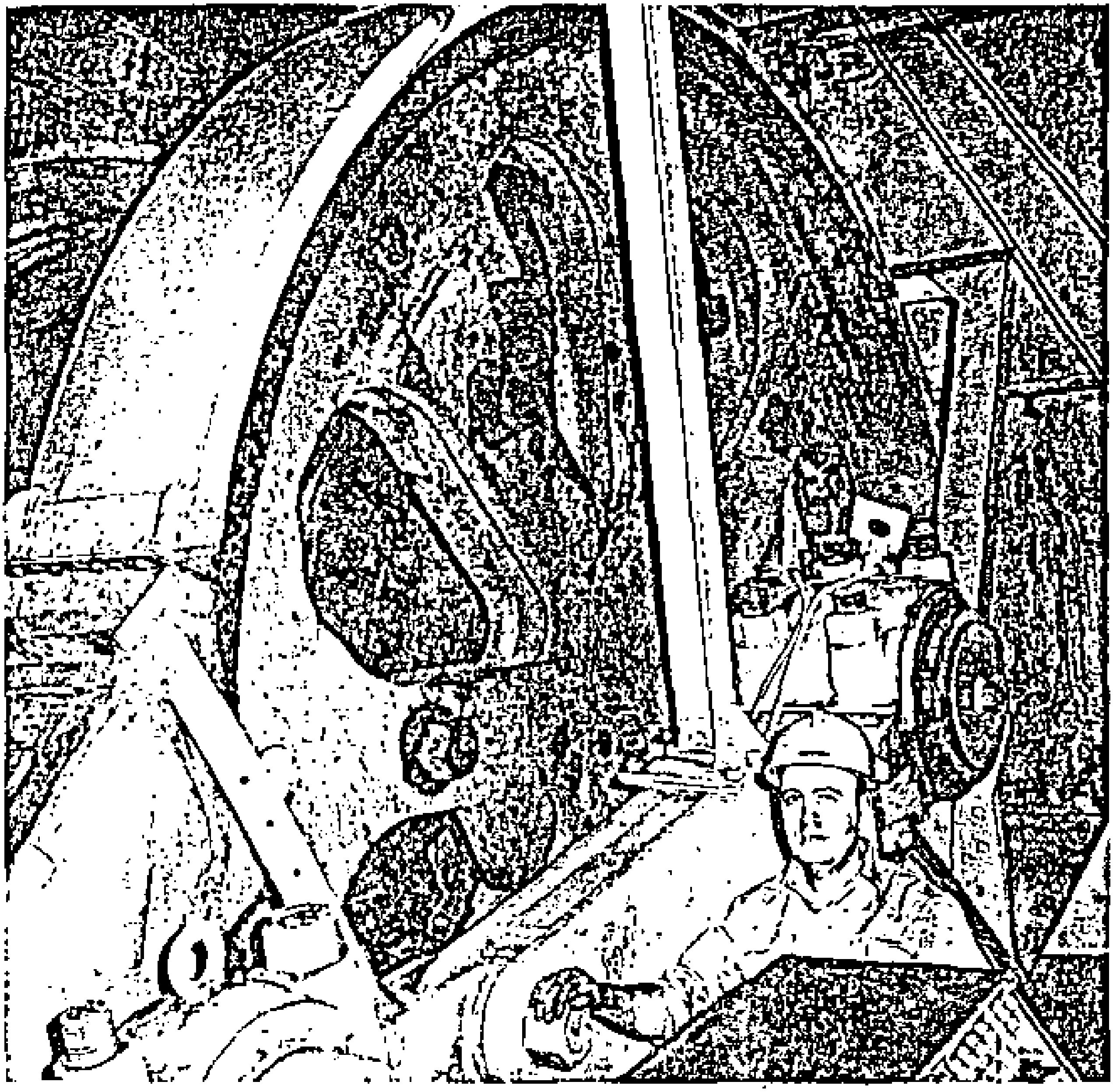
1. Use low-hydrogen electrodes.
2. Preheat. Use high preheats for heavier plate and rigid joints.
3. Reduce penetration by using low currents and small electrodes. This reduces the amount of alloy added to the weld from melted base metal.

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

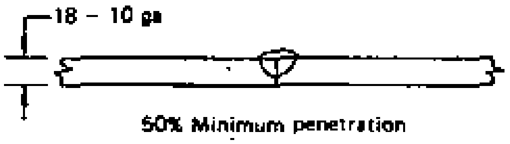


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)*
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(+)	40†	70†	80	120	135
Arc Speed (in./min)	22 – 26	30 – 35	25 – 30	20 – 24	17 – 21
Electrode Req'd (lb/ft)	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

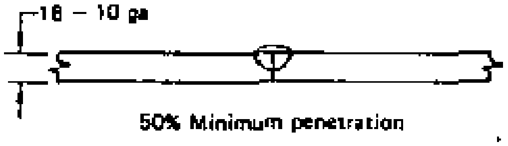


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)*
Pass	1	1	1	1	1
Electrode Class	E6011	E6011	E6011	E6011	E6011
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) AC	50	100	105	130	145
Arc Speed (in./min)	20 – 24	28 – 33	26 – 31	24 – 29	22 – 27
Electrode Req'd (lb/ft)	0.0251	0.0326	0.0367	0.0527	0.0648
Total Time (hr/ft of weld)	0.00909	0.00656	0.00702	0.00755	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

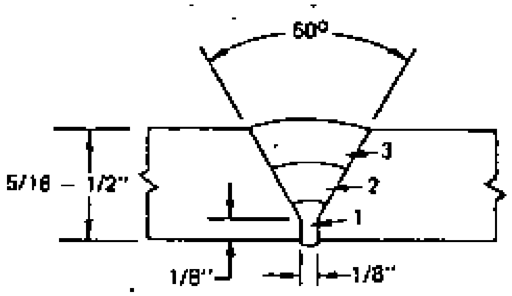
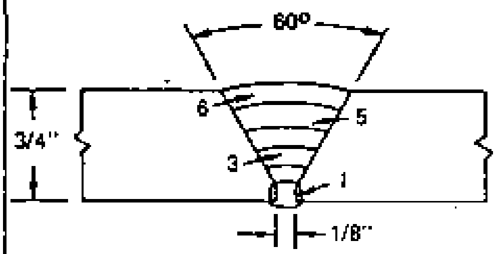


Plate Thickness (in.)	5/16		3/8		1/2		
Pass	1	2	1	2 & 3	1	2	3
Electrode Class	E6011	E6027	E6011	E6027	E6011	E6011	E6027
Size	5/32	5/32	5/32	5/32	5/32	1/4	1/4
Current (amp) AC	135	240	135	240	135	275	400
Arc Speed (in./min)	5.5-6.5	12.0-14.0	5.5-6.5	12.0-14.0	5.5-6.5	8.0-10.0	10.0-12.0
Electrode Req'd (lb/ft)	0.168	0.142	0.168	0.284	0.168	0.228	0.364
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



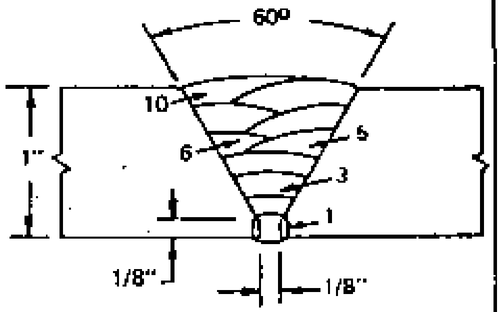


Plate Thickness (in.)	3/4			1		
Pass	1	2	3 – 6	1	2	3 – 10
Electrode Class	E6011	E6011	E6027	E6011	E6011	E6027
Size	5/32	1/4	1/4	5/32	1/4	1/4
Current (amp) AC	135	275	400	135	275	400
Arc Speed (in./min)	5.5 – 6.5	8.0 – 10.0	11.0 – 13.0	5.5 – 6.5	8.0 – 10.0	11.0 – 13.0
Electrode Req'd (lb/ft)	0.168	0.228	1.47	0.168	0.228	2.84
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

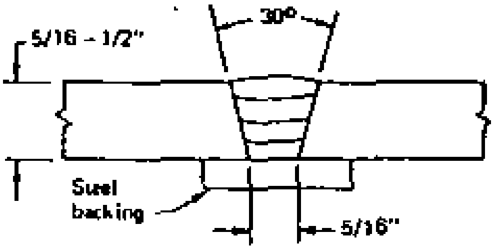


Plate Thickness (in.)	5/16		3/8		1/2	
Pass	1	2 – 3	1	2 – 3	1	2 – 4
Electrode Class	E6027	E6027	E6027	E6027	E6027	E6027
Size	3/16	1/4	3/16	1/4	3/16	1/4
Current (amp) AC	300	400	300	400	300	400
Arc Speed (in./min)	13.0-15.0	15.0-18.0	13.0-15.0	11.5-13.5	13.0-15.0	12.5-14.5
Electrode Req'd (lb/ft)	0.228	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

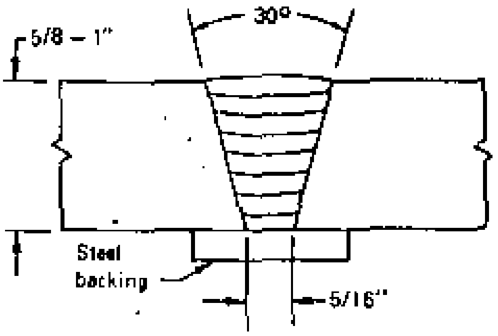


Plate Thickness (in.)	5/8		3/4		1	
Pass	1	2 – 5	1	2 – 6	1	2 – 8
Electrode Class	E6027	E6027	E6027	E6027	E6027	E6027
Size	3/16	1/4	3/16	1/4	3/16	1/4
Current (amp) AC	300	400	300	400	300	400
Arc Speed (in./min)	13.0-15.0	12.5-14.5	13.0-15.0	12.5-14.5	13.0-15.0	12.5-14.5
Electrode Req'd (lb/ft)	0.228	1.35	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

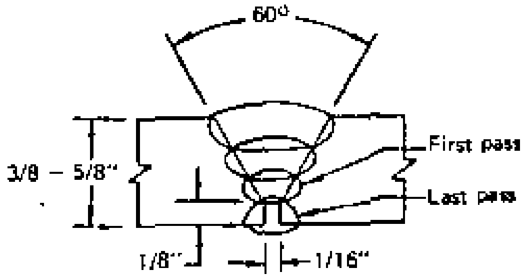


Plate Thickness (in.)	3/8		1/2		5/8		
Pass	1	2 & 3	1	2 & 3	1	2 & 3	4
Electrode Class	E6011	E6027	E6011	E6027	E6011	E6027	E6027
Size	3/16	3/16	1/4	7/32	1/4	1/4	7/32
Current (amp) AC	175	280	275	340	275	375	340
Arc Speed (in./min)	8.0-10.0	14.5-17.5	7.0-9.0	13.5-15.5	7.0-9.0	12.5-14.5	11.5-13.5
Electrode 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

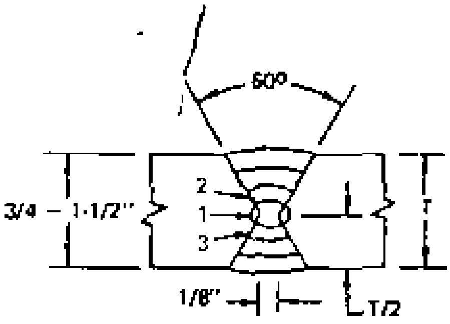


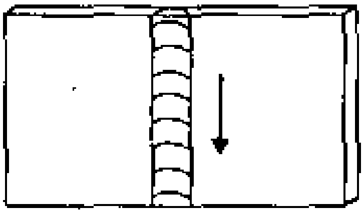
Plate Thickness (in.)	3/4			1			1-1/2		
Pass	1	2 & 3	4 & 5	1	2 & 3	4 – 7	1	2 & 3	4 – 10
Electrode Class	E6011	E6011	E6027	E6011	E6011	E6027	E6011	E6011	E6027
Size	3/16	1/4	1/4	3/16	1/4	1/4	3/16	1/4	1/4
Current (amp) AC	135	276	400	135	275	400	135	276	400
Arc Speed (in./min)	5.5-6.5	8.0-10.0	11.0-13.0	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	150
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

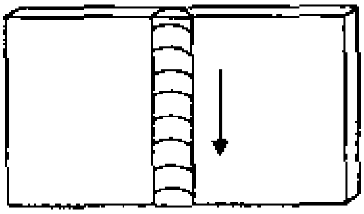
* Use 1/16 in. gap and whip the electrode.

† Use DC(–)

SHIELDED METAL-ARC (MANUAL)

Position: Vertical down
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

18 – 10 ga



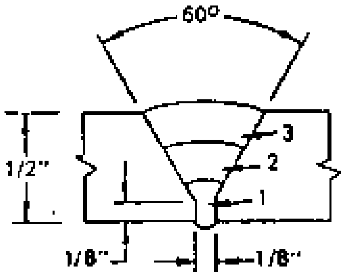
50% Minimum penetration

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	0.0876	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



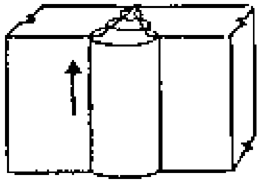
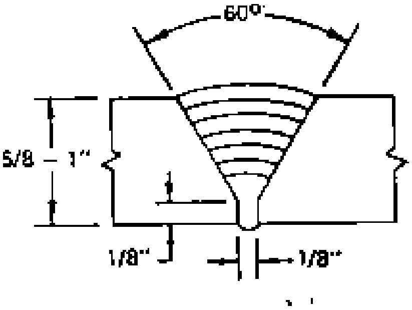


Plate Thickness (in.)	1/4	5/16	3/8	1/2
Pass	1 & 2	1 & 2	1 & 2	1 – 3
Electrode Class	E6010	E6010	E6010	E6010
Size	5/32	5/32	3/16	3/16
Current (amp) DC(+)	110	120	150	170
Arc Speed (in./min)*	5.2-5.8	3.8-4.2	4.8-5.3	3.8-4.2
Electrode Req'd (lb/ft)	0.323	0.440	0.586	0.990
Total Time (hr/ft of weld)	0.0901	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



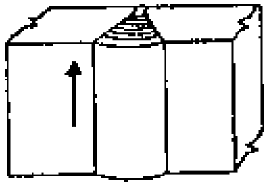
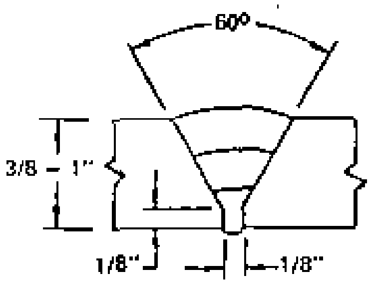


Plate Thickness (in.)	5/8	3/4	1
Pass	1 – 4	1 – 6	1 – 10
Electrode Class	E6010	E6010	E6010
Size	3/16	3/16	3/16
Current (amp) DC(+)	170	170	170
Arc Speed (in./min)*	3.8 – 4.2	3.8 – 4.2	3.8 – 4.2
Electrode Req'd (lb/ft)	1.48	2.08	3.56
Total Time (hr/ft of weld)	0.228	0.318	0.547

* 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



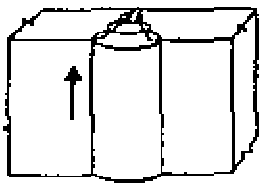
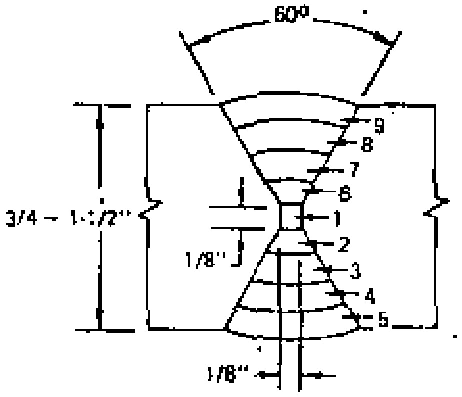


Plate Thickness (in.)	3/8		1/2		3/4		1	
Pass	1	2	1	2 – 3	1	2 – 7	1	2 – 11
Electrode Class	E6010	E7018	E6010	E7018	E6010	E7018	E6010	E7018
Size	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32
Current (amp) DC(+)	160	160	160	160	160	160	160	160
Arc Speed (in./min)	4.3-4.7	3.2-3.5*	4.3-4.7	3.2-3.5*	4.3-4.7	3.2-3.5*	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		0.178		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



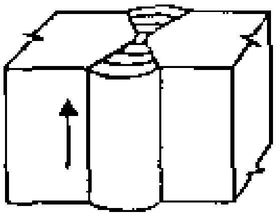


Plate Thickness (in.)	3/4		1		1-1/4		1-1/2	
Pass	1	2 – 5	1	2 – 7	1	2 – 7	1	2 – 9
Electrode Class	E6010	E7018	E6010	E7018	E6010	E7018	E6010	E7018
Size	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32
Current (amp) DC(+)	140	160	140	160	140	160	140	160
Arc Speed (in./min)	3.5-4.1	4.1-4.9	3.5-4.1	3.5-4.1	3.9-4.1	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

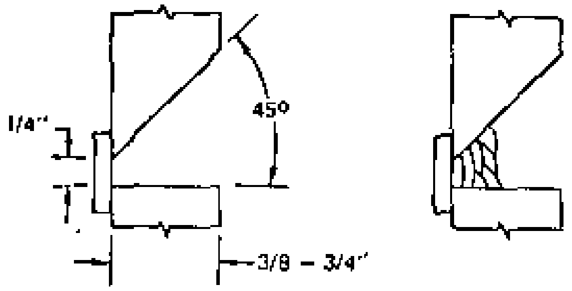


Plate Thickness (in.)	3/8		1/2		5/8		3/4	
Pass	1	2 – 5	1	2 – 7	1	2 – 9	1	2 – 11
Electrode Class	E7018		E7018		E7018		E7018	
Size (in.)	3/16		3/16		3/16		3/16	
Current (amp) DC(+)	240		240		240		240	
Arc Speed (in./min)	4.5-5.5	8.5-9.5	4.5-5.5	7.5-8.5	4.5-5.5	6.7-7.4	5.5-6.5	6.2-6.8
Electrode Req'd (lb/ft)	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

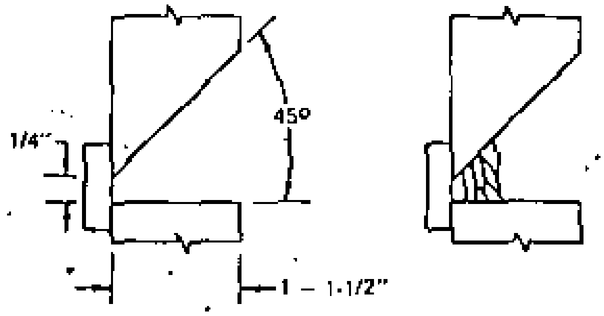


Plate Thickness (in.)		1		1-1/4		1-1/2	
Pass	1*	2 – 13	14 – 19†	2 – 17	18 – 24†	2 – 22	23 – 31†
Electrode Class	E7018	E7018		E7018		E7018	
Size (in.)	3/16	7/32	3/16	7/32	3/16	7/32	3/16
Current (amp) DC(+)	240	280	240	280	240	280	240
Arc Speed (in./min)	5 – 6	6.2-6.8	9.5-10.5	5.7-6.3	9.5-10.5	5.2-5.8	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

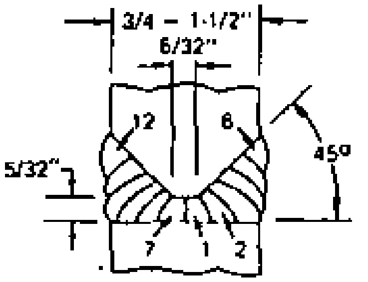


Plate Thickness (in.)	3/4		1		1-1/4		1-1/2	
Pass	1	2 – 6	1	2 – 10	1	2 – 10	1	2 – 12
Electrode Class	E7018	E7018	E7018	E7018	E7018	E7018	E7018	E7018
Size	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16
Current (amp) DC(+)	240	240	240	240	240	240	240	240
Arc Speed (in./min)	5.5-6.5	9.0-11.0	4.4-5.2	8.5-10.5	3.8-4.6	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

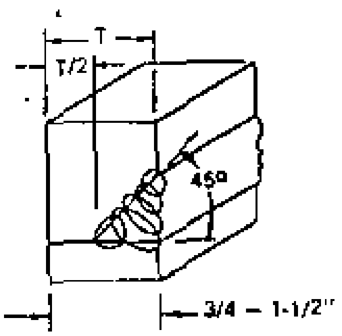
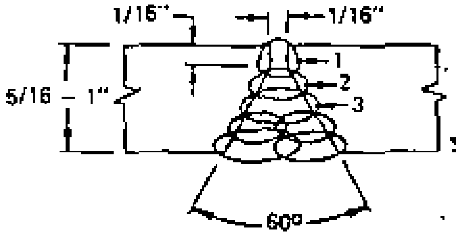


Plate Thickness (in.)		3/4	1	1-1/4	1-1/2
Pass	1*	2 – 3	2 – 5	2 – 5	2 – 6
Electrode Class	E7018	E7018	E7018	E7018	E7018
Size (in.)	3/16	3/16	3/16	3/16	3/16
Current (amp) DC(+)	240	240	240	240	240
Arc Speed (in./min)	4.0-6.0	9.5-10.5	9.0-10.0	5.7-6.3	4.7-5.3
Electrode Req'd (lb/ft)		0.470	0.740	1.80	1.92
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



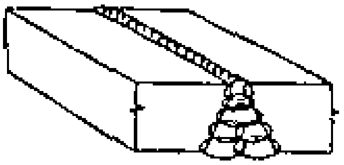
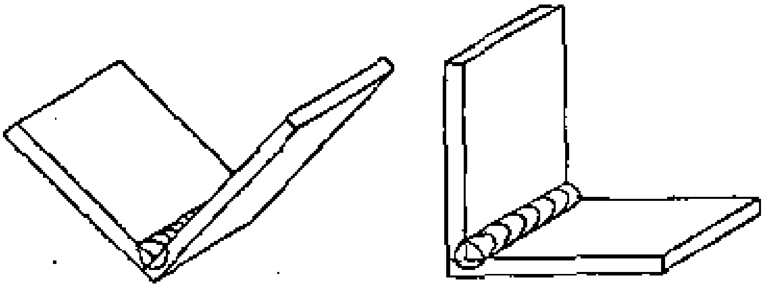


Plate Thickness (in.)	5/16		3/8		1/2		3/4		1	
Pass	1	2	1	2 – 3	1	2 – 5	1	2 – 9	1	2 – 13
Electrode Class	E6010	E7018	E6010	E7018	E6010	E7018	E6010	E7018	E6010	E7018
Size	1/8	5/32	1/8	5/32	1/8	5/32	1/8	5/32	1/8	5/32
Current (amp) DC(+)	110	170	110	170	110	170	110	170	110	170
Arc Speed (in./min)	4.3 – 4.7	3.4 – 3.8	4.3 – 4.7	3.3 – 3.7	4.3 – 4.7	3.8 – 4.0	4.3 – 4.7	4.3 – 4.7	4.3 – 4.7	3.8 – 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)	0.0899		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

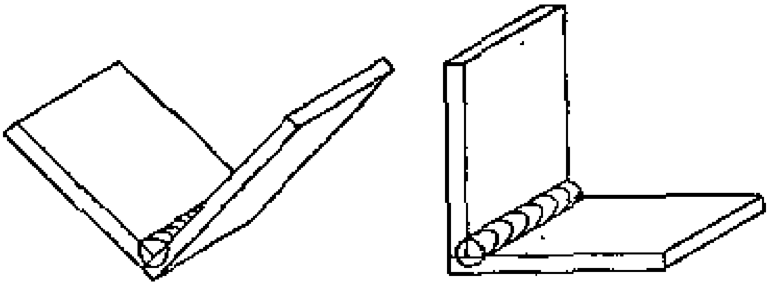


18 – 10 ga

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	18 – 20	20 – 24	16 – 20
Electrode Req'd (lb/ft)	0.0413	0.0583	0.0848	0.0865	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

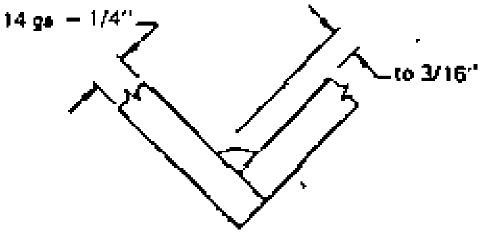


18 – 10 ga

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	0.0926
Total Time (hr/ft of weld)	0.0125	0.0125	0.0118	0.0125	0.0125

SHIELDED METAL-ARC (MANUAL)

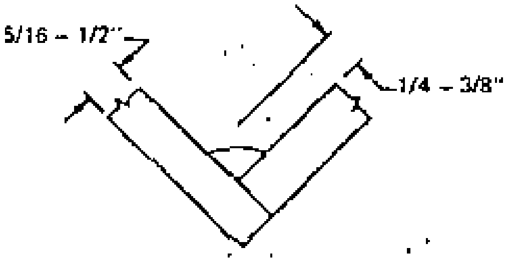
Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good



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)	14.5-18.0	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)

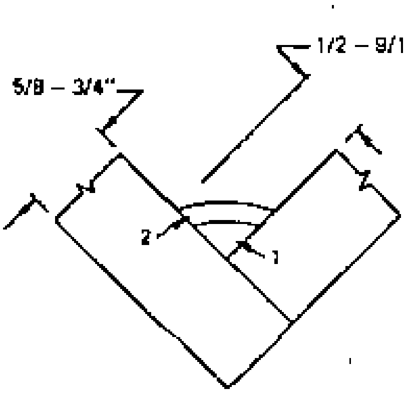
Position: Flat
Weld Quality Level Commercial
Steel Weldability: Good

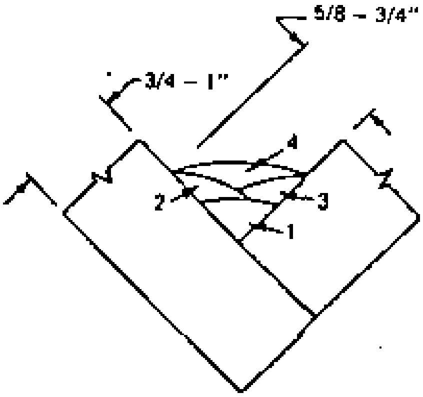


Weld Size, L (in.)	1/4	1/4	9/32	5/16	3/8
Plate Thickness (in.)	5/16		3/8		1/2
Pass	1	1	1	1	1
Electrode Class	E7024	E7024	E7024	E7024	E7024
Size	3/16	7/32	1/4	1/4	5/16
Current (amp) AC	275	325	375	375	475
Arc Speed (in./min)	14.0-16.0	16.0-18.0	17.0-19.0	14.0-15.0	11.0-12.0
Electrode Req'd (lb/ft)	0.19	0.20	0.22	0.29	0.38
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

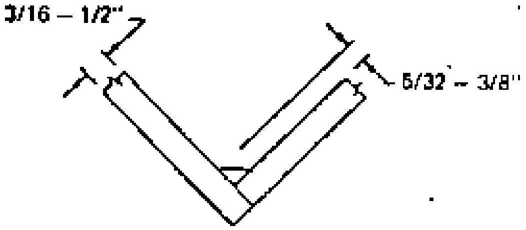




Weld Size, L (in.)	1/2		9/16		5/8		3/4	
Plate Thickness (in.)	5/8		3/4		3/4		1	
Pass	1	2	1	2	1	2 & 3	1	2 – 4
Electrode Class	E7024	E7024	E7024	E7024	E7024	E7024	E7024	E7024
Size	5/16	5/16	5/16	5/16	5/16	5/16	5/16	5/16
Current (amp) AC	475	550	475	550	475	550	475	550
Arc Speed (in./min)	13.0-15.0	14.0-16.0	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		0.85		1.07		1.46	
Total Time (hr/ft of weld)	0.0276		0.0333		0.0429		0.587	

SHIELDED METAL-ARC (MANUAL)

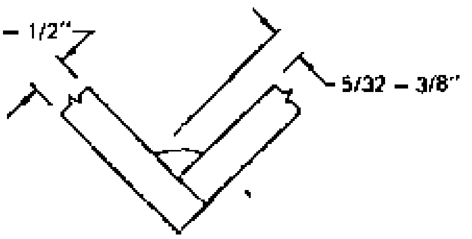
Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good



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	0.191	0.270	0.375
Total Time (hr/ft of weld)	0.0154	0.0160	0.0174	0.0211	0.0250

SHIELDED METAL-ARC (MANUAL)

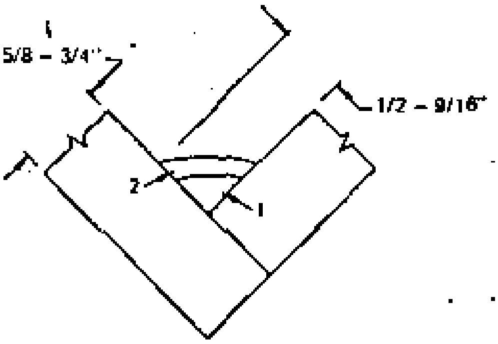
Position: Flat
Weld Quality Level: Code
Steel Weldability: Good

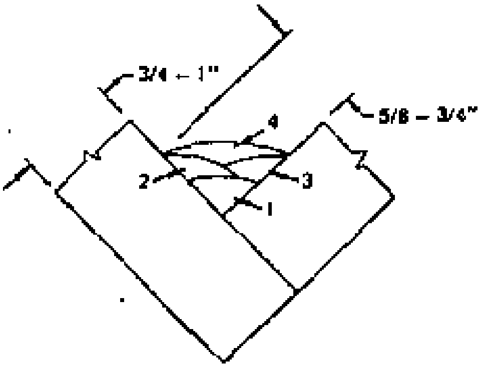


Weld Size, L (in.)	5/32	3/16		1/4		9/32	5/16	3/8
Plate Thickness (in.)	3/16	1/4		5/16		3/8		1/2
Pass	1	1	1	1	1	1	1	1
Electrode Class	E6027	E6027	E6027	E6027	E6027	E6027	E6027	E6027
Size	5/32	5/32	3/16	3/16	7/32	1/4	1/4	1/4
Current (amp) AC	210	220	260	270	335	380	390	400
Arc Speed (in./min)	15.5-17.0	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	0.269	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

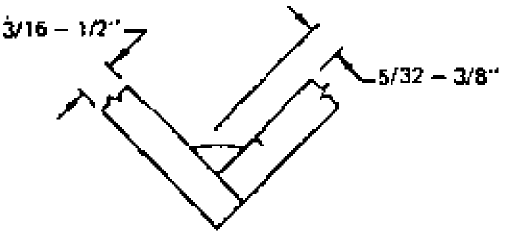




Weld Size, L (in.)	1/2		9/16		5/8		3/4	
Plate Thickness (in.)	5/8		3/4		3/4		1	
Pass	1	2	1	2	1	2 & 3	1	2 – 4
Electrode Class	E6027	E6027	E6027	E6027	E6027	E6027	E6027	E6027
Size	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4
Current (amp) AC	400	400	400	400	400	400	400	400
Arc Speed (in./min)	11.5-12.5	11.5-12.5	11.5-12.5	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

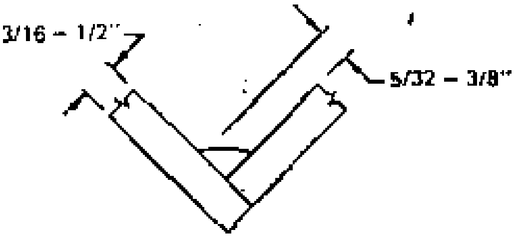


Weld Size, L (in.)	5/32	3/16	1/4	5/16	3/8
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2
Pass	1	1	1	1	1
Electrode Class	E7028	E7028	E7028	E7028	E7028
Size	5/32	3/16	3/16	7/32	1/4
Current (amp) AC	215	260	280	330	400
Arc Speed (in./min)	13.5-15.0	13.5-15.0	11.0-12.0	10.0-12.0	8.5-9.5
Electrode Req'd (lb/ft)	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)

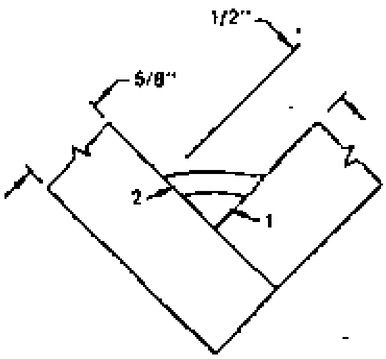
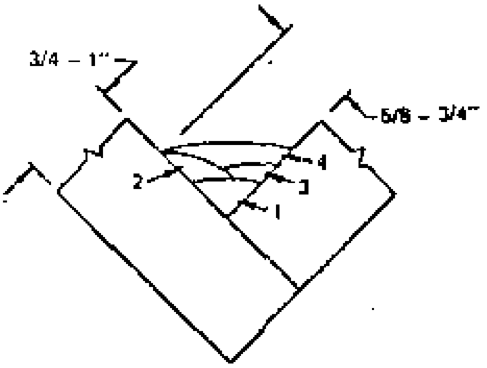
Position: Flat
Weld Quality Level: Code
Steel Weldability: Poor



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	350
Arc Speed (in./min)	13.5-15.0	13.0-14.0	9.0-10.0	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

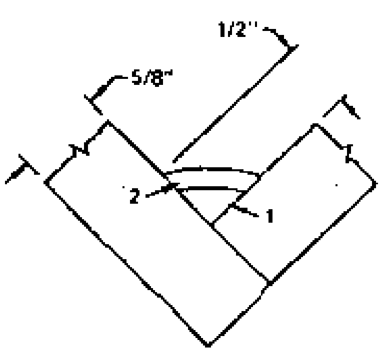
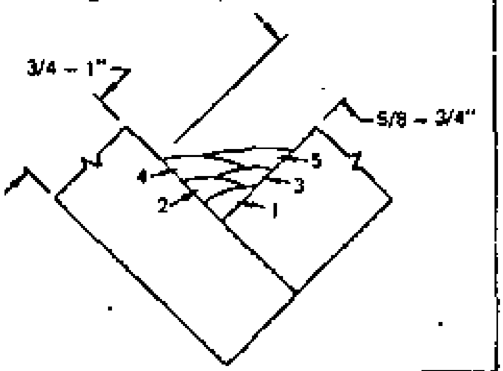
Preheat may be necessary depending on plate material.

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	360	350	350
Arc Speed (in./min)	6.9 – 7.6	6.7 – 7.5	6.8 – 7.4
Electrode Req'd (lb/ft)	0.727	1.14	1.50
Total Time (hr/ft of weld)	0.0665	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

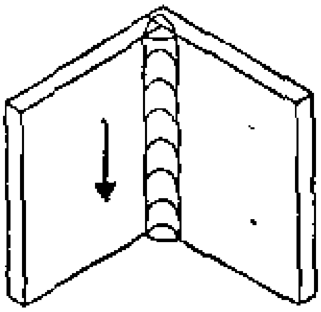


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6012	E6012	E6012	E6012
Size	3/32	1/8	5/32	3/16	3/16
Current (amp) DC(−)	70	105	150	200	210
Arc Speed (in./min)	17 – 21	18 – 22	21 – 25	23 – 28	21 – 25
Electrode Req'd (lb/ft)	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

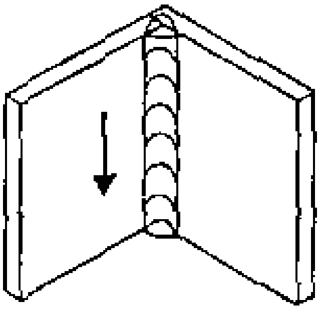
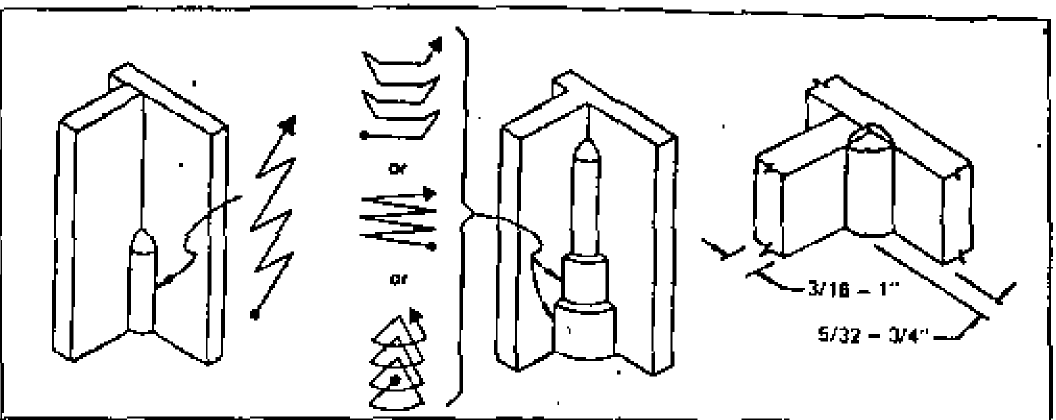


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6013	E6013	E6013	E6013
Size	3/32	1/8	5/32	5/32	3/16
Current (amp) AC	75	115	165	170	225
Arc Speed (in./min)	16 – 20	17 – 21	19 – 23	18 – 22	16 – 20
Electrode Req'd (lb/ft)	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

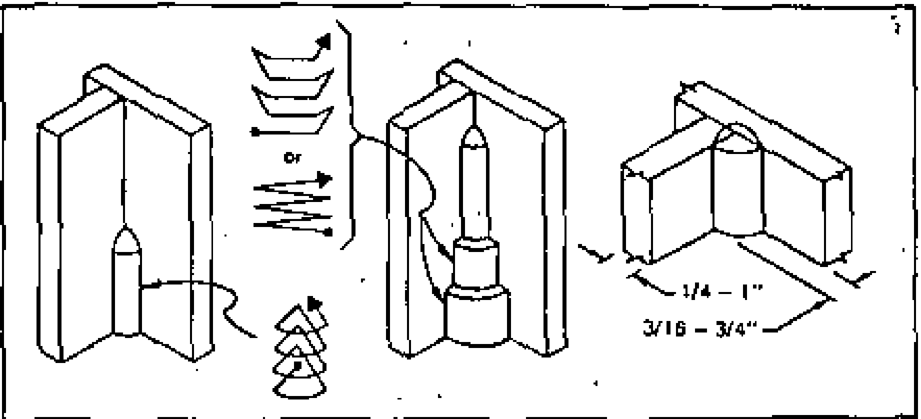


Weld Size, L (in.)	5/32	3/16	1/4	5/16	3/8	1/2	5/8	3/4
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2	5/8	3/4	1
Pass	1	1	1	1	1	1 – 2	1 – 3	1 – 4
Electrode Class	E6010	E6010	E6010	E6010	E6010	E6010	E6010	E6010
Size	5/32	3/16	3/16	3/16	3/16	3/16	3/16	3/16
Current (amp) DC(+)	120	150	155	155	155	160	160	160
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	0.0258	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

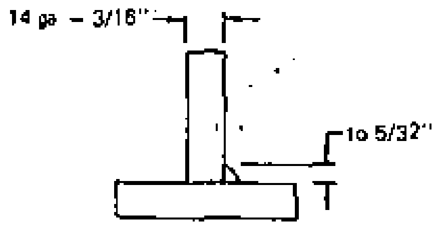


Weld Size, L (in.)	3/16	1/4	5/16	3/8	1/2	5/8	3/4
Plate Thickness (in.)	1/4	5/16	3/8	1/2	5/8	3/4	1
Pass	1	1	1	1	1	1 – 2	1 – 3
Electrode Class	E7018	E7018	E7018	E7018	E7018	E7018	E7018
Size	1/8	1/8	1/8	5/32	5/32	5/32	5/32
Current (amp) DC(+)	135	140	140	150	150	150	150
Arc Speed (in./min)	5.4-5.8	3.8-4.2	2.3-2.6	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)

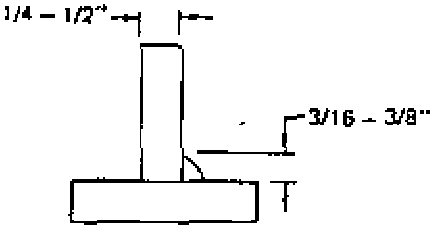
Position: Horizontal
Weld Quality Level: Commercial
Steel Weldability: Good



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	14.5-16.6	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)

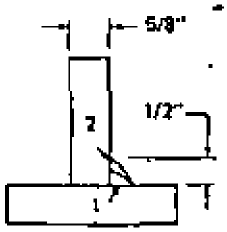
Position: Horizontal
Weld Quality Level: Commercial
Steel Weldability: Good

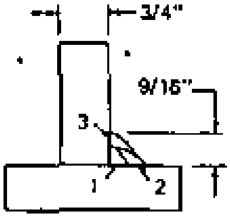


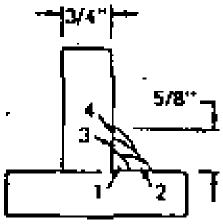
Weld Size, L (in.)	3/16		1/4		9/32	5/16	3/8
Plate Thickness (in.)	1/4		5/16		3/8		1/2
Pass	1	1	1	1	1	1	1
Electrode Class	E7024	E7024	E7024	E7024	E7024	E7024	E7024
Size	5/32	3/16	3/16	7/32	1/4	1/4	1/4
Current (amp) AC	230	270	275	325	376	375	375
Arc Speed (in./min)	13 5-15.0	16.0-17.0	14.0-15 0	16.0-18.0	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

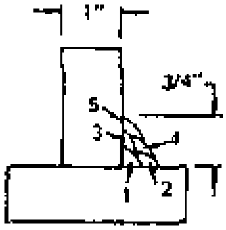
SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Commercial
Steel Weldability: Good





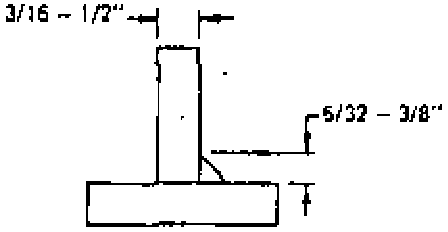




Weld Size, L (in.)	1/2		9/16		5/8		3/4	
Plate Thickness (in.)	5/8		3/4		3/4		1	
Pass	1	2 & 3	1	2 & 3	1	2 – 4	1	2 – 5
Electrode Class	E7024	E7024	E7024	E7024	E7024	E7024	E7024	E7024
Size	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4
Current (amp) AC	375	375	375	376	375	375	375	375
Arc Speed (in./min)	10.5-11.5	11.0-12.0	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)

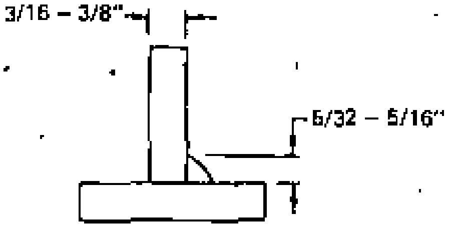
Position: Horizontal
Weld Quality Level: Code
Steel Weldability: Good



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

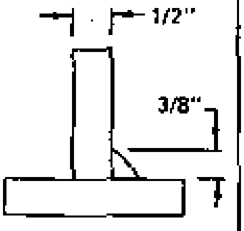


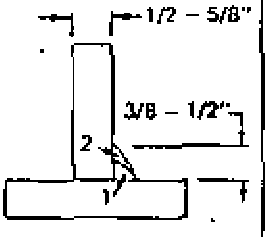
Weld Size, L (in.)	5/32	3/16	1/4		5/16	
Plate Thickness (in.)	3/16	1/4	5/16		3/8	
Pass	1	1	1	1	1	1
Electrode Class	E7028	E7028	E7028	E7028	E7028	E7028
Size	5/32	3/16	3/16	7/32	7/32	1/4
Current (amp) AC	215	260	280	335	335	390
Arc Speed (in./min)	12.5-13.5	11.5-12.5	9.5-10.5	12.0-13.0	9.5-10.5	11.5-12.5
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

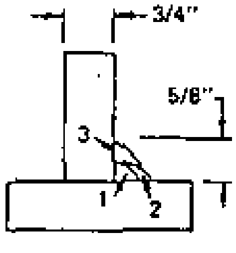
Preheat may be necessary depending on plate material.

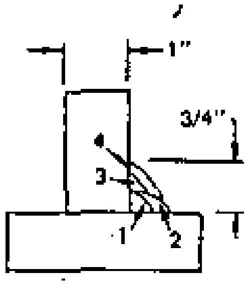
SHIELDED METAL-ARC (MANUAL)

Position: Horizontal
Weld Quality Level: Code
Steel Weldability: Poor







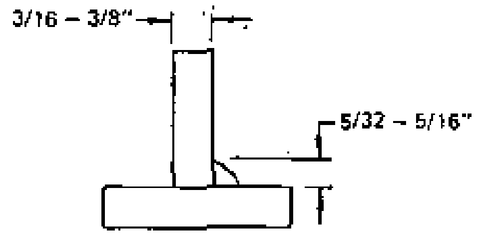


Weld Size, L (in.)	3/8*	3/8	1/2	5/8	3/4
Plate Thickness (in.)	1/2	1/2	5/8	3/4	1
Pass	1	1 – 2	1 – 2	1 – 3	1 – 4
Electrode Class	E7028	E7028	E7028	E7028	E7028
Size	1/4	7/32	1/4	1/4	1/4
Current (amp) AC	390	335	390	390	390
Arc Speed (in./min)	7.5 – 8.5	11.5 – 12.5	9.0 – 10.0	9.0 – 10.0	8.0 – 9.0
Electrode 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.

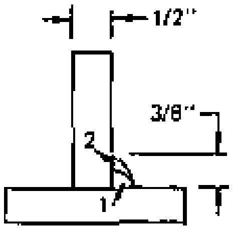
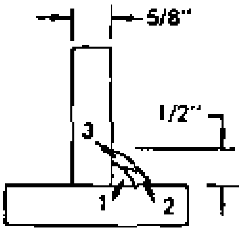
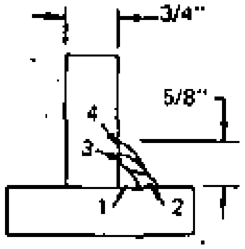
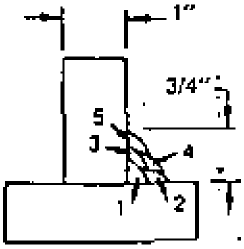
* May not be full 3/8 in. on the vertical leg

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

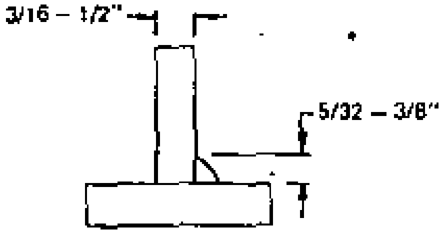
Preheat may be necessary depending on plate material.

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

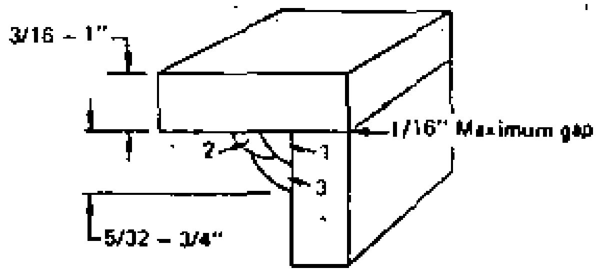
Preheat may be necessary depending on plate material.

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



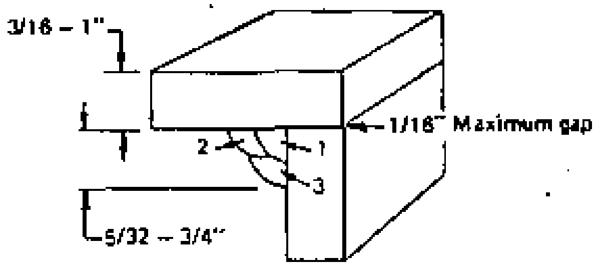
Weld Size, L (in.)	5/32	3/16	1/4	5/16	3/8	1/2	5/8	3/4
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2	5/8	3/4	1
Pass	1	1	1	1 – 2	1 – 3	1 – 6	1 – 10	1 – 15
Electrode Class	E6010	E6010	E6010	E6010	E6010	E6010	E6010	E6010
Size	5/32	3/16	3/16	3/16	3/16	3/16	3/16	3/16
Current (amp) DC(+)	130	170	170	170	170	170	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	0.0396	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)*	10.5-11.6	7.2-8.0	8.2-9.1	8.2-9.1	8.6-9.4	7.0-7.7	7.2-8.0	8.1-8.9
Electrode Req'd (lb/ft)	0.107	0.165	0.277	0.394	0.570	1.01	1.59	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

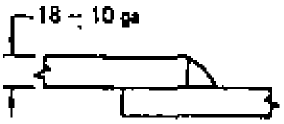
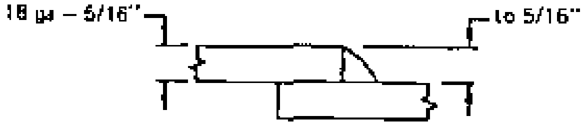


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6012	E6012	E6012	E6012
Size	3/32	1/8	5/32	3/16	3/16
Current (amp) DC(–)	70	105	145	200	210
Arc Speed (in./min)	19 – 23	21 – 26	20 – 24	18 – 22	14 – 18
Electrode Req'd (lb/ft)	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	165	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

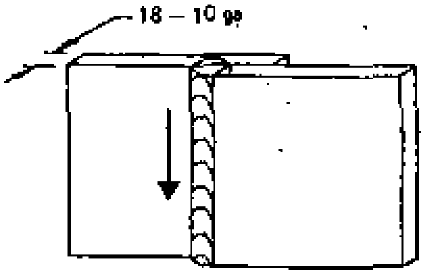


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6012	E6012	E6012	E6012
Size	3/32	1/8	5/32	3/16	3/16
Current (amp) DC(–)	75	115	155	210	220
Arc Speed (in./min)	22 – 27	27 – 32	27 – 32	25 – 30	22 – 27
Electrode Req'd (lb/ft)	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

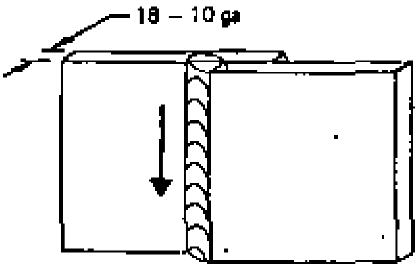


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6013	E6013	E6013	E6013	E6013
Size	3/32	1/8	5/32	5/32	3/16
Current (amp) AC	85	125	170	175	225
Arc Speed (in./min)	19 – 23	20 – 24	21 – 26	19 – 23	16 – 20
Electrode Req'd (lb/ft)	0.0358	0.0444	0.0548	0.0631	0.0922
Total Time (hr/ft of weld)	0.00953	0.00910	0.00860	0.00953	0.0111

SHIELDED METAL-ARC (MANUAL)

Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

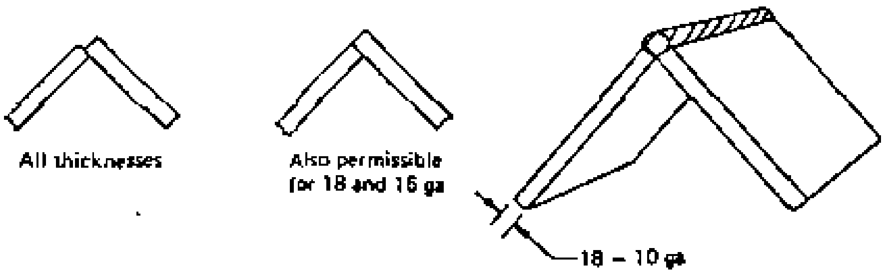
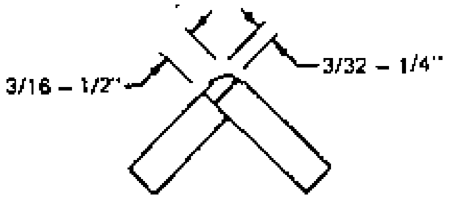


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(−)	45	80	85	110	155*
Arc Speed (in./min)	30 – 35	35 – 40	35 – 40	33 – 38	27 – 32
Electrode Req'd (lb/ft)	0.0197	0.0282	0.0300	0.0432	0.0506
Total Time (hr/ft of weld)	0.00616	0.00533	0.00533	0.00563	0.00678

* Use DC(+)

SHIELDED METAL-ARC (MANUAL)

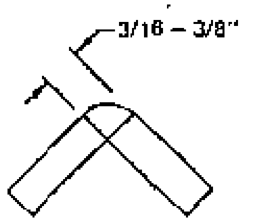
Position: Flat
Weld Quality Level: Commercial
Steel Weldability: Good
Welded From: One side

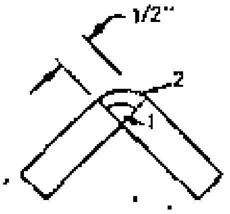


Weld Size, L (in.)	3/32	1/8	5/32	3/16	1/4
Plate Thickness (in.)	3/16	1/4	5/16	3/8	1/2
Pass	1	1	1	1	1
Electrode Class	E7024	E7024	E7024	E7024	E7024
Size	5/32	3/16	7/32	7/32	1/4
Current (amp) AC	215	275	350	360	410
Arc Speed (in./min)	22.0-27.0	19.0-23.0	18.5-22.5	16.5-19.5	14 – 17
Electrode Req'd (lb/ft)	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

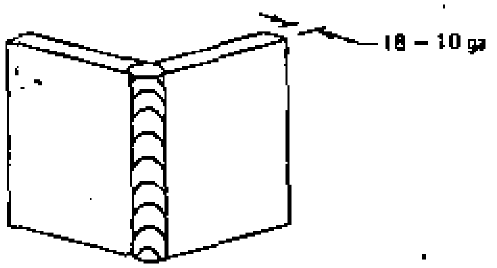


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(–)	50	90	95	120	170*
Arc Speed (in./min)	35 – 40	40 – 45	40 – 45	37 – 42	33 – 38
Electrode Req'd (lb/ft)	0.0184	0.0278	0.0293	0.0436	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

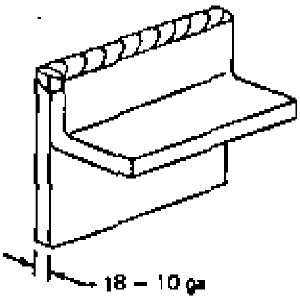


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(–)	50	80	85	115	140
Arc Speed (in/min)	45 – 50	43 – 48	40 – 45	40 – 45	37 – 42
Electrode Req'd (lb/ft)	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

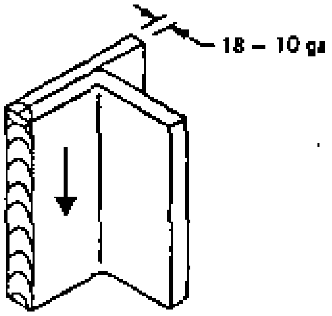


Plate Thickness (in.)	0.048 (18 ga)	0.060 (16 ga)	0.075 (14 ga)	0.105 (12 ga)	0.135 (10 ga)
Pass	1	1	1	1	1
Electrode Class	E6010	E6010	E6010	E6010	E6010
Size	3/32	1/8	1/8	5/32	3/16
Current (amp) DC(–)	55	90	95	125	155
Arc Speed (in./min)	53 – 58	50 – 55	47 – 52	47 – 52	43 – 48
Electrode Req'd (lb/ft)	0.0141	0.0225	0.0751	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

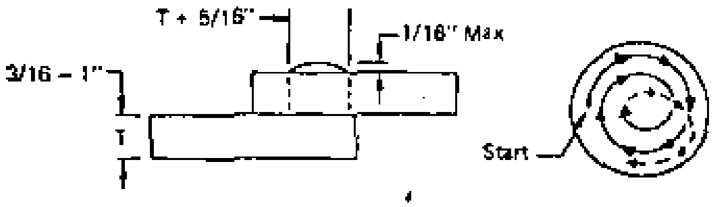


Plate Thickness (in.)	3/16	5/16	3/8	1/2	3/4	1
Electrode Class	E7018	E7018	E7018	E7018	E7018	E7018
Size	1/8	3/16	3/16	7/32	1/4	1/4
Current (amp) AC	140	250	250	300	350	360
Arc Speed (in./min)						
Electrode Req'd*	0.0154	0.0440	0.0642	0.113	0.300	0.606
Total Time* (hr)	0.00417	0.00500	0.00731	0.0118	0.0236	0.0475

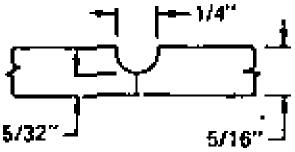
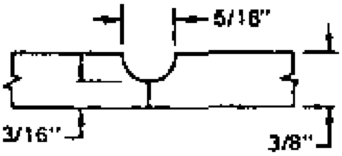
Weld with spiral motion and continue as long as slag can be kept molten or until the weld is completed.

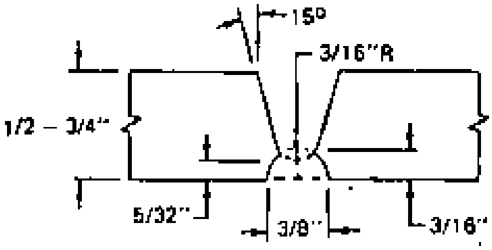
* Per weld

† 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 Class†				
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 Class†						
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)	0.188		0.238		0.313	
Interpass Temperature, Max. (°F)	175		200		225	

* Second side is gouged after first side is completed.

† See Tables 6-13 and 6-17.

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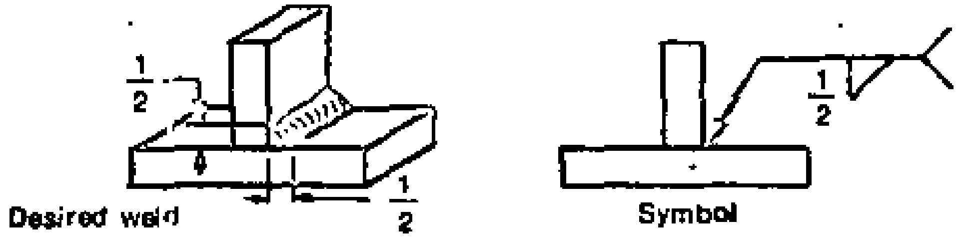
PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

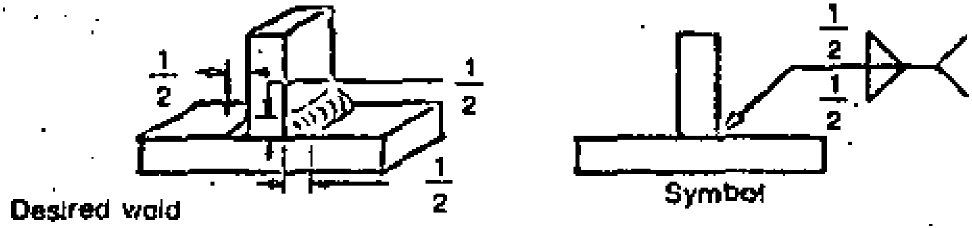
SOLDADURA

ING. JOSE LUIS SANCHEZ MARTINEZ

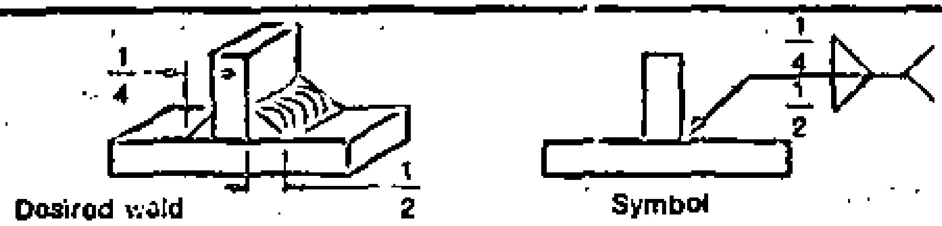
JULIO, 1979



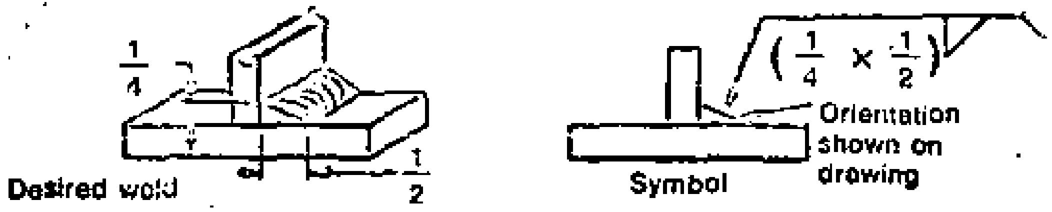
(A) Size of single-fillet weld



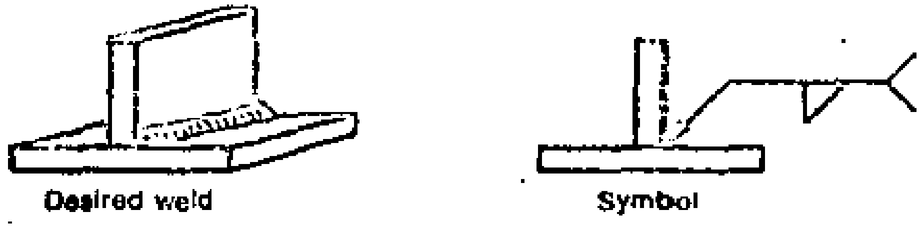
(B) Size of equal double-fillet welds



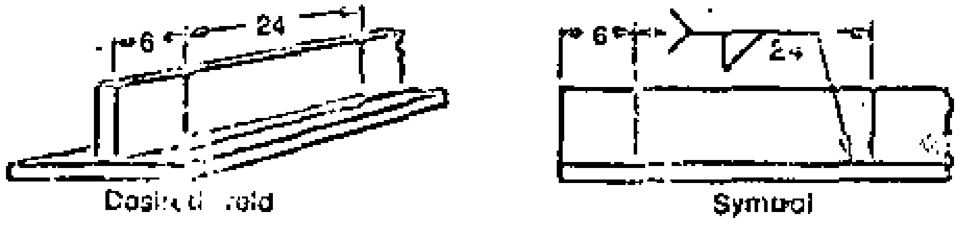
(C) Size of unequal double-fillet welds



(D) Size of fillet weld having unequal legs

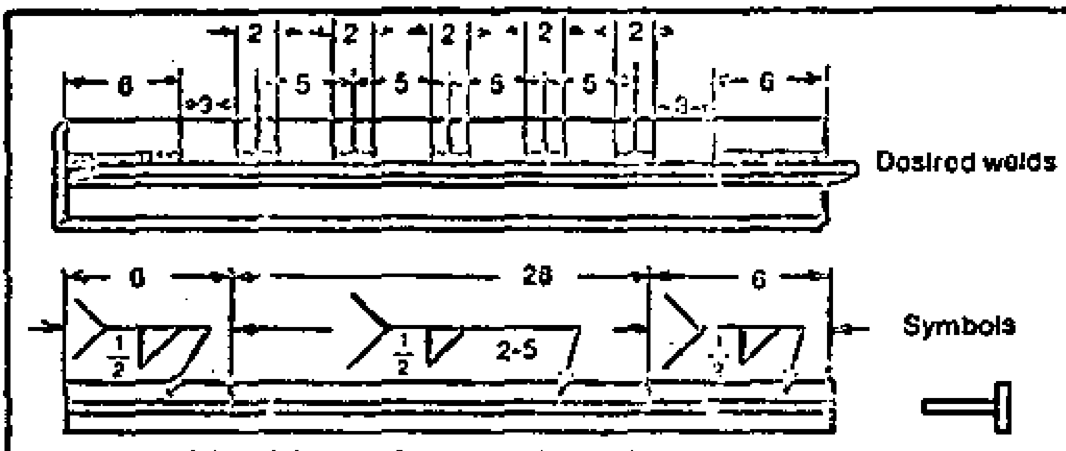


(E) Continuous fillet weld

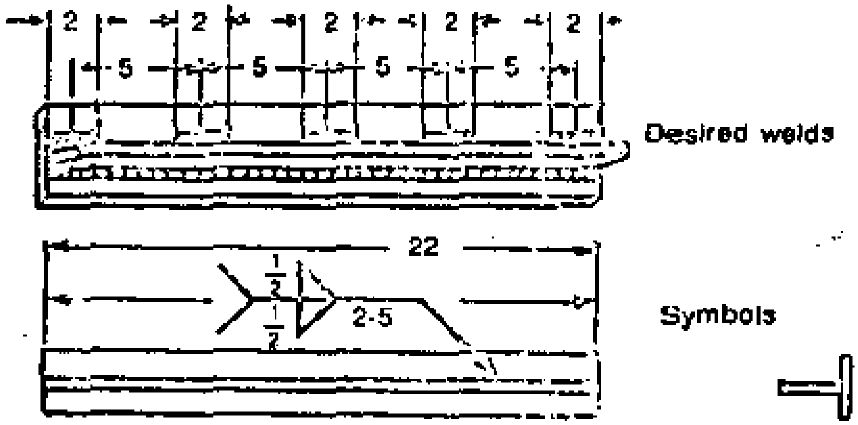


(F) Length of fillet weld

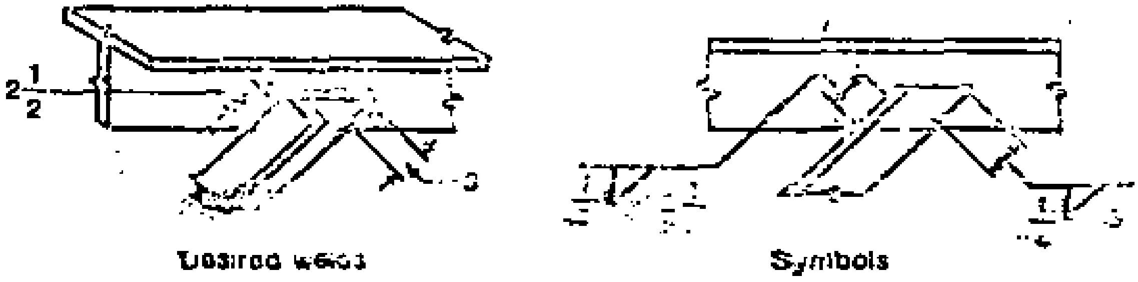
Fig. [illegible]--Application of dimensions to fillet weld symbols.



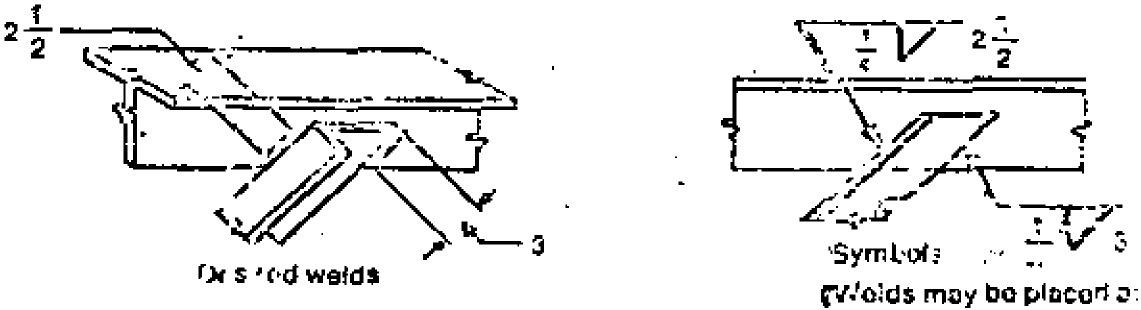
(A) Combined intermittent and continuous welding (one side of joint)



(B) Combined intermittent and continuous welding (opposite sides of joint)



(C) Welds definitely located

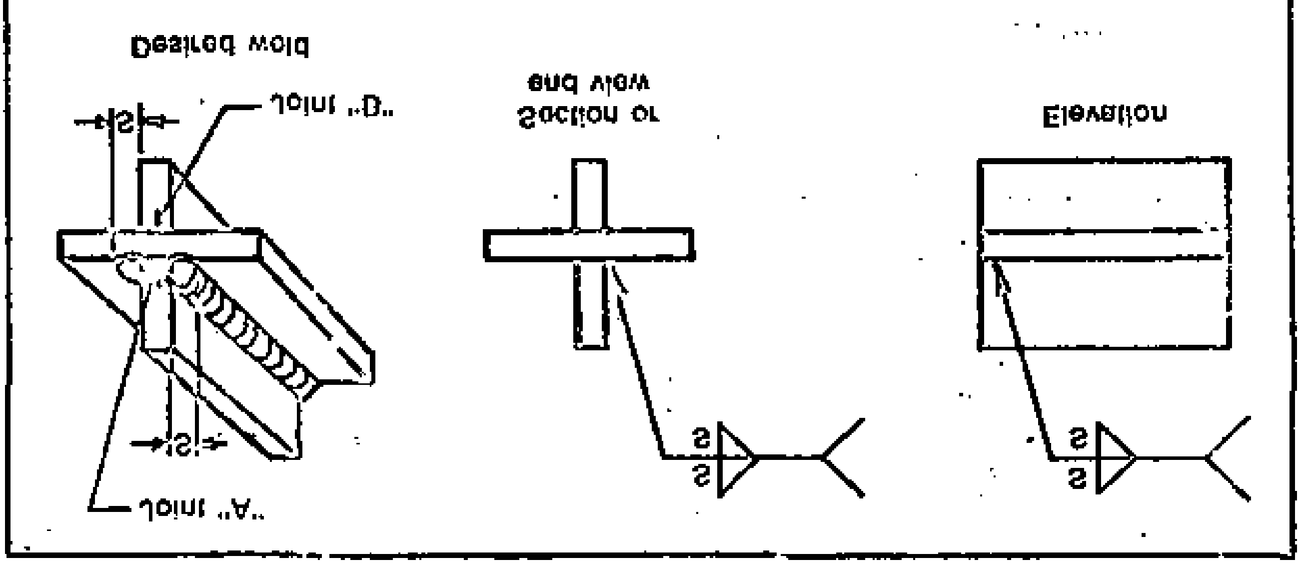


(Welds may be placed anywhere along the joint)

(D) Welds approximately located

Fig. 7—Designation of location and extent of fillet welds.

(C) Both sides fillet weld symbols for one joint



(D) Both sides fillet weld symbols for two joints

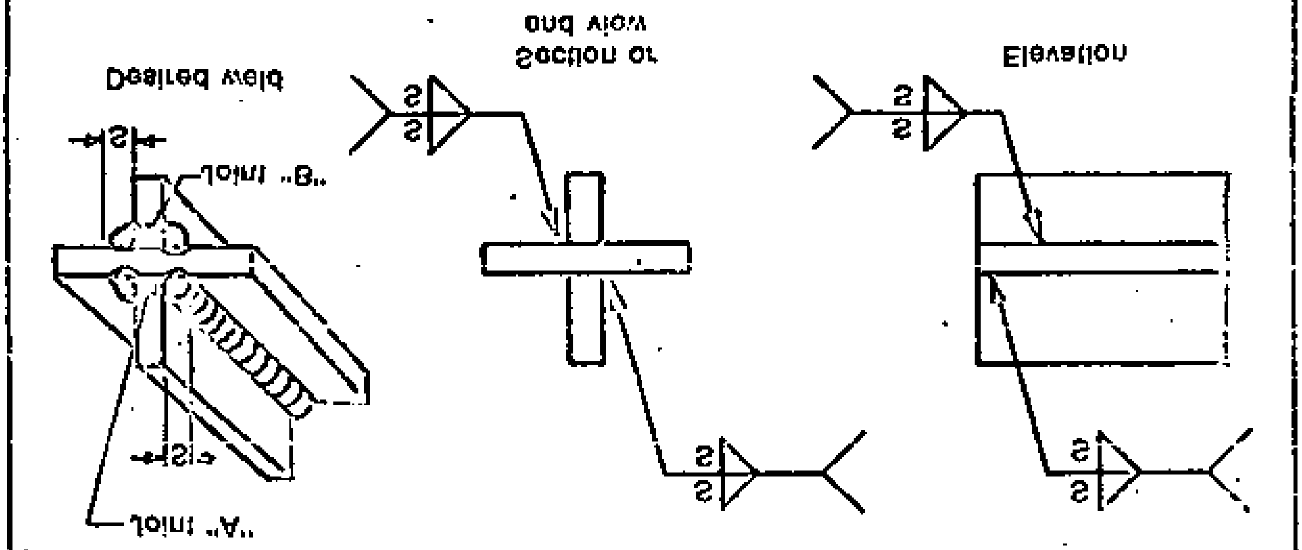
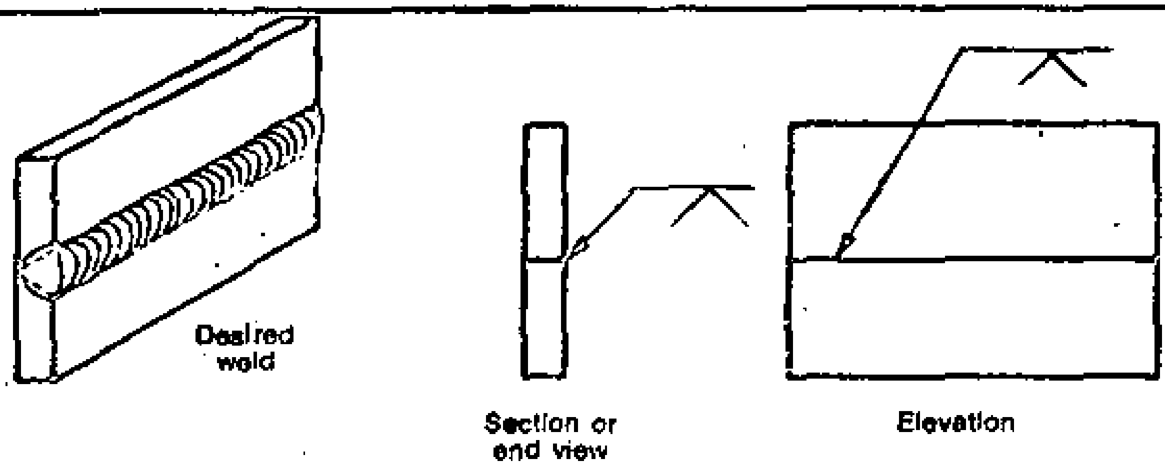
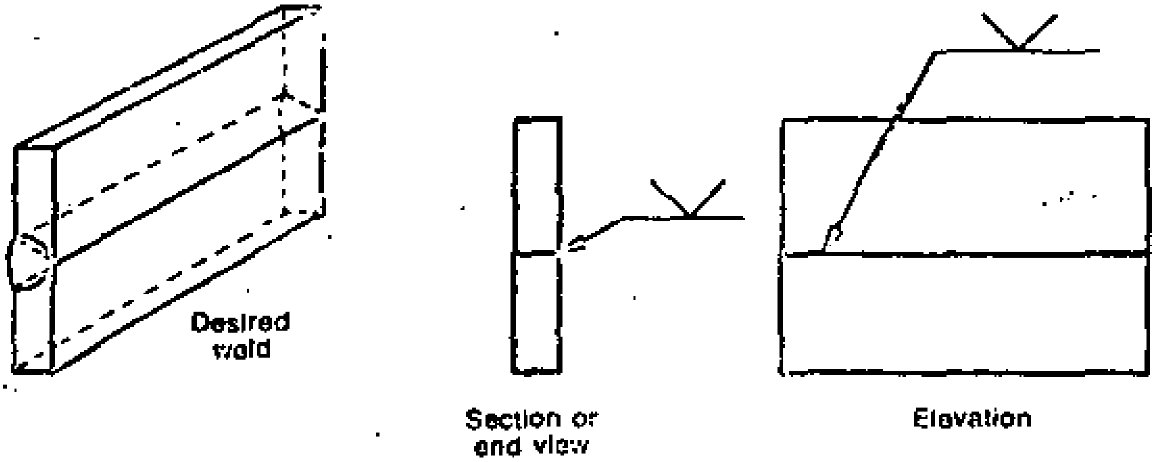


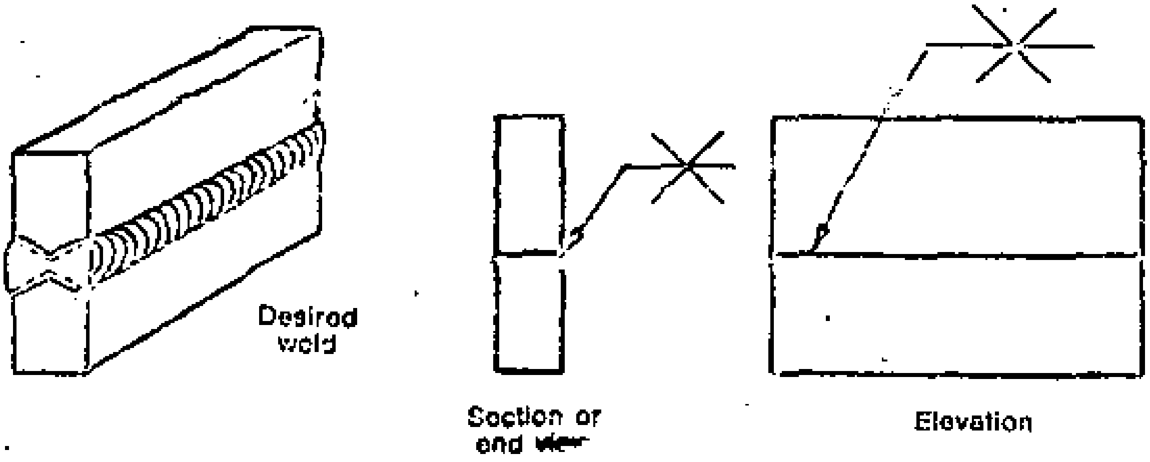
Fig. 15 (cont.)—Application of fillet weld symbols.



(A) Arrow side V-groove weld symbol

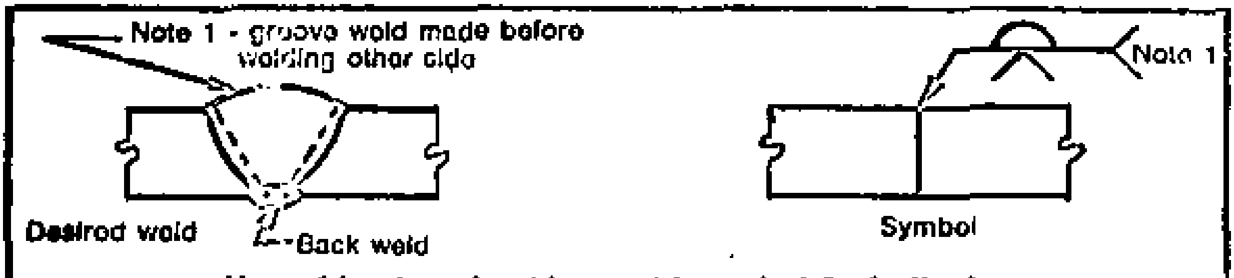


(B) Other side V-groove weld symbol

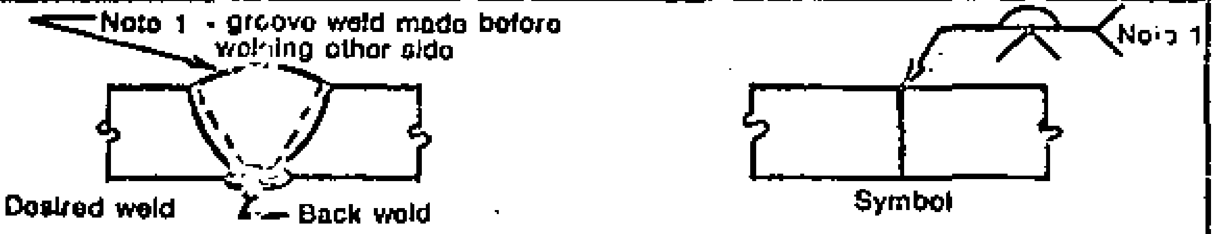


(C) Both sides V-groove weld symbol

Fig. 5—Application of arrow side and other side convention.

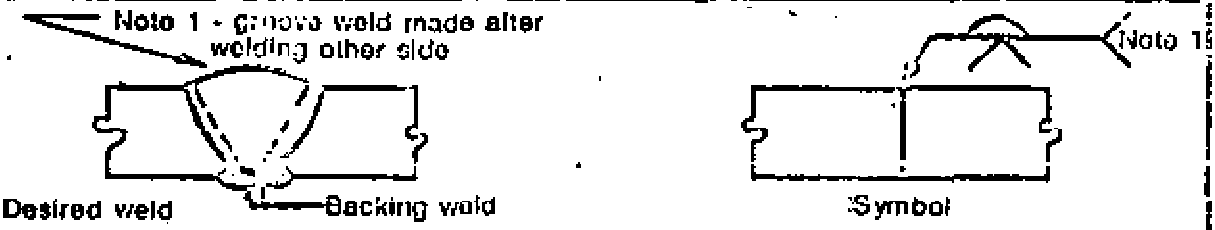


(A) Use of back or backing weld symbol to indicate single-pass back weld

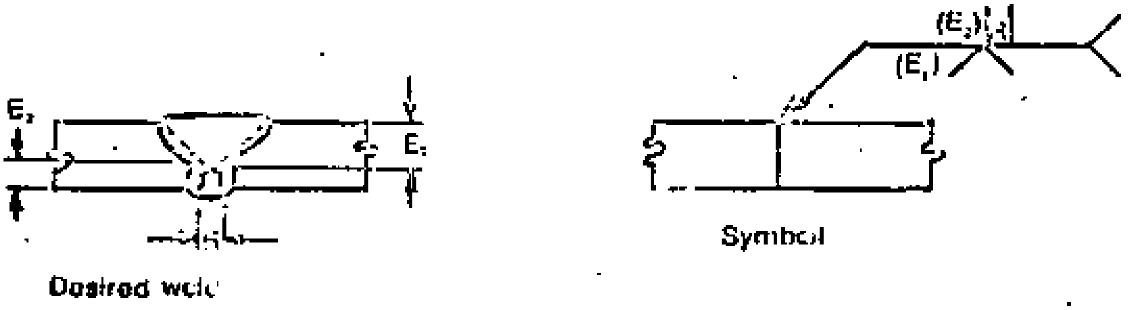


(B) Use of back or backing weld symbol to indicate multiple pass back weld

(C) Use of back or backing weld symbol to indicate single pass backing weld

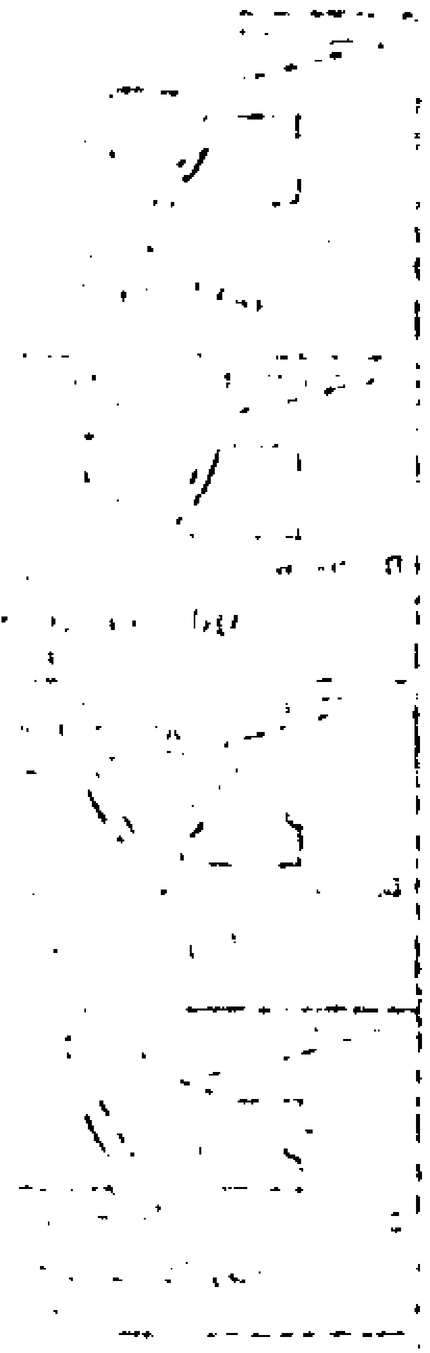


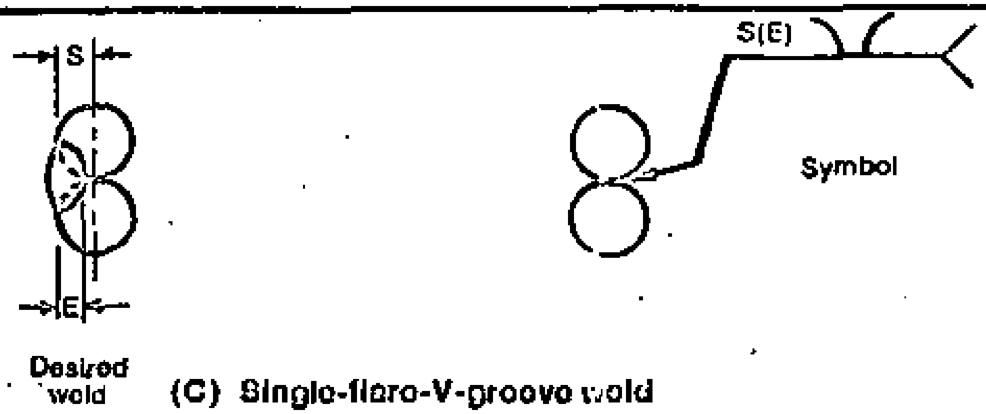
(D) Use of back or backing weld symbol to indicate multiple pass backing weld



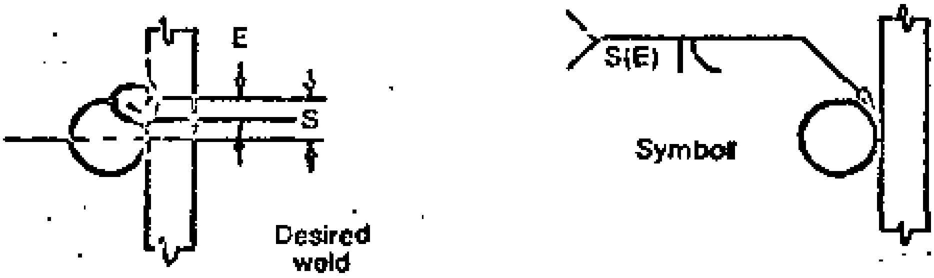
(E) Use of back weld with [illegible] spacing

Fig. 55—Application of back or backing weld symbol.

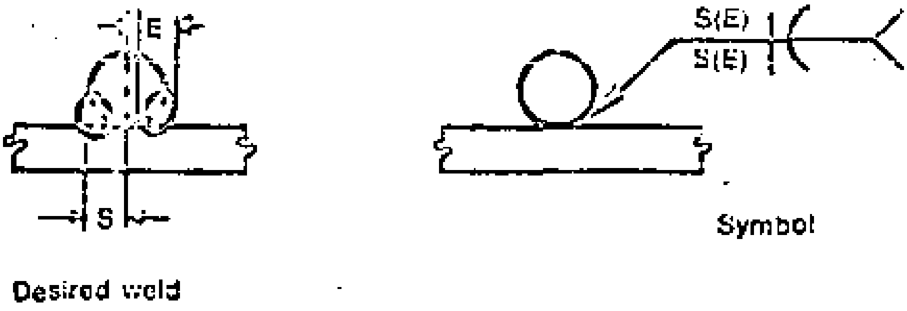




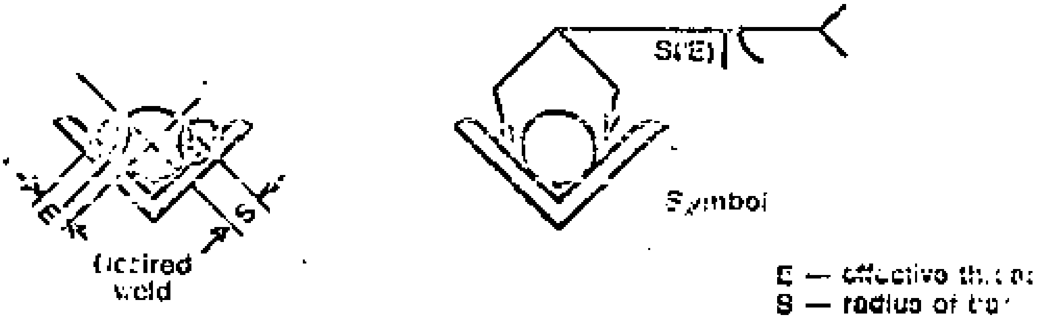
(C) Single-flare-V-groove weld



(D) Single-flare-bevel-groove weld



(E) Double-flare-bevel-groove weld



(F) Two single-flare-bevel-groove welds

Fig. 31 (cont.)—Application of flare-bevel- and flare-V-groove weld symbols

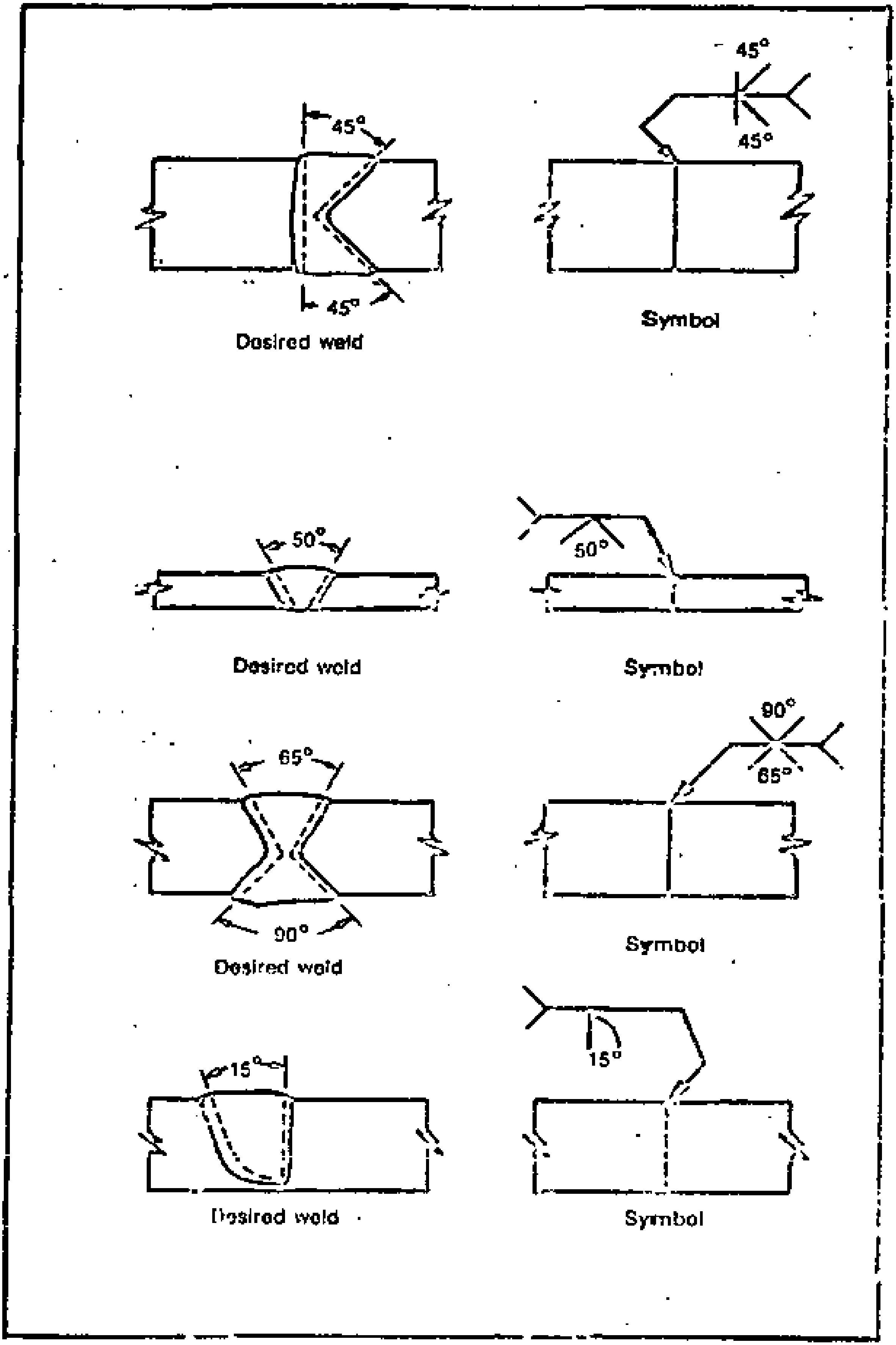


Fig. 33--Designation of groove angle of groove welds.

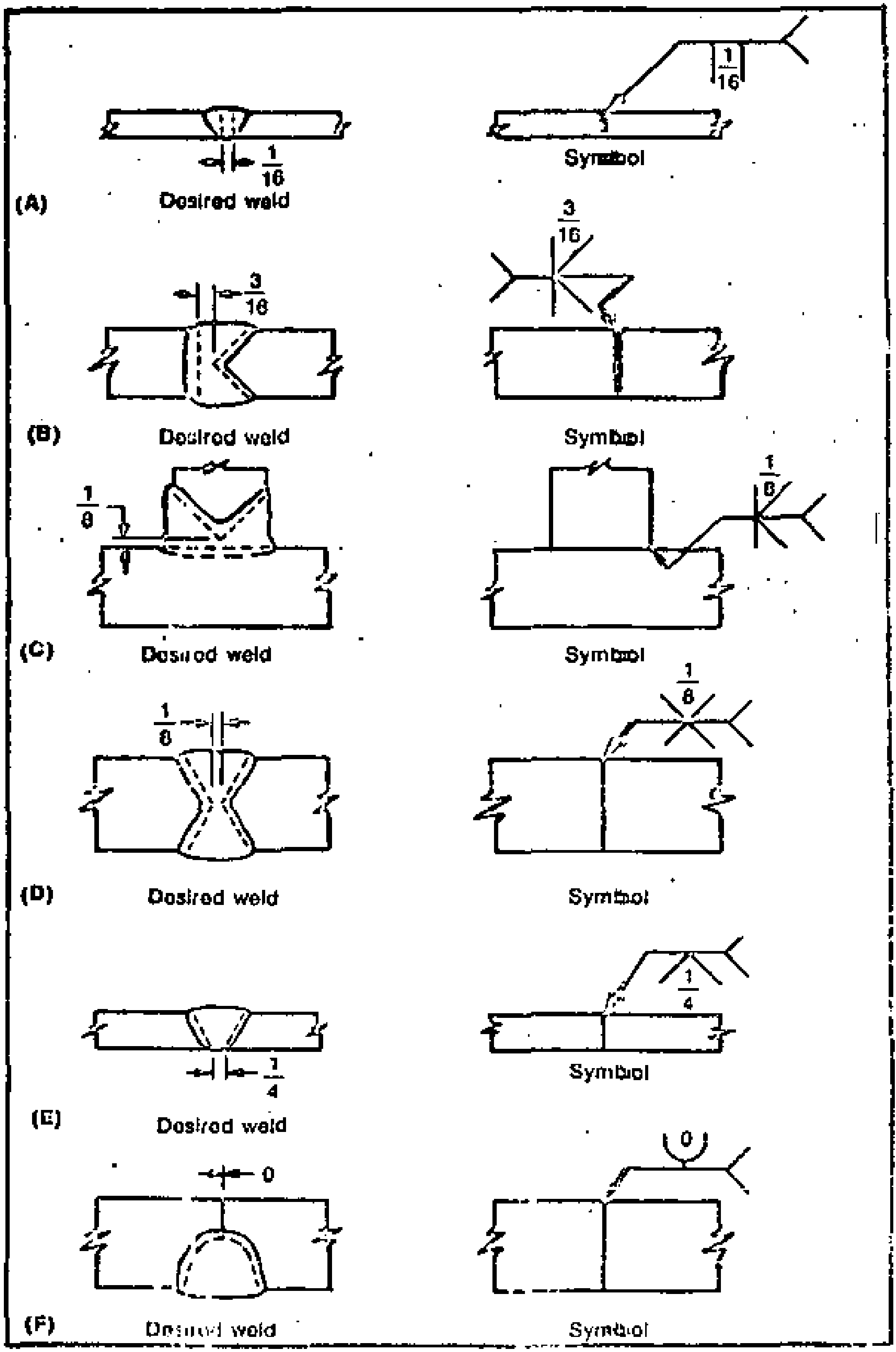
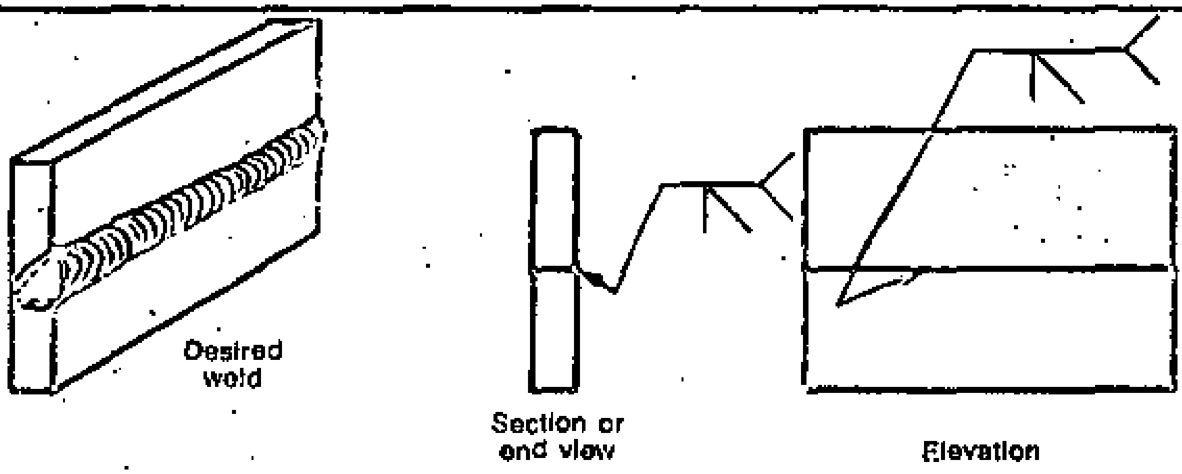
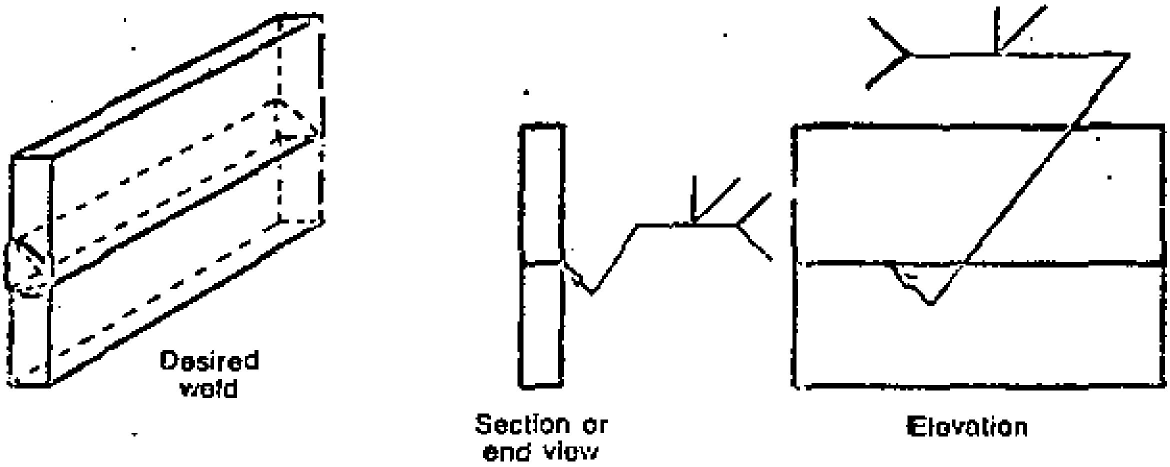


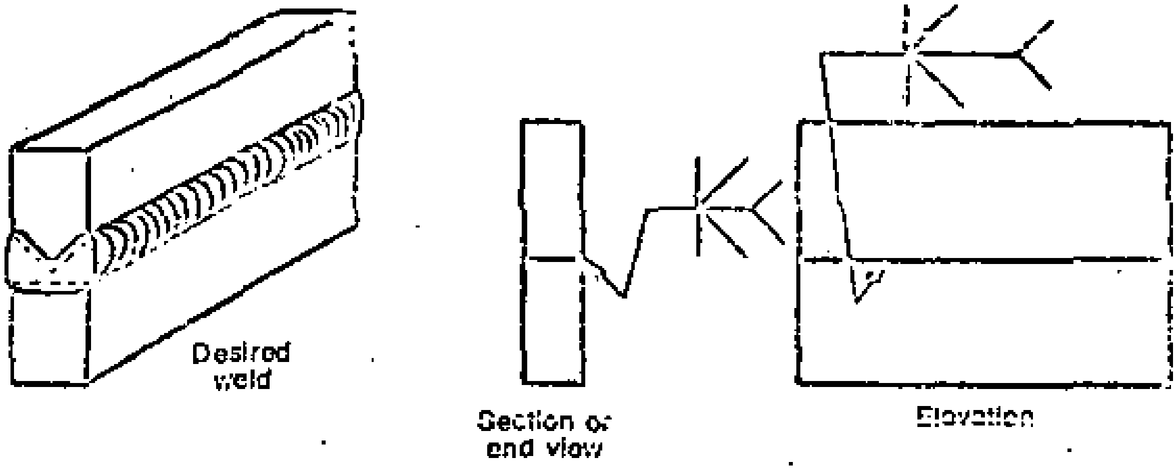
Fig. 32—Designation of root opening of groove welds.



(A) Arrow side



(B) Other side



(C) Both sides

Fig. 9—Application of break in arrow of welding symbol (bevel-groove weld).

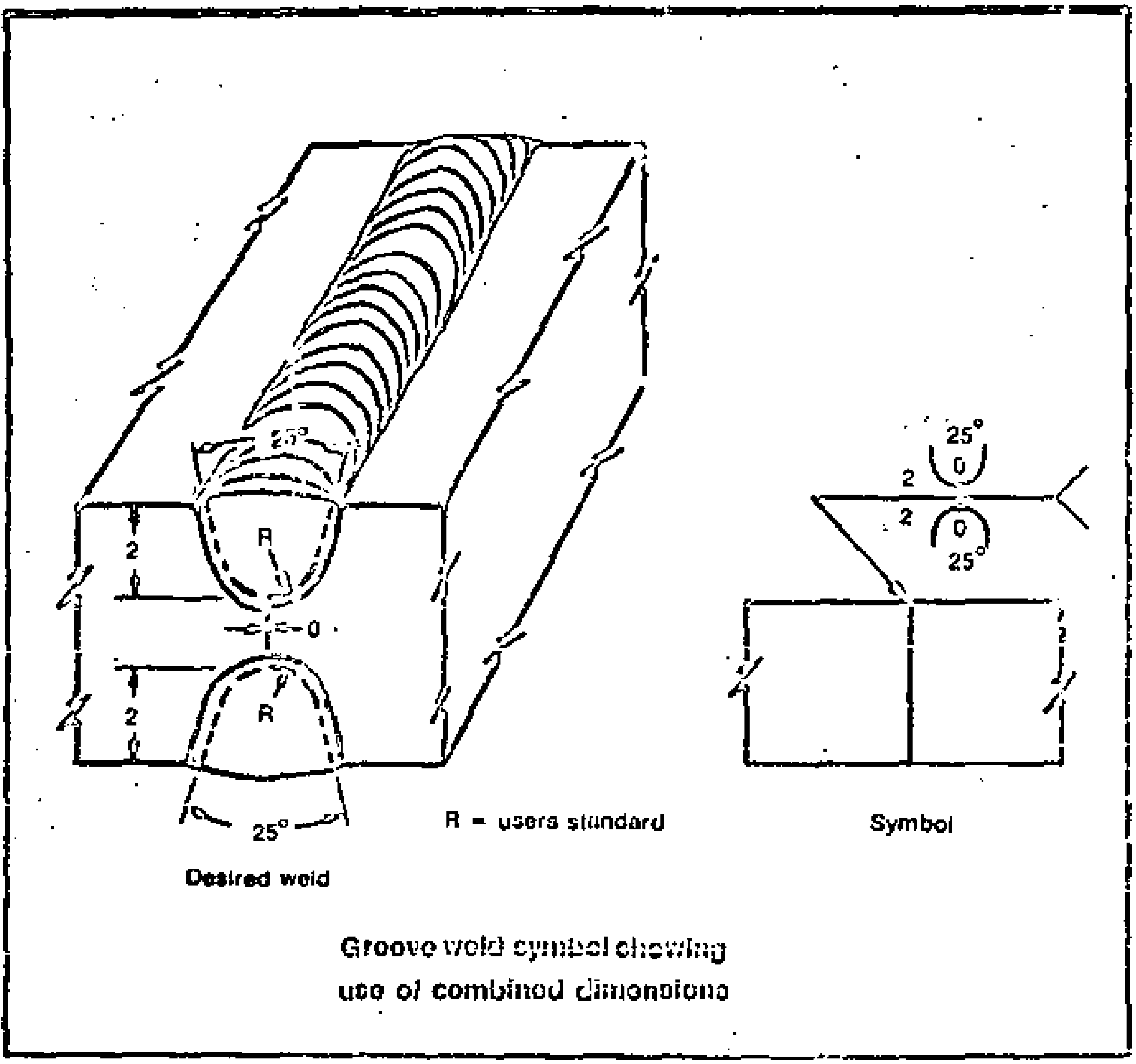
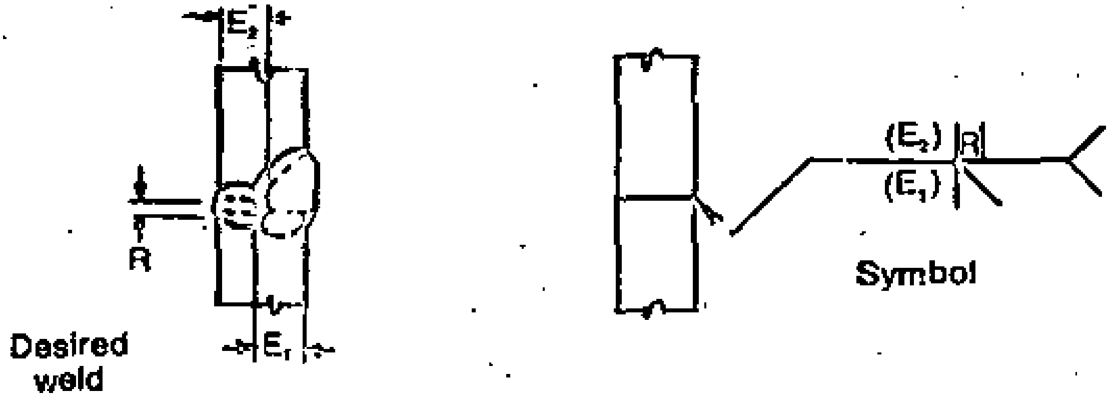
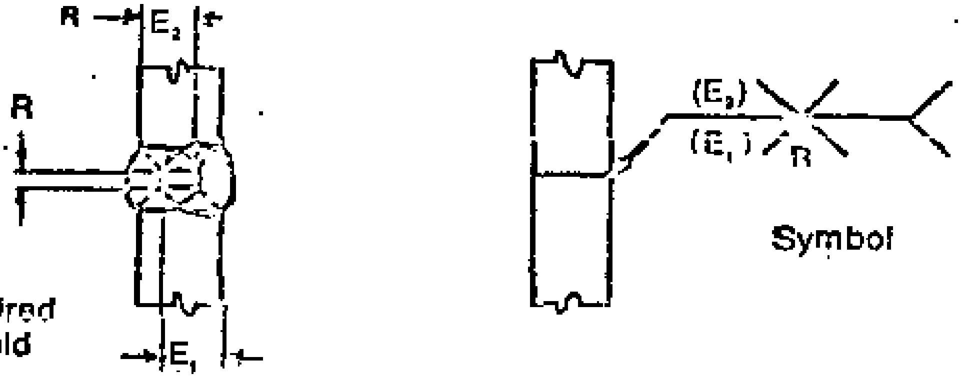


Fig. 24—Application of dimensions to groove weld symbols.



(E) Arrow side bevel-groove weld with root opening



(F) Both sides V-groove weld with root opening

Fig. 26 (cont.)—Designation of effective throat of groove welds with specified joint preparation.

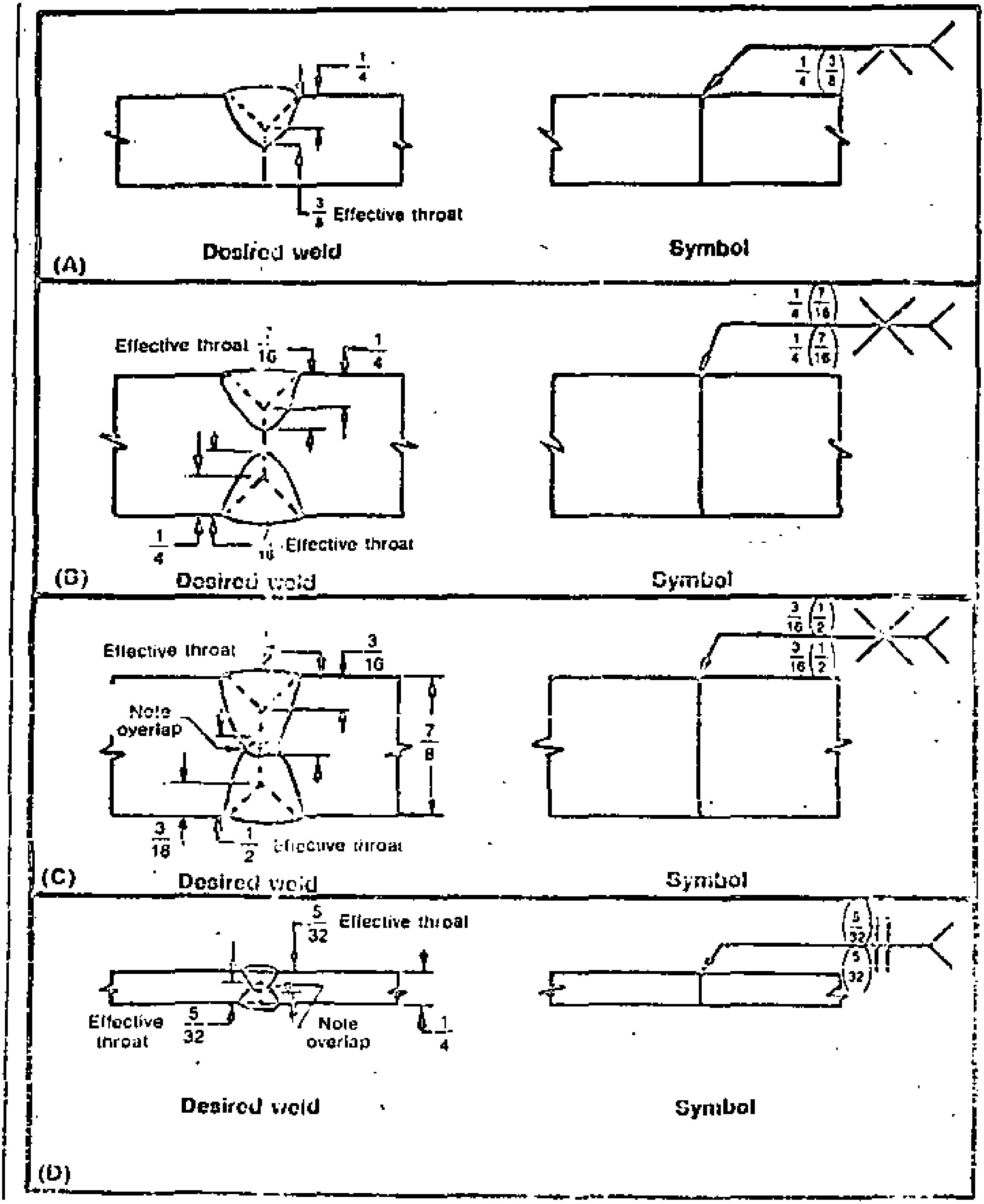


Fig. 26—Designation of effective throat of groove welds with specified joint preparation.

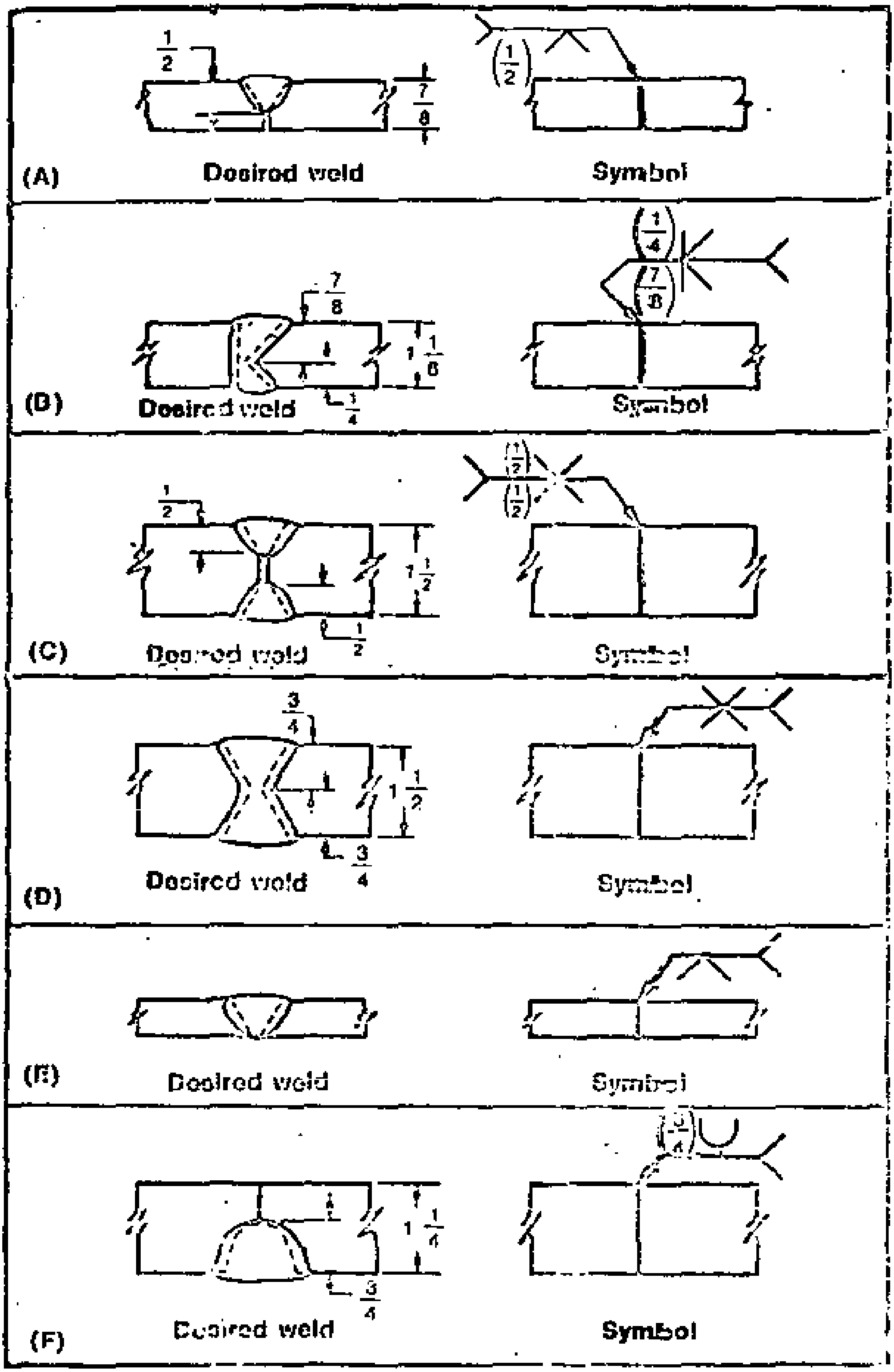


Fig. 25—Designation of effective throat of groove welds, size of bevel not specified.

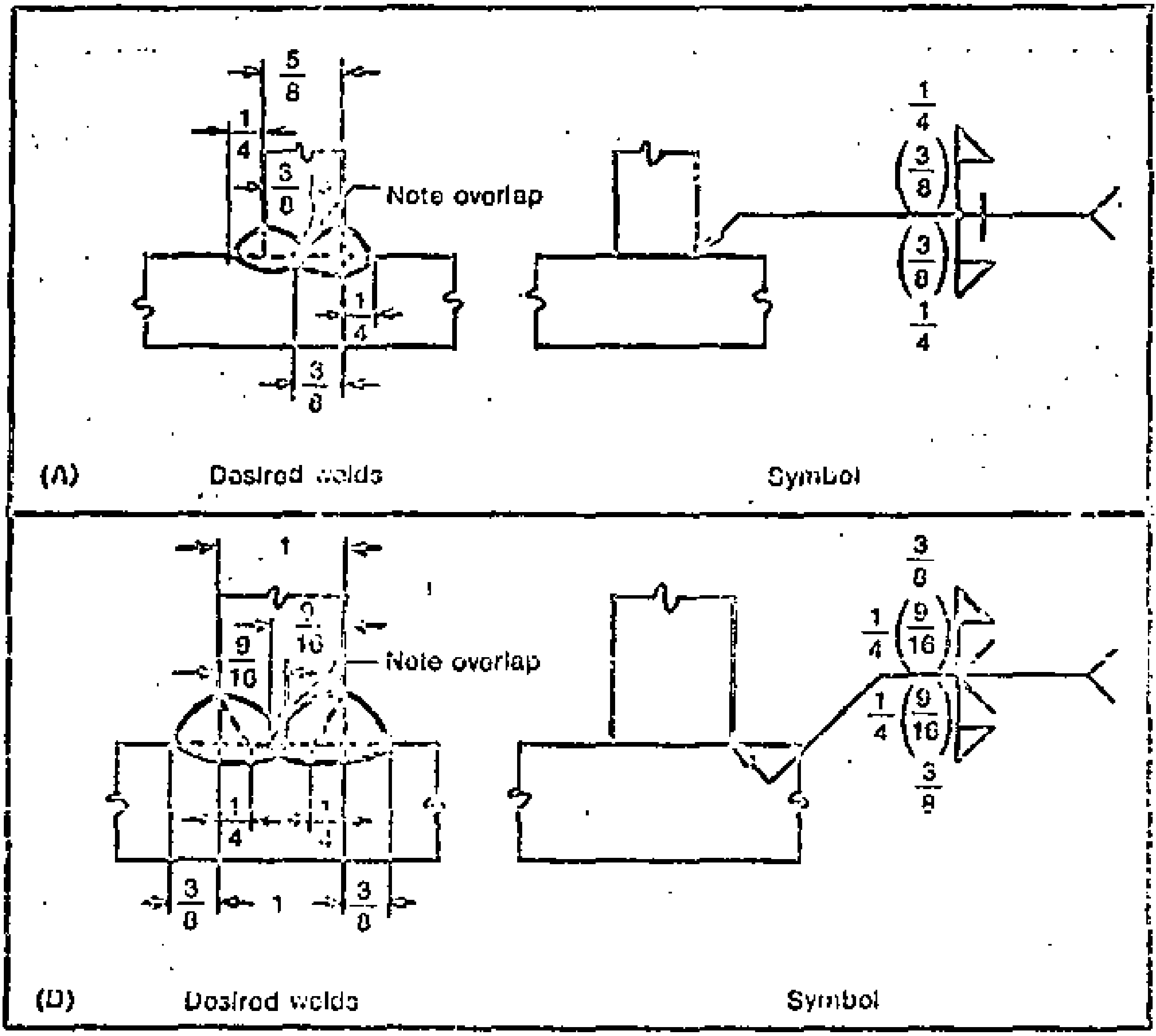


Fig. 27—Designation of effective throat of combined welds.

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

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 %

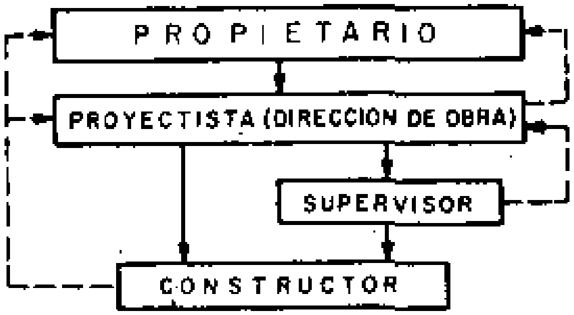
CARACTERISTICAS DE UNA BUENA SUPERVISION

Una buena supervisión debe ser :

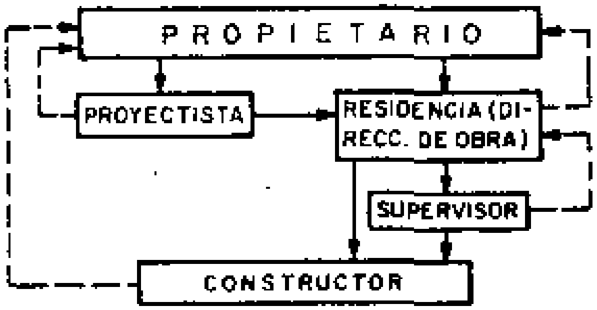
a).- OPORTUNA . La actitud del supervisor debe ser preventiva mas que correctiva, es decir antes de cada una de las etapas constructivas es cuando debe ejercer su principal función.

b).- CONTINUA . Todas las etapas constructivas son importantes y requieren de una inspección, de tiempo completo.

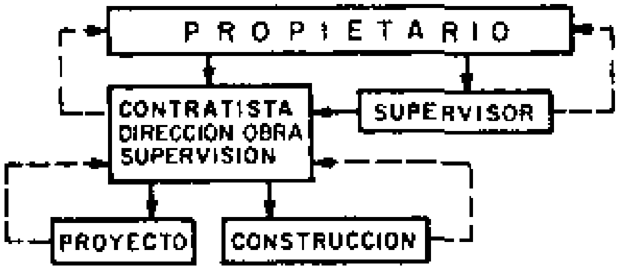
c).- ESTRICTA. El principal objetivo de la supervisión es lograr que la construcción se realice con apego a los planos , especificaciones y programa, sin embargo el supervisor debe mantener en mente, la idea de que la unificación de sus esfuerzos con los del contratista, redundará en los mejores beneficios 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:

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.

g) 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 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, rellenado, 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.

3) Montaje

a) Verificación de la forma de descarga y estiba de las piezas.

b) Verificación de la posición de elementos verticales, coincidencia de agujeros en anclas y apiete de tuercas.

c) Verificación inicial del plomeo y arriostramiento temporal en elementos verticales.

d) Verificación de la posición de elementos horizontales de su conexión con elementos temporales (clips de montaje).

e) Verificación de la nivelación y alineamiento de los elementos horizontales.

f) Verificación final del plomeo de los elementos verticales y autorización para la soldadura de campo o colocación de tornillos.

g) Inspección de la soldadura de campo. Esta etapa es similar a la inspección de la soldadura de taller.

h) Inspección de la colocación de tornillos. En las estructuras donde existan conexiones de campo atornilladas, se verificará lo siguiente:

Coincidencia de agujeros.

Número, diámetro y longitud de tornillos en cada junta, de acuerdo a planos de montaje.

Apriete de tuercas. De acuerdo con el tipo de tornillos, puede requerirse una técnica especial para el apriete. Tal es el caso de los tornillos de alta resistencia cuya técnica de colocación se describe por separado.

i) Verificación de la posición, número y dimensiones de los accesorios y elementos que se colocan en el campo.

j) Verificación del acabado final de las piezas. Esmerilado, remoción de accesorios auxiliares de montaje y retoques de pintura.

k) Control de avance de la fabricación y elaboración de reportes.

ESPECIFICACION PARA EL APRIETE DE TORNILLOS DE ALTA RESISTENCIA (A - 325 Y A-490)

APRIETE CON LLAVES CALIBRADAS

Cuando se emplean llaves calibradas para dar al tornillo la tensión especificada de acuerdo con la tabla (A), deben ajustarse de tal manera que la tensión inducida al tornillo sea del orden de 5 a 10% mayor que el valor indicado. Estas llaves deben calibrarse por lo menos una vez por cada día de trabajo, apretando por lo menos 3 tornillos típicos de cada diámetro por colocar, en un dispositivo capaz de indicar la tensión real en el tornillo. La llave de operación mecánica deben ajustarse para que se detengan al llegar a la tensión indicada. En las llaves de operación manual debe anotarse la torsión correspondiente a la tensión calibrada, para usarse en la instalación de todos los tornillos del lote probado. Las tuercas deben estar en movimiento apretado cuando se mide la tensión. Cuando se usen llaves calibradas para instalar varios tornillos en una misma junta, deben apretarse nuevamente los que se apretaron inicialmente, ya que pueden haberse aflojado al apretar los siguientes, hasta lograr que todos queden apretados a la tensión especificada.

APRIETE POR EL METODO DE GIRO DE LA TUERCA

Cuando se empleé este método para lograr la tensión indicada en la tabla (A), debe tenerse un número suficiente de tornillos apretados en condición de " apriete ajustado ", a fin de asegurar que todas las partes de la junta están en contacto pleno. La condición de " apriete ajustado " se define como la que se obtiene con unos cuantos golpes de una llave de impacto o con el esfuerzo máximo de un hombre que use una llave de tuercas ordinaria. A continuación de esta operación inicial, se colocarán los tornillos en los agujeros restantes, apretándolos hasta la condición de " apriete ajustado ". Entonces se apretarán adicionalmente todos los tornillos de la junta, haciendo girar la tuerca, la cantidad indicada en la tabla (B), comenzando por los tornillos colocados en la parte más rígida de la junta, siguiendo sistemáticamente hacia los bordes libres.

TABLA (A) TENSION EN LOS TORNILLOS

Diámetro del Tornillo (Pulg.)	Tensión Mínima en Kg	
	Torns. A - 325	Torns. A - 490
1/2	5430	6800
5/8	8620	10900
3/4	12700	15900
7/8	17650	22250
1	23150	29100
1 1/8	25400	36300
1 1/4	32200	46300
1 3/8	38600	55000
1 1/2	46800	67100

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

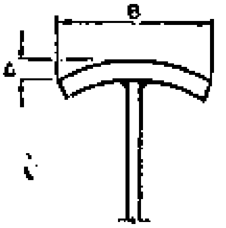
METODOS DE ENSAYO NO DESTRUCTIVO

	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.

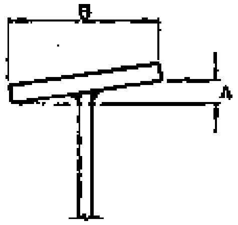
PERFILES COMPUESTOS DE TRES PLACAS SOLDADAS

Tolerancias permitidas

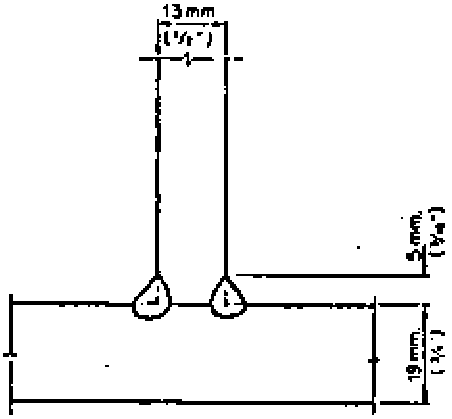


DEFLEXION DEL PATIN

$\Delta = \frac{B}{100}$



FUERA DE ESCUADRA DEL PATIN

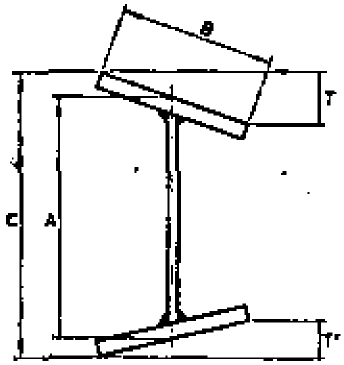


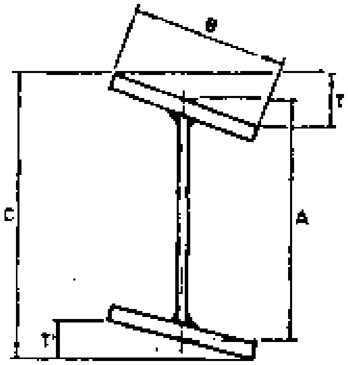
EJEMPLO TIPICO DE SOLDADURA

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	50 (3/16").	50 (3/16")
De 14 a 19 mm. (9/16" a 3/4") incl.	60 (1/4")	50 (3/16")
De 21 a 32 mm (13/16" a 1 1/4") incl.	80 (5/16")	7.0 (9/32")
De 33 a 51 mm (1 5/16" a 2") incl	100 (3/8")	80 (5/16")

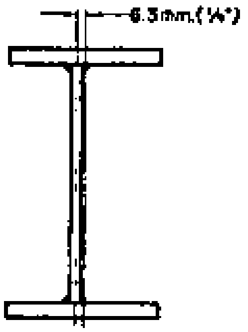
PERFILES COMPUESTOS DE TRES PLACAS SOLDADAS

Tolerancias permitidas





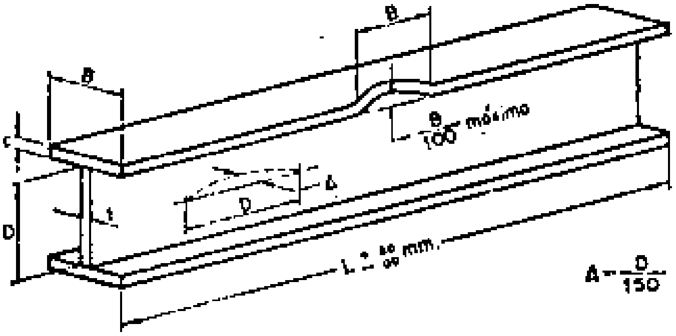
PERALTE NOMINAL "A" en mm. y Pulgadas	TOLERANCIAS PERMITIDAS en mm y Pulgadas					
	PERALTE "A"		PATIN "B"		Fuera de Paralelismo T + T'	C menos el peralte nominal A
	Mas	Menos	Mas	Menos		
Hasta 305 mm.(12") inclusive	3.2	3.2	6.3	4.8	8	8
	1/8	1/8	1/4	3/16	5/16	5/16
Mas de 305mm.(12") inclusive	3.2	3.2	6.3	4.8	10	8
	1/8	1/8	1/4	3/16	3/8	5/16



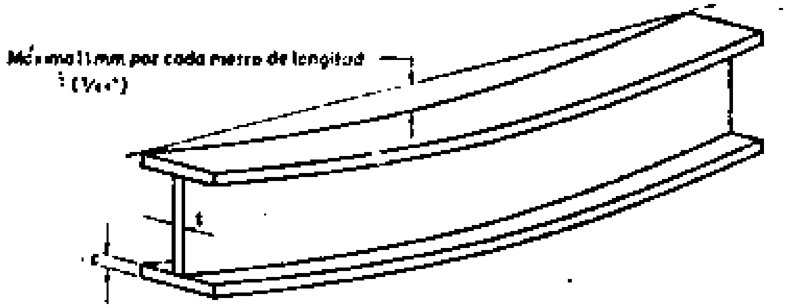
DESCENTRAMIENTO PERMITIDO DEL ALMA

PERFILES COMPUESTOS DE TRES PLACAS SOLDADAS

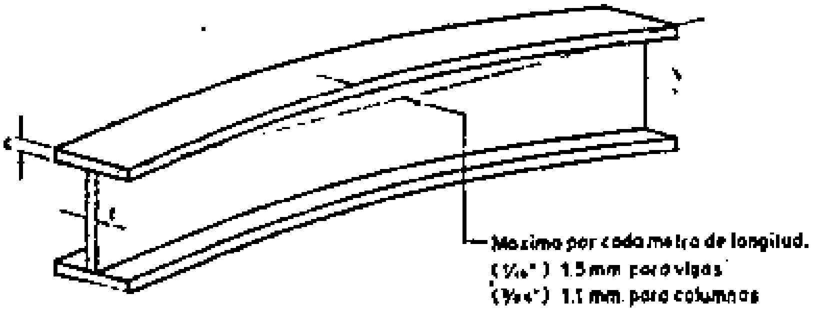
Tolerancias permitidas



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.

23

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 PRESTIGIO.

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 CONSTRUCCION, 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 EXIGEN LOS REGLAMENTOS VIGENTES ASI COMO LOS PLANOS ESTRUCTURALES, ARQUITECTONICOS Y DE INSTALACIONES Y LAS PRESENTES ESPECIFICACIONES.

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 CABO.

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 REPRESENTANTES 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, ESCORIA, OXIDOS, HUMEDAD, GRASA, PINTURA O CUALQUIER MATERIAL EXTRAÑO QUE DIFICULTE LA SOLDADURA O PRODUZCA HUMOS PERJUDICIALES.

SE PERMITE QUE HAYA COSTRAS DE LAMINADO QUE RESISTAN UN CEPILLADO VIGOROSO HECHO CON CEPILLO DE ALAMBRE, UNA CAPA ANTICORROSIVA 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 POSIBLE. 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 TAMANO DE LA SOLDADURA DE FILETE SE AUMENTARA EN UNA CANTIDAD IGUAL A LA SEPARACION. LA SEPARACION ENTRE LAS SUPERFICIES DE FALLA DE JUNTAS TRASLAPADAS Y ENTRE PARTES 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 SUFICIENTE 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 SENALA 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	JUNTAS EN LAS QUE SE TRABAJA LA RAIZ
	MM	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.	+ 1.5, -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-

SOLDADURAS DEFINITIVAS, Y SE LIMPIARAN CUIDADOSAMENTE.

LOS PUNTOS QUE NO SE INCORPOREN EN LAS SOLDADURAS DEFINITIVAS DEBERAN REMOVERSE, A MENOS QUE LA DIRECCION DE LA OBRA INDIQUE LO CONTRARIO.

COLOCACION DE LA SOLDADURA

SE ADMITE QUE LAS SOLDADURAS DE TALLER SE DEPOSITEN EN POSICION PLANA U HORIZONTAL Y, OCASIONALMENTE, EN POSICION VERTICAL. NO SE ADMITEN LAS SOLDADURAS DE TALLER SOBRE CABEZA, POR LO QUE HABRA QUE COLOCAR LAS PIEZAS QUE SE VAYAN A SOLDAR DE MANERA QUE NO SE TENGA QUE DEPOSITAR SOLDADURA EN ESA POSICION. SIEMPRE QUE SEA POSIBLE, LAS PIEZAS SE COLOCARAN DE MANERA QUE LA SOLDADURA PUEDA DEPOSITARSE EN POSICION PLANA.

AL ENSAMBLAR Y UNIR PARTES DE UNA ESTRUCTURA O MIEMBRO COMPUESTO, Y AL SOLDAR REFUERZOS A LOS MIEMBROS, EL PROCEDIMIENTO Y LA SECUENCIA DE LA SOLDADURA DEBEN SER TALES QUE SE EVITEN DISTORSIONES INNECESARIAS Y LOS ESFUERZOS DE CONTRACCION SE REDUZCAN A UN MINIMO.

SIEMPRE QUE SEA POSIBLE, LAS SOLDADURAS SE DEPOSITARAN EN UNA SECUENCIA TAL QUE SE BALANCEE EL CALOR PRODUCIDO POR ELLAS DURANTE EL PROCESO DE COLOCACION.

LA DIRECCION GENERAL DE COLOCACION DE LA SOLDADURA EN UN MIEMBRO SERA DESDE LOS PUNTOS EN QUE LAS PARTES ESTEN RELATIVAMENTE FIJAS EN POSICION, UNAS RESPECTO A OTRAS, Y HACIA LAS ZONAS EN QUE HAYA UNA MAYOR LIBERTAD DE MOVIMIENTO RELATIVO.

LAS JUNTAS EN LAS QUE SE ESPEREN CONTRACCIONES IMPORTANTES DEBERAN SOLDARSE EN GENERAL ANTES QUE AQUELLAS EN LAS QUE LAS CONTRACCIONES SEAN REDUCIDAS, ADEMAS, DURANTE LA COLOCACION DE LA SOLDADURA SE PROCURARA QUE LAS PARTES POR UNIR ESTEN TAN LIBRES COMO SEA POSIBLE.

TODOS LOS EMPALMES DE TALLER DE CADA UNA DE LAS PARTES COMPONENTES DE TRABES ARMADAS, VIGAS CON CUBREPLACAS O MIEMBROS COMPUESTOS, DEBEN HACERSE ANTES DE SOLDAR LAS PARTES ENTRE SI. LAS TRABES ARMADAS LARGAS PUEDEN HACERSE EMPALMANDO EN EL TALLER VARIOS TRAMOS, CADA UNO DE ELLOS HECHO DE ACUERDO CON EL PARRAFO ANTERIOR.

CUANDO SE HAGAN SOLDADURAS BAJO CONDICIONES EXTERIORES QUE RESTRINJAN SEVERAMENTE LAS CONTRACCIONES, LA SOLDADURA SE HARA -

PLACAS DE RESPALDO

CUANDO SE USE PLACA DE RESPALDO DE MATERIAL IGUAL AL METAL BASE, DEBE QUEDAR FUNDIDA CON LA PRIMERA CAPA DE METAL DE APORTACION. NO ES NECESARIO QUITAR LAS PLACAS DE RESPALDO. CUANDO SE ESPECIFIQUE QUE SE QUITEN LA REMOCION PUEDE HACERSE CON SOPLETE, DESPUES DE COMPLETAR LA SOLDADURA, TOMANDO LAS PRECAUCIONES NECESARIAS PARA NO DANAR EL METAL BASE NI EL DE APORTACION, Y DEJANDO LA SUPERFICIE DE LA SOLDADURA A RAS O LIGERAMENTE CONVEXA DE MANERA QUE SE CONSERVE EL TAMANO COMPLETO DE LA GARGANTA.

PLACAS DE EXTENSION

LOS EXTREMOS DE LAS SOLDADURAS DE PENETRACION COMPLETA DEBEN TERMINARSE DE UNA MANERA QUE ASEGURE SU SANIDAD. CUANDO SEA POSIBLE, SE HARA UTILIZANDO PLACAS DE EXTENSION. NO ES NECESARIO QUITARLAS DESPUES DE TERMINAR LA SOLDADURA, A MENOS QUE LO PIDA LA DIRECCION DE LA OBRA. EN ESTE CASO LOS BORDES EXTREMOS DE LA SOLDADURA DEBEN ALINEARSE Y ENPASARSE CON LOS DE LAS PARTES UNIDAS.

EN FORMA CONTINUA HASTA COMPLETARLA, O HASTA LLEVARLA A UN PUNTO QUE ASEGURE QUE NO SE PRESENTARAN GRIETAS ANTES DE QUE LA JUNTA SE ENFRIE POR DEBAJO DE LA TEMPERATURA MINIMA ESPECIFICADA DE CALENTAMIENTO E INTERPASO.

SOLDADURAS DE PENETRACION COMPLETA

EN PLACAS DE GRUESO NO MAYOR DE 6.3MM PUEDE LOGRARSE PENETRACION COMPLETA SIN PREPARAR LOS BORDES, ES DECIR, CON LOS CANTOS A ESCUADRA, DEPOSITANDO LA SOLDADURA MANUALMENTE POR AMBOS LADOS, EN POSICION PLANA, DEJANDO ENTRE LAS DOS PARTES UNA HOLGURA NO MENOR QUE LA MITAD DEL GRUESO DE LA PLACA MAS DELGADA.

EN TODOS LOS DEMAS CASOS DEBEN BISELARSE LOS EXTREMOS DE LAS PLACAS ENTRE LAS QUE SE VA A COLOCAR LA SOLDADURA PARA PERMITIR EL ACCESO DEL ELECTRODO, Y UTILIZARSE PLACA DE RESPALDO O, DE NO SER ASI, DEBE QUITARSE CON UN CINCEL O CON OTRO MEDIO ADECUANDO LA CAPA INICIAL DE LA RAIZ DE LA SOLDADURA, HASTA DESCUBRIR METAL SANO Y ANTES DE COLOCAR LA SOLDADURA POR EL SEGUNDO LADO, PARA LOGRAR FUSION COMPLETA EN TODA LA SECCION TRANSVERSAL.

LIMPIEZA

EN SOLDADURAS DEPOSITADAS EN VARIOS PASOS DEBE QUITARSE --- CUIDADOSAMENTE LA ESCORIA DE CADA UNO DE ELLOS ANTES DE COLOCAR- EL SIGUIENTE.

PRECALENTAMIENTO

ANTES DE EMPEZAR A DEPOSITAR MATERIAL DE APORTACION, EL METAL BASE DEBE PRECALENTARSE A LA TEMPERATURA INDICADA EN LA TABLA.

CUANDO EL METAL BASE ESTE A UNA TEMPERATURA INFERIOR A CERO GRADOS CENTIGRADOS DEBE PRECALENTARSE A 20 GRADOS CENTIGRADOS -- COMO MINIMO, O A LA TEMPERATURA INDICADA EN LA TABLA, SI ESTA ES MAYOR.

EL PRECALENTAMIENTO DEBE HACERSE DE MANERA QUE LAS SUPERFICIES DE LAS PARTES EN LAS QUE SE DEPOSITA LA SOLDADURA ESTEN A - UNA TEMPERATURA IGUAL O MAYOR QUE LA ESPECIFICADA EN UNA DISTANCIA NO MENOR QUE EL GRUESO DEL MATERIAL O QUE 7.6 CM, A AMBOS -- LADOS Y ADELANTE DE LA SOLDADURA. LA TEMPERATURA DE PRECALENTAMIENTO DEBE MANTENERSE COMO TEMPERATURA MINIMA DURANTE TODO EL

PROCESO DE COLOCACION DEL METAL DE APORTACION.

LAS TEMPERATURAS DE PRECALENTAMIENTO E INTERPASO DEBEN SER SUFICIENTES PARA EVITAR FORMACION DE GRIETAS, POR LO QUE EN SOLDADURAS MUY RESTRINGIDAS PUEDE SER NECESARIO UTILIZAR TEMPERATURAS MAS ALTAS QUE LAS INDICADAS EN LA TABLA.

NO SE EFECTUARA NINGUNA SOLDADURA CUANDO LA TEMPERATURA AMBIENTE SEA INFERIOR A -18 GRADOS CENTIGRADOS.

TABLA DE TEMPERATURA MINIMA DE PRECALENTAMIENTO Y DE INTERPASO, EN GRADOS CENTIGRADOS.

	PROCESO DE SOLDADURA	
GRUESO MAXIMO DEL METAL BASE EN EL PUNTO DE COLOCACION DE LA SOLDADURA. (MM)	ARCO ELECTRICO CON ELECTRODO RECUBIERTO QUE NO SEA DE BAJO CONTENIDO DE HIDROGENO.	ARCO ELECTRICO CON ELECTRODO RECUBIERTO DE BAJO CONTENIDO DE HIDROGENO. ARCO SUMERGIDO O ARCO ELECTRICO PROTEGIDO CON GASES INERTES.
HASTA 19, INCLUSIVE	NINGUNA (1)	NINGUNA (1)

MAS DE 19 HASTA 38, INCL.	70	10 (1)
MAS DE 38 HASTA 64, INCL.	110	70
MAS DE 64	150	110

(1) EXCEPTO CUANDO LA TEMPERATURA DEL METAL BASE SEA INFERIOR A 0 GRADOS CENTIGRADOS, EN CUYO CASO DEBE PRECALENTARSE A 20 GRADOS CENTIGRADOS, COMO MINIMO, CONSERVANDO ESTA TEMPERATURA DURANTE TODO EL PROCESO.

MARTILLEO

LAS CAPAS INTERMEDIAS DE SOLDADURAS DE VARIOS PASOS PUEDEN GOLPEARSE LIGERAMENTE CON UN MARTILLO MECANICO, USANDO UNA HERRAMIENTA DE PUNTA REDONDA. ESTA OPERACION SE EFECTUARA CUANDO LA SOLDADURA SE HAYA ENFRIADO A UNA TEMPERATURA A LA QUE SE SIENTA LIGERAMENTE CALIENTE AL TOCARLA CON LA MANO. NO SE MARTILLARA EL CORDON DE RAIZ NI LOS DE SUPERFICIE, NI TAMPOCO EL METAL BASE A LOS LADOS DE LA SOLDADURA. DEBE TENERSE CUIDADO PARA EVITAR TRASLAPE DE LA SOLDADURA O AGRIETAMIENTO DE ESTA O DEL METAL BASE

EL MARTILLEO TIENE POR OBJETO CONTROLAR LOS ESFUERZOS DE --

CONTRACCION EN SOLDADURAS GRUESAS.

ESPECIFICACIONES COMPLEMENTARIAS

LA TECNICA EMPLEADA PARA DEPOSITAR LA SOLDADURA, LA CALIDAD Y APARIENCIA DE LAS SOLDADURAS TERMINADAS, Y LOS METODOS UTILIZADOS PARA CORREGIR TRABAJOS DEFECTUOSOS, SE AJUSTARAN A LAS NORMAS DE LAS SECCIONES 4 Y 7 DE LA ULTIMA REVISION DEL CODIGO PARA SOLDADURA ESTRUCTURAL DE LA SOCIEDAD AMERICANA DE LA SOLDADURA. (STRUCTURAL WELDING CODE, AMERICAN WELDING SOCIETY, AWS - D1.1). ESE CODIGO SE TOMARA TAMBIEN COMO BASE EN TODOS LOS CASOS QUE NO ESTEN CUBIERTOS EN ESTAS ESPECIFICACIONES.

ACABADO

LOS EXTREMOS DE PARTES DE JUNTAS EN COMPRESION EN LOS QUE LA FUERZA SE TRANSMITA POR CONTACTO DIRECTO DEBERAN SER LISOS Y ESTAR EN INTIMO CONTACTO. PARA ELLO SE PREPARARAN POR MEDIO DE CEPILLADO, CORTES CON SIERRA U OTRO MEDIO ADECUADO.

TOLERANCIAS DE FABRICACION

EXCEPTO EN LOS CASOS EN QUE SE ESPECIFIQUE OTRA COSA, LOS MIEMBROS FORMADOS PRINCIPALMENTE POR UN PERFIL LAMINADO SE CONSIDERARAN RECTOS CUANDO ESTEN DENTRO DE LAS TOLERANCIAS PERMITIDAS POR LA ESPECIFICACION ASTM-A6 O CUANDO CUMPLAN LOS REQUISITO QUE SE FIJAN EN EL PARRAFO SIGUIENTE, Y LOS MIEMBROS ARMADOS SOLDADOS, REMACHADOS O ATORNILLADOS, CUANDO CUMPLAN LAS TOLERANCIAS PERMITIDAS PARA PERFILES DE ALAS ANCHAS EN ASTM-A6 O LAS PRESCRITAS EN EL PARRAFO SIGUIENTE.

EN MIEMBROS QUE TRABAJARAN EN COMPRESION EN LA ESTRUCTURA NO SE PERMITEN DESVIACIONES, CON RESPECTO A LA LINEA RECTA QUE UNE SUS EXTREMOS, MAYORES DE UN MILESIMO DE LA DISTANCIA ENTRE PUNTOS QUE ESTARAN SOPORTADOS LATERALMENTE EN LA ESTRUCTURA TERMINADA. LAS PIEZAS TERMINADAS EN TALLER DEBEN ESTAR LIBRES DE TORCEDURAS, DOBLECES Y JUNTAS ABIERTAS.

LA DISCREPANCIA MAXIMA, CON RESPECTO A LA LONGITUD TEORICA, QUE SE PERMITE EN MIEMBROS QUE TENGAN SUS DOS EXTREMOS CEPILLADOS PARA TRABAJAR POR CONTACTO DIRECTO, ES UN MILIMETRO. EN PIEZAS NO CEPILLADAS DE LONGITUD NO MAYOR DE DIEZ METROS SE PERMITE UNA DISCREPANCIA DE 1.5 MM, QUE AUMENTARA A 3MM CUANDO LA LONGITUD DE LA PIEZA ES MAYOR QUE LA QUE SE ACABA DE INDICAR.

IDENTIFICACION

TODAS LAS PIEZAS DEBEN SALIR DE LA PLANTA DEBIDAMENTE IDENTIFICADAS, CON MARCAS QUE CORRESPONDAN A LAS INDICADAS EN LOS -- PLANOS DE MONTAJE.

PINTURA

DESPUES DE INSPECCIONADAS Y APROBADAS, Y ANTES DE SALIR DEL TALLER, TODAS LAS PIEZAS QUE DEBAN PINTARSE SE LIMPIARAN CEPILLANDOLAS VIGOROSAMENTE, A MANO, CON CEPILLO DE ALAMBRE, O UTILIZANDO OTRO METODO APROPIADO, PARA ELIMINAR ESCAMAS DE LAMINACION, OXIDO, ESCORIA DE SOLDADURA, BASURA Y, EN GENERAL, TODA -- MATERIA EXTRANA. EL ACEITE Y LA GRASA SE QUITARAN POR MEDIO DE SOLVENTES.

LAS PIEZAS QUE NO REQUIEREN PINTURA DE TALLER SE DEBEN LIMPIAR TAMBIEN, DE MANERA ANALOGA A COMO SE INDICA EN EL PARRAFO - ANTERIOR.

A MENOS QUE SE ESPECIFIQUE OTRA COSA, LAS PIEZAS DE ACERO - QUE VAYAN A QUEDAR CUBIERTAS POR ACABADOS INTERIORES DEL EDI—

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.

A.- 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

DURANTE EL MONTAJE, LOS DIVERSOS ELEMENTOS QUE CONSTITUYEN LA ESTRUCTURA DEBEN SOSTENERSE INDIVIDUALMENTE O LIGARSE ENTRE SI POR MEDIO DE TORNILLOS, PERNOS O SOLDADURAS PROVISIONALES QUE PROPORCIONEN LA RESISTENCIA REQUERIDA EN ESTAS NORMAS, BAJO LA ACCION DE CARGAS MUERTAS Y ESFUERZOS DE MONTAJE, VIENTO O SISMO. ASI MISMO, DEBEN TENERSE EN CUENTA LOS EFECTOS DE CARGAS PRODUCIDAS POR MATERIALES, EQUIPO DE MONTAJE, ETC. CUANDO SEA NECESARIO, SE COLOCARA EN LA ESTRUCTURA EL CONTRAVENTEO PROVISIONAL REQUERIDO PARA RESISTIR LOS EFECTOS MENCIONADOS .

TOLERANCIAS

SE CONSIDERARA QUE CADA UNA DE LAS PIEZAS QUE COMPONEN UNA ESTRUCTURA ESTA CORRECTAMENTE PLOMEADA, NIVELADA Y ALINEADA, SI LA TANGENTE DEL ANGULO QUE FORMA LA RECTA QUE UNE LOS EXTREMOS DE LA PIEZA CON EL EJE DE PROYECTO NO EXCEDE DE 1/500. EN VIGAS TEORICAMENTE HORIZONTALES ES SUFICIENTE REVISAR QUE LAS PROYECCIONES VERTICAL Y HORIZONTAL DE SU EJE SATISFACEN LA CONDICION ANTERIOR.

DEBEN CUMPLIRSE, ADEMAS, LAS CONDICIONES SIGUIENTES

1.- EL DESPLAZAMIENTO DEL EJE DE COLUMNAS ADYACENTES A CUBOS DE ELEVADORES, MEDIDO CON RESPECTO AL EJE TEORICO, NO ES MAYOR DE 25 MM EN NINGUN PUNTO EN LOS PRIMEROS 20 PISOS. ARRIBA DE ESTE NIVEL, EL DESPLAZAMIENTO PUEDE AUMENTAR 1 MM POR CADA PISO ADICIONAL, HASTA UN MAXIMO DE 50 MM.

2.- EL DESPLAZAMIENTO DEL EJE DE COLUMNAS EXTERIORES, MEDIDO CON RESPECTO AL EJE TEORICO, NO ES MAYOR DE 25 MM HACIA FUERA DEL EDIFICIO, NI 50 MM HACIA DENTRO EN NINGUN PUNTO EN LOS PRIMEROS 20 PISOS. ARRIBA DE ESTE NIVEL, LOS LIMITES ANTERIORES PUEDEN AUMENTARSE EN 1.5 MM POR CADA PISO ADICIONAL, PERO NO DEBEN EXCEDER, EN TOTAL, DE 50 MM HACIA FUERA NI 75 MM HACIA DENTRO DEL EDIFICIO.

ALINEADO Y PLOMEADO

NO SE COLOCARAN REMACHES, PERNOS NI SOLDADURAS PERMANENTES HASTA QUE LA PARTE DE LA ESTRUCTURA QUE QUEDE RIGIDIZADA POR ELLOS ESTE ALINEADA Y PLOMEADA.

SOLDADURAS DE CAMPO

SI HAY PINTURA EN LAS SUPERFICIES ADYACENTES A LAS JUNTAS - QUE SE SOLDARAN EN EL CAMPO, ANTES DE EFECTUAR LA SOLDADURA LA - PELICULA DE PINTURA SE REDUCIRA A UN MINIMO POR MEDIO DE UN CEPILLADO VIGOROSO CON CEPILLO DE ALAMBRE.

PINTURA DE CAMPO

LA RESPONSABILIDAD DE LA LIMPIEZA Y RETOQUE, ASI COMO DE - LA PINTURA DE CAMPO EN GENERAL, SE ASIGNARA DE ACUERDO CON LAS - INDICACIONES ESPECIFICAS DE LA DIRECCION DE LA OBRA, Y SE ASENTARA EXPLICITAMENTE EN EL CONTRATO.

INSPECCION

EL FABRICANTE DEBE UTILIZAR LOS PROCEDIMIENTOS DE CONTROL - DE CALIDAD QUE SEAN NECESARIOS PARA ASEGURAR QUE TODO SU TRABAJO SE LLEVA A CABO DE ACUERDO CON ESTAS ESPECIFICACIONES. ADEMAS, EL MATERIAL Y LA MANO DE OBRA PUEDEN SER INSPECCIONADOS EN CUALQUIER MOMENTO POR REPRESENTANTES DE LA DIRECCION DE LA OBRA, SIN QUE ESTA INSPECCION RELEVE AL FABRICANTE DE SU RESPONSABILIDAD - SOBRE LA CALIDAD DE LA ESTRUCTURA.

LOS REPRESENTANTES DE LA DIRECCION DE LA OBRA REALIZARAN SU INSPECCION, HASTA DONDE SEA POSIBLE, EN LA PLANTA DEL FABRICANTE, Y ESTE LES DARA LAS FACILIDADES NECESARIAS PARA QUE TENGAN ACCESO A TODOS LOS LUGARES DONDE SE EFECTUA EL TRABAJO. LA INSPECCION SE PROGRAMARA DE MANERA QUE OCASIONE INTERRUPCIONES MINIMAS EN EL TRABAJO DEL FABRICANTE.

DEBEN REVISARSE LOS BORDES DE LAS PIEZAS EN QUE SE COLOCARA LA SOLDADURA, ANTES DE DEPOSITARLA, PARA CERCIORARSE DE QUE LOS BISELES, HOLGURAS, ETC., SON CORRECTOS Y ESTAN DE ACUERDO CON LOS PLANOS.

UNA VEZ REALIZADAS, LAS UNIONES SOLDADAS DEBEN INSPECCIONARSE OCULARMENTE Y SE REPARARAN TODAS LAS QUE PRESENTEN DEFECTOS APARENTES DE IMPORTANCIA, TALES COMO TAMANO INSUFICIENTE, CRATERES O SOCAVACIONES DEL METAL BASE. TODA SOLDADURA AGRIETADA DEBE RECHAZARSE. CUANDO HAYA DUDAS, Y EN JUNTAS IMPORTANTES DE PENETRACION COMPLETA, LA REVISION SE COMPLETARA POR MEDIO DE RADIOGRAFIAS Y/O ENSAYES NO DESTRUCTIVOS DE OTROS TIPOS.

EN CADA CASO SE HARA UN NUMERO DE PRUEBAS NO DESTRUCTIVAS DE SOLDADURA DE TALLER SUFICIENTE PARA ABARCAR LOS DIFERENTES TIPOS QUE HAYA EN LA ESTRUCTURA Y PODERSE FORMAR UNA IDEA GENERA

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).

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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:

.- 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.

.- 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.

.- 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.

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

.- 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 aceros 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 aplicaciones 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.

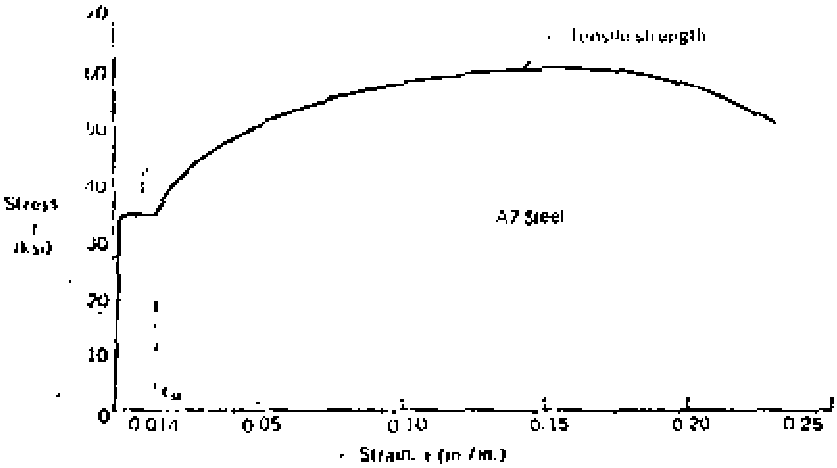

Fig. 2.1 Complete Tensile Stress-Strain Diagram for Structural Carbon Steel

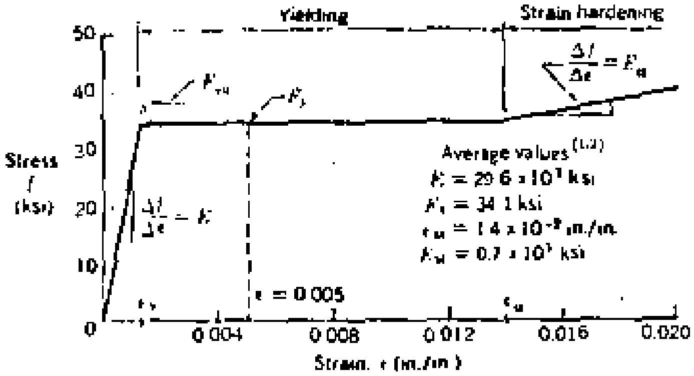

Fig. 2.2 Portion of Stress-Strain Diagram for A7 Steel

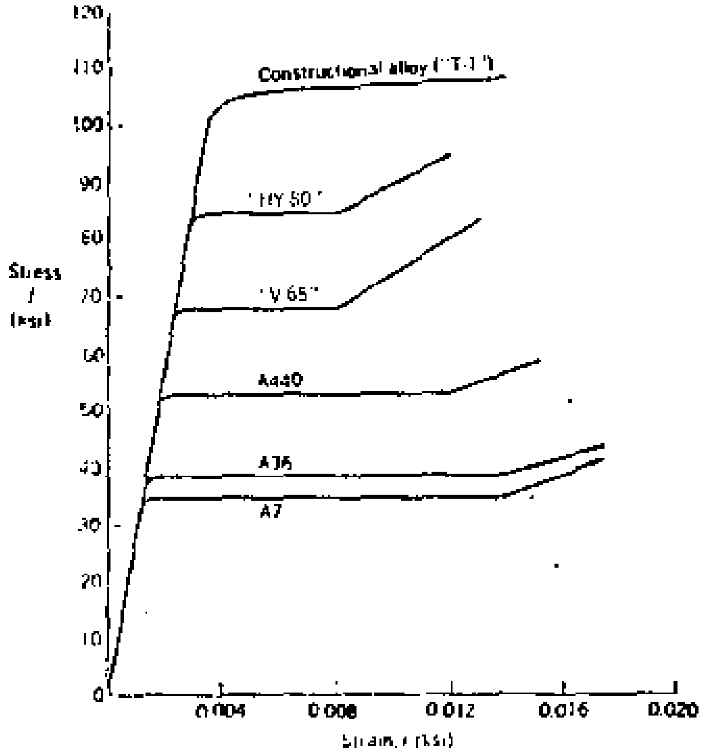

Fig. 2.12 Stress-Strain Curves for Various Steels

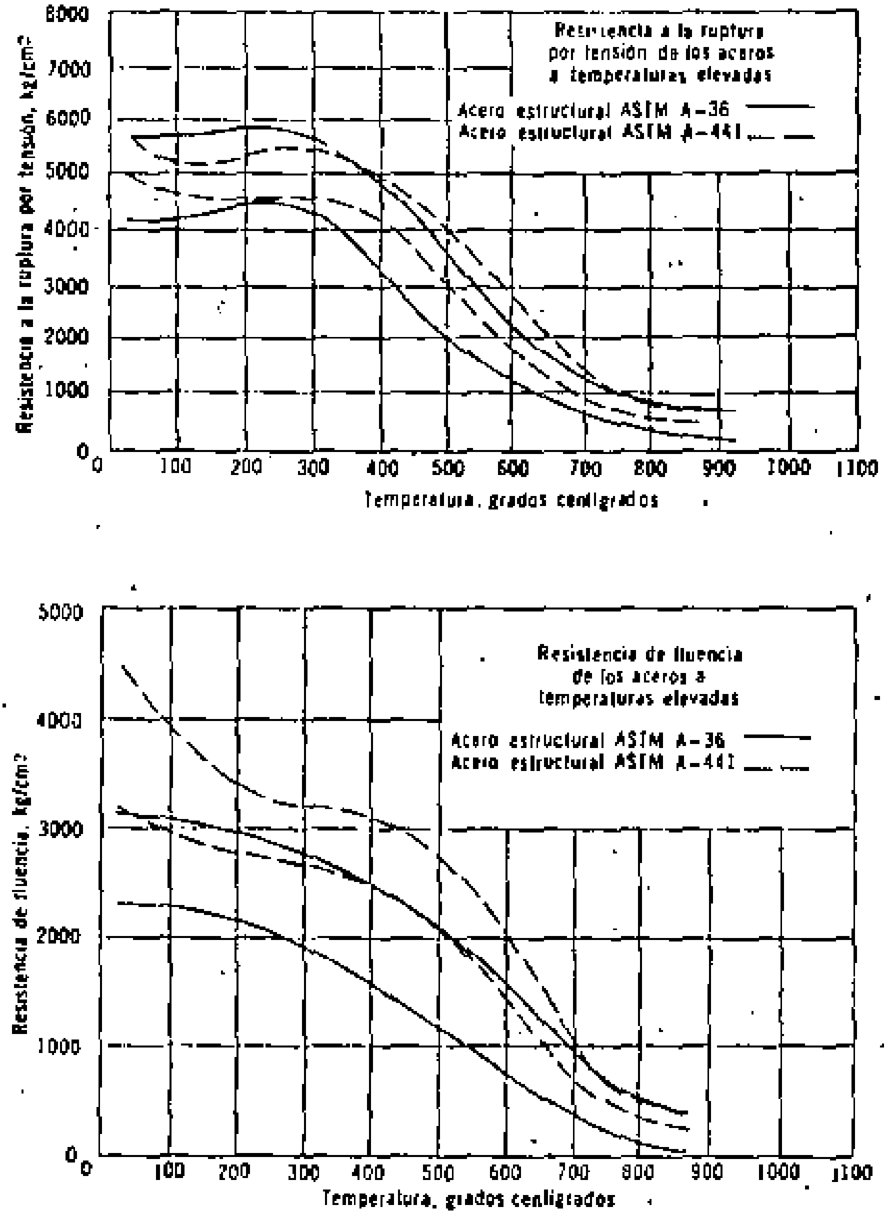

Fig. 2-1 Resistencia de tensión y de cedencia a temperaturas elevadas (Cortesía de la *Applied Research Laboratory, United States Steel Corp.*)

Tabla 2.1 Propiedades mecánicas de los aceros estructurales al carbono

Tipo ASTM	Espesor, pulgs	Punto de fluencia mínimo Kg/cm.²	Resistencia a la tensión Kg/cm.²
A7		2320	4220-5275
A373	hasta 4	2250	4050-5275
A36	hasta 8	2530	4080-5625

Table 2.2 Chemical Requirements for Structural Carbon Plates[2.1]

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	.20	—	—
	Over ½ to 1	.25	.60-.90	—
	Over 1 to 2	.26	.60-.90	.15-.30
	Over 2 to 4	.27	.60-.90	.15-.30

Tabla 2.2 Propiedades mecánicas de los aceros de alta resistencia y baja aleación

Tipo ASTM	Espesor, pulgs.	Punto de fluencia mín Kg/cm.²	Resistencia a la tensión Kg/cm.²
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[2.1]

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 tratados y templados

Tipo ASTM	Espesor, pulgs.	Punto de fluencia en mín Kg/cm.²	Resistencia a la tensión Kg/cm.²
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	7385-9490

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		2 510	3 570	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 aleacion, 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 zinc	A446	A	0.1736	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

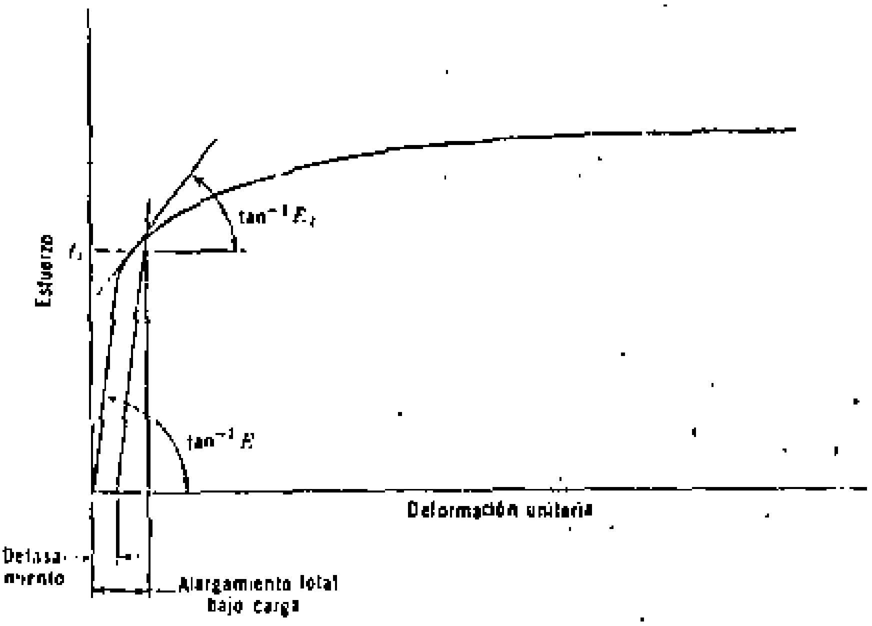

Fig. 2-5 Curva esfuerzo-deformación típica para láminas y tiras de acero.

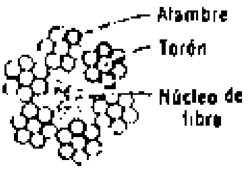

Fig. 2-7 Sección transversal de un cable de alambre.

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

Recubrimiento, Clase	Diámetro plgs.	Resistencia min. a la tensión, Kg/cm.²	Resistencia min. de fluencia a 0.7 % de extensión bajo carga	Elongación total min. 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

bla 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 0.197	0.90	1.80	2.70
Más de 0.187	1.00	2.00	3.00

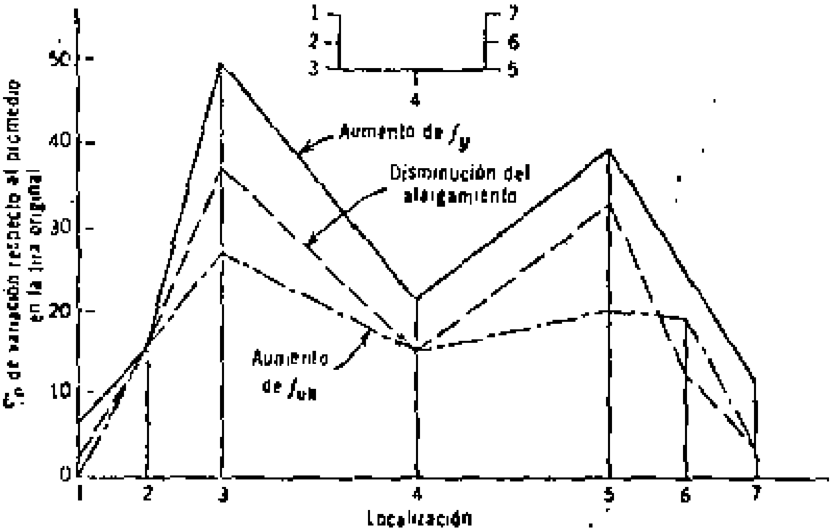

Fig. 2.6 Comparación de las propiedades mecánicas del material original y de la sección suministrada, en siete localizaciones específicas indicadas.[4]

Tabla 2.7 Propiedades mecánicas de los torones para puentes recubiertos de zinc

Normas establecidas por la "Wire Rope Technical Board"

Diámetro nominal plg.	*Resistencia mínima de ruptura en toneladas métricas* Clase "A" recubrimiento completo	Clase "A" recubrimiento en los alambres interiores Clase "B" recubrimiento en los alambres exteriores	Clase "A" recubrimiento en los alambres interiores Clase "C" 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	75.2	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	5.59
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	9.45	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	187.5	13.61	11.00
1 15/16	208.7	205.0	200.5	14.52	11.74
2	222.3	218.6	215.0	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	281.2	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	529.5	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	9.482
1 7/8	148.7	8.97	10.901
2	168.7	10.19	12.384
2 1/8	190.5	11.50	13.997
2 1/4	213.1	12.89	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	314.7	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	32.508
3 1/2	503.4	31.25	37.604
3 3/4	550.5	35.71	43.022
4	662.1	40.18	46.956

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

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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	4780 a 5765	20
A502 Grado 1	1970	3655 a 4360	24
A502 Grado 2	2670	4780 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 E60	3515 y 3870	4360 y 4710	17,22,25
Series E70	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)
A307-64T	Low carbon steel external and internal threaded standard fastener	All	55	None
A325-64T	High-strength steel bolts for structural steel joints	½–1	120	85
		1⅛, 1	115	78
		1¼–1½	105	74
A490-63	High-strength alloy steel bolts for structural steel joints	½–4	160‡	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	Diámetro Real		Construcción	Area de Acero		Resistencia Real (min.)	Peso/Metro Lineal
Nominal	Plg.	m.m.		Plg.^{2}	m.m^2	Kgs.	Kg/m
5/16"	0.324"	0.823	6/1	6.28×10^{-2}	40.49	6 030	.307
3/8 "	0.382"	0.970	6/1	8.72×10^{-2}	56.24	8 370	.409
1/2 "	0.506"	1.285	6/1	15.01×10^{-2}	96.81	14 030	.775
5/8 "	0.632"	1.605	12/6/1	23.42×10^{-2}	151.00	21 890	1.184
3/4 "	0.748 "	1.900	12/6/1	32.74×10^{-2}	211.17	29 600	1.718
7/8 "	0.882 "	2.240	12/6/1	45.65×10^{-2}	294.44	41 280	2.352
1 "	1.002 "	2.545	18/12/6/1	58.65×10^{-2}	378.29	53 040	3.061
1 1/8 "	1.134 "	2.880	18/12/6/1	75.07×10^{-2}	484.3	76 000	4.004
1 1/4"	1.282 "	3.256	18/12/6/1	82.70×10^{-2}	533.4	92 000	4.833
1 3/8"	1.390 "	3.530	18/12/6/1	91.03×10^{-2}	587.2	103 000	5.788
1 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 CARGA 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).

1. 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 incluír 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.

TABLA 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 ácido	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 calidad comercial.

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

2.2.4. Requisitos mecánicos.

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

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

2.2.4.3. A menos que se especifique otra cosa, las barras lisas y con rosca usadas para anclaje, se sujetarán a pruebas mecánicas y deberán cumplir con los requisitos de tensión indicados en 2.2.4.4; los pernos con cabeza usados para propósitos de anclaje y todas las tuercas, cumplirán con los requisitos de la Norma Oficial 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 lo especificado en 2.2.4.2, debe cumplir los requisitos de tensión especificados en - la Tabla II.

TABLA II.

REQUISITOS DE TENSION

	Placas perfiles y barras
Resistencia a la tensión en kg/mm^2	
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/mm^2	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 que no sean soleras menores de 12.70 mm de espesor o diámetro, no necesitan sujetarse a pruebas de tensión por el fabricante.

2.2.4.4.3. Para materiales menores de 7.94 mm en espesor o diámetro, se podrá hacer una deducción de 1.25 % del porcentaje de alargamiento en especímenes de longitud calibrada de 203.20 mm especificado en la Tabla II, por cada disminución 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 deberá hacer una deducción de 0.50 % del porcentaje de alargamiento en especímenes de longitud calibrada de 203.20 mm, especificado en la Tabla II por cada aumento de 3.18 mm en el espesor o diámetro especificado arriba de 19.05 mm. Esta deducción no deberá exceder del 3 %.

2.2.4.4.5. Para material con espesor o diámetro mayor de 88.90 mm, se debe hacer una deducción de 0.50 % en el porcentaje de alargamiento en especímenes de longitud calibrada de 50.80 mm especificado en la Tabla II, por cada aumento de 12.70 mm en el espesor o diámetro especificado arriba de 88.90 mm. Esta deducción no deberá 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 a 180º sin agrietarse la parte exterior de la porción doblada sobre un mandril, cuyo diámetro debe tener una relación con el espesor del espécimen de acuerdo con la Tabla III.

TABLA III.

REQUISITOS DE LA PRUEBA DE DOBLADO.

Espesor del material, en mm	Relación del diámetro del mandril al espesor del espécimen, para placas, perfiles 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 manganeso de cada soplada y una determinación de cobre cuando se especifique acero al cobre 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. METODOS 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 - 65.

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".

OMITE 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 1.

NORMA DE PRODUCTO

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 alargamiento 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 de 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.

TABLA 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.

Camesa, S.A.

Manufacturas Métalicas Ajax, S.A.

Comisión Federal de Electricidad (IIIE)

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 1, 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 d comprobació
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 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 l rras que no sean soleras, con espesor o diámetro menor de 12.7 mm, no están su 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 minución de 0.79 mm en el espesor o diámetro especificado por abajo de 7.94 m be hacerse una deducción de 1.25% del porcentaje de alargamiento en 203.20 mm longitud calibrada especificado en la Tabla II.

2.1.4.2. Doblado.

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

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

ASTM - A - 529 - 70

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 L
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 barras de acero estructural de baja aleación y alta resistencia. Esta Norma est 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; hoga 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 tensió indicados en la Tabla I.

N O R M A D E P R O D U C T O

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 180° 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 cumple 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

Hojalata y Lámina, S.A.

Secretaría de Obras Públicas

Tubacero, S.A.

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Altos Hornos de México, S.A.

Secretaría de Recursos Hidráulicos (Depto. Ingeniería Experimental)

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 y 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

ASTM A 440 70

4.4. PARTICIPANTES

Secretaría de Obras Públicas

Hojalata y Lámina, S. A.

Fundidora Monterrey, S. A.

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Centro de Investigación de Materiales (UNAM)

Instituto Mexicano del Petróleo

Comisión Federal de Electricidad

Norma Definitiva

NORMA DE CALIDAD [illegible]

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 si
tura, de acero al carbono, formados en caliente de secciones cuadradas, rectangu
res o de secciones especiales para usos estructurales en construcciones metálica
ra 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 sec
circular para estas mismas aplicaciones, se recomienda el uso de tubos cubiertos
la Norma Oficial DGN-B-10 en vigor, los tubos cubiertos por la Norma Oficial DGN
177 en vigor, dependiendo su elección de la calidad del tubo requerida, adiciona
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 dato
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 a 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 má 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.

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 longitudinalment 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 180° sin mostrar grietas en el exterior de la porción doblada. El doblado debe ser hecho alrededor de un mandril co 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 profundida 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 cubierto apropiados.

2.2.5.3.3. El metal de la soldadura proyectado debe ser removido por amolado para p ducir 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 previo y en este caso las tolerancias dimensionales deben ser las mismas que aquellas mostradas en esta Norma para tipos y tamaños similares.

TABLA IV.

DIMENSIONES MAS COMUNES PARA TUBOS ESTRUCTURALES CUADRADOS

Tamaños exteriores dimensionales a través de los lados planos cm	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 IV. (Continuación)

63.50 por 63.50	6.43	3,58
	8.32	4,78
	10,57	6,35
76.20 por 76.20	8.60	3,96
	10.21	4,78
	13.10	6,35
88.90 por 88,90	10.24	3,96
	12.11	4,78
	15.63	6.35
	18.38	7,92
101.60 por 101,60	13.85	4,78
	17.89	6,35
	21,61	7,92
	25.06	9.53
	31.07	12,70
127.00 por 127,00	17,65	4,78
	22,95	6,35
	27,92	7,92
	32,65	9.53
	41.19	12,70
152.40 por 152.40	21.44	4,78
	28.00	6,35
	34.26	7,92
	40.24	9,53
	51.31	12,70
177.80 por 177.80	25.08	4,78
	32.80	6,35
	40.17	7,92
	47.22	9,53
	60.34	12,70
203.20 por 203.20	37.86	6,35
	46.49	7,92
	54.81	9,53
	70.46	12,70
	84.80	15,88
	97.18	19,05
254.00 por 254.00	47.90	6,35
	59.14	7,92
	69.99	9.53
	90.70	12,70
	110.09	15.88
	128.18	19.05
	160.41	[illegible]

TABLA V.

Tamaños exteriores, dimensionales a través de los lados mm	Peso teórico kg/m	Espesor nominal de pared calculado mm
76.20 por 50.80	6.42	3.58
	8.32	4.78
	10.57	6.35
101.60 por 50.80	8.60	3.96
	10.21	4.78
	13.10	6.35
101.60 por 76.20	10.24	3.96
	12.11	4.78
	15.63	6.35
	18.88	7.92
127.00 por 76.20	13.85	4.78
	17.89	6.35
	21.61	7.92
	25.06	9.53
152.40 por 76.20	15.74	4.78
	20.42	6.35
	24.78	7.92
	28.86	9.53
152.40 por 101.60	17.65	4.78
	22.95	6.35
	27.93	7.92
	33.53	9.53
	42.75	12.70
177.80 por 127.00	21.44	4.78
	28.01	6.35
	34.26	7.92
	40.24	9.53
	51.31	12.70
203.20 por 101.60	21.44	4.78
	28.01	6.35
	34.26	7.92
	40.24	9.53
	51.31	12.70
203.20 por 152.40	25.08	4.78
	32.80	6.35
	40.17	7.92
	47.22	9.53
	60.34	12.70

TABLA 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	Tolerancía (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
Tolerancía 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

10.

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.

11.

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-139-2966.	Norma Oficial de "Requisitos Generales para Tubos de Acero al Carbono, de Aleaciones Ferríticas y de Aceros Austeníticos Aleados.

12.

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

1. 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 contínua, 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.

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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).

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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/m², 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 presente 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 re -

gistrada, 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 atado 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.

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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 alcado 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 228.60 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 por 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.

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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"

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"

BIBLIOGRAFIA

ASTM A 6 1971

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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 X 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 X 343 hasta 493 W 84 X 300 hasta 386 W 76 X 291 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 506 hasta 610 W 36 X 361 hasta 536 W 30 X 305 hasta 483	W 36 X 556 hasta 1397	W 36 X 1537 has
s M	Hasta 52 kg/m	Más de 52 kg/m			
es S	Hasta 52 kg/m	Más de 52 kg/m			
es HP		Hasta 152 kg/m	Más de 152 kg/m		
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 d 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.

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 %.

15.-

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)

Elemento	Limite o intervalo máximo, en %	Tolerancia en más, limite máximo o en menos, limite 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.

16.-

TABLA [illegible]

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

r, en mm (a)	Tolerancia en más, en el promedio del peso del lote(b), expresada en % de los pesos nomina 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	De ma
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	
6.2 a 101.6 excl	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.0	4.5	
1.6 a 152.4 excl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5	
2.4 a 203.2 excl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
3.2 a 254.0 excl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
4.0 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

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

3. La t[redacted]cia en sobrepeso para las planchas circular[redacted] plantilla, aisladas, es de 1.66 veces las can[redacted]ades de e Tabla.

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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 %.
Niquel	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 %.

TABLA 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, aplíquese la Tabla I.

TABLA III

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

ESPECIFICADOS		Tolerancias en el promedio del peso del lote, (a) expresadas en % de los pesos nominales, para los anchos siguientes:																						
Kg/m²		De 1219 y mayores		Mayores de 1219 a 1524 excl		De 1524 a 1629 excl		De 1629 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 mayo
o	a excl																							
–	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	---	---	---	---	---	---	---
9	61	4.0	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	4.0	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	---
	85	3.5	3.0	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
5	98	3.5	2.5	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
	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
2	145	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
5	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
5	398	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
3	598	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
8	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
7	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
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
4	1992	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
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
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

l 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 bla.

ANCIAS EN ANCHO Y LONGITUD PARA PLANCHAS DE 38.10 mm Y MENORES EN ESPESOR, CORTADAS CON CIZALLA; EN LONGITUD SOLAMENTE SE AP.
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 espesor 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 5 incl	
				PESOS							
				Hasta 75 excl		De 75 hasta 125- excl		De 125 hasta 199 excl		De 199 hasta incl	
LONGITUD		ANCHO									
	a exclusive	De	a exclusive	Ancho	Longitud	Ancho	Longitud	Ancho	Longitud	Ancho	Lon
29	----	----	1.52	14.3	50.8	19.1	54.0	22.2	57.2	25.4	6
		1.52	2.13	19.1	50.8	22.2	54.0	25.4	57.2	28.6	6
		2.13	2.74	19.1	50.8	22.2	54.0	25.4	57.2	31.8	6
		2.74	----	25.4	50.8	28.6	60.3	31.8	63.5	34.9	7

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
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		Tolerancia, en más, en mm
De	a exclusive	(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					
		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
De	a exclusive						
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.

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TABLA 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 par 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.

TABLA 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. 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.

TABLA 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 l 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.

24.-

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 De	 a exclusive	Tolerancia en más(a), en mm, para todos los anchos o longitudes especificados
-----	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 Mayor de	 hasta	Peso, en kg/m^2 De	 hasta	Ancho, en mm	Tolerancia en flechas para espesores y anchos dados, en mm.
----	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 trata de planchas, es la curvatura horizontal de la orilla, medida sobre la longitud total de la plancha en una posición plana.

TABLA XIII

…IA 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

TABLA 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/m^2		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 3048 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
50.8	199	398	9.5	12.7	12.7	14.3	14.3	15.9	15.9	15.9	17.5	28.6
101.6	398	797	7.9	9.5	11.1	12.7	12.7	12.7	12.7	14.3	15.9	22.2
152.4	797	1195	9.5	11.1	12.7	12.7	14.3	14.3	15.9	19.1	22.2	22.2
203.2	1195	1594	11.1	12.7	12.7	15.9	17.5	19.1	22.2	22.2	25.4	25.4
254.0	1594	1992	12.7	12.7	15.9	17.5	19.1	20.6	22.2	23.8	25.4	25.4
304.8	1992	2390	12.7	15.9	19.1	20.6	22.2	23.8	25.4	25.4	25.4	25.4
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 to
gitud 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/mm^2 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]ila y las notas correspondientes, cubren l[redacted]rancias para una planeza de planchas circular[redacted] de plant b[redacted]se en la dimensión máxima de dichas planchas[redacted]

TABLA XV

* [illegible] PLANEZA PARA PLANCHAS DE ACERO DE ALTA RESISTENCIA Y BAJA ALEACION, RECTANGULARES CORTADAS CON CIZALLA, EN [illegible]
[illegible] CIRCULARES Y CORTADAS CON PLANTILLA, LAMINADAS EN CALIENTE O TRATADAS TERMICAMENTE (no aplicables a acero de [illegible].)

[illegible]		Peso, en kg/m²		Tolerancias en mm a partir de una superficie plana, para los anchos, en mm siguientes (a).										
	a exclusive	De	a exclusive	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 [illegible] a 4267 excl	[illegible] res
[illegible]	6.4	----	50	20.6	28.6	34.9	47.6	50.8	57.2	60.3	66.7	69.9	----	---
[illegible]	9.5	50	75	19.1	23.8	28.6	34.9	44.5	47.6	50.8	57.2	60.3	----	----
[illegible]	12.7	75	100	19.1	22.2	23.8	23.8	28.6	33.3	38.1	41.3	47.6	69.9	79.4
[illegible]	19.1	100	149	15.9	19.1	20.6	22.2	25.4	28.6	31.8	34.9	41.3	57.2	[illegible]
[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	66.
[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	57.
[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	44.
[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	38.
[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.
[illegible]	254.0	1594	2041	19.1	20.6	23.8	25.4	28.6	31.8	33.3	34.9	38.1	38.1	38.
[illegible]	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.
[illegible]	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.

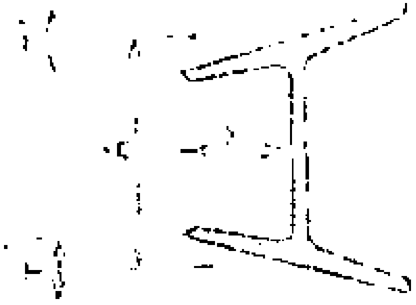
lerancia en planeza en sentido longitudinal. Se considera longitud a la dimensión mayor, la tolerancia a lo largo de toda la ngitud no debe exceder de la cantidad especificada para el ancho, en planchas hasta de 3.6 m de longitud o en cualquier tramo 6 m en planchas de mayor longitud.

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.

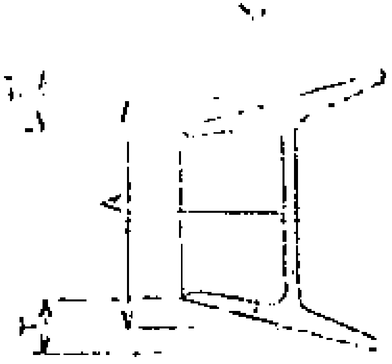
Esta tabla y las notas cubren las tolerancias en planeza para planchas circulares y de plantilla, tomando como base las dimensiones máximas de dichas planchas.

T A B L A [illegible]

[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".

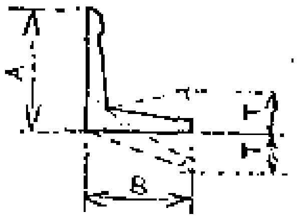
T + T' se aplica cuando los patines de las canales están in hacia adentro o hacia afuera.

S E C C I O N	TAMAÑO NOMINAL, en mm	"A" peralte (a), en mm		"B" ancho del patín, en mm		T + ra d dra'' por
		Arriba del teórico	Abajo del teórico	Arriba del teórico	Abajo del teórico	
estándar	76.2 hasta 177.8 Mayor de 177.8 hasta 355.6 Mayor de 355.6 hasta 609.6	2.4 3.2 4.8	1.6 2.4 3.2	3.2 4.0 4.8	3.2 4.0 4.8	
"H" de laminador estándar	101.6 127.0 152.4 hasta 203.2	2.4 2.4 3.2	1.6 1.6 2.4	3.2 4.0 4.8	3.2 4.0 4.8	
les	76.2 hasta 177.8 Mayor de 177.8 hasta 355.6 Mayores de 355.6	2.4 3.2 4.8	1.6 2.4 3.2	3.2 3.2 [illegible]	3.2 4.0 4.8	

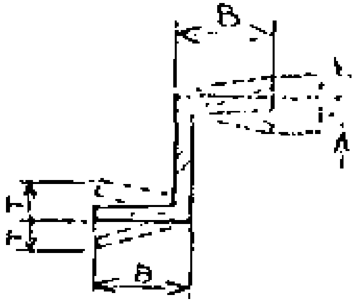
T A B L A XVII

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

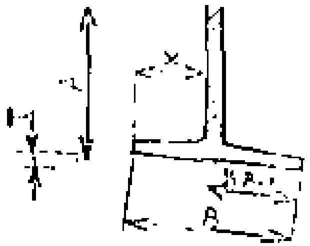
Angulo



Angulo de bulbo



Zeta



Te

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

S E C C I O N	TAMAÑO, en mm		"A" peralte, en mm		"B" ancho del patín o longitud del ala, en mm		"T" fuera de escuadra en mm por mm de "B"	"E" des tramien del alm máximo, mm
	Mayor de	hasta	Arriba del teórico	Abajo del teórico	Arriba del teórico	Abajo del teórico		
los (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)	-
los 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

TABLA 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

TABLA XIX

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

PERFILES	TOLERANCIAS
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 milimetro 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.

TABLA XX

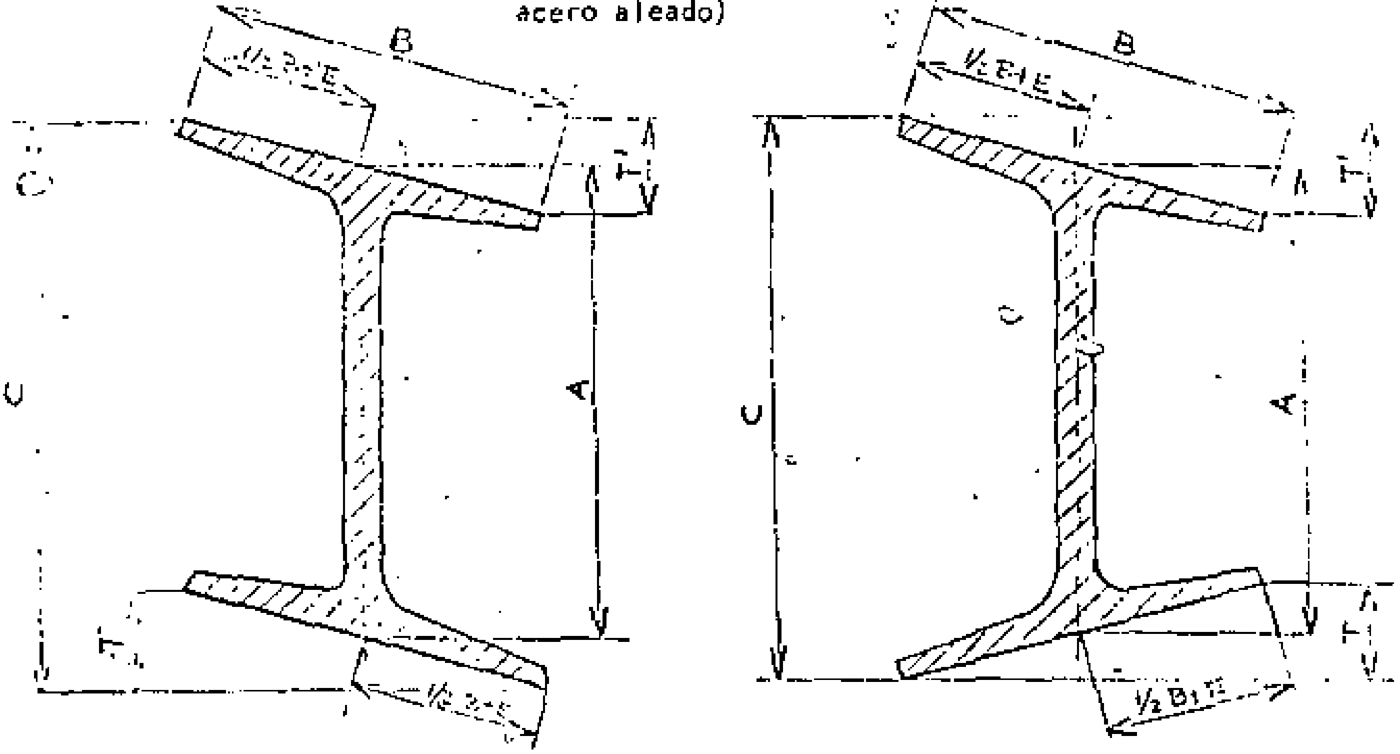
TOLERANCIAS EN RECTITUD, PARA PERFILES ESTANDAR (no aplicables a acero aleado)

	TOLERANCIAS, 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.

30.-

TABLA 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 patin, 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 patin

C se mide paralela al alma

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

TABLA 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.

TABLA 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 d escuadr del ext mo maqu nado, e 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.

TABLA XXIV

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

Perfiles de patín ancho	Tolerancias
lecha (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.

TABLA 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.

TABLA 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.

TABLA 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 por "fuera de escuadra" d 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.-

TABLA XXVIII

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

Tamaño de la te (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	
Hasta 31.8	1.19	1.19	0.25	0.25	0.13	0.51	0.79
Mayores de 31.8 hasta 50.8	1.59	1.59	0.30	0.30	0.25	0.51	1.59
Mayor de 50.8 a 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.

TABLA XXIX

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

ANCHO, 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 m 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 fu ra 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 posible

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 alcado)

Las tolerancias en barras medio caña, óvalos y otros perfiles barra especiales, qu

TABLA XXXIII

OLERANCIA 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.

TABLA XXXIV

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

amaño de redondos, cuadrados-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		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
ayor de	hasta	Mayor de	hasta	Mayor de	hasta					
-----	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
tras dimensiones		----	----	-----	-----	15.88	25.40	38.10	50.60	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.

TABLA XXXV

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

amaño de secciones redondas, uadradas. hexagonales; anchos e soleras y dimensión máxima e otras secciones, en mm		Tolerancia en mm, para longitudes en m siguientes:			
		Hasta 3.66 m		Mayor de 3.66 m	
ayor de	hasta	En más	En menos	En más	En menos
-----	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

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.

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 tolerancias

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PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

Complemento

ING. RAUL GRANADOS G.

Julio,1979.

MAYO 22 DE 1979

REPORTE DE AVANCE DE FABRICACION Y MONTAJE

CONCEPTO		NO. TOTAL DE PIEZAS	FABRICACION			MONTAJE		PESO DE PIEZAS FABRICADAS (KGS)
			PIEZAS ARMADAS	PIEZAS SOLDADAS	PIEZAS PINTADAS	PIEZAS COLOCADAS	PIEZAS SOLDADAS	
TRABE TA- 1	NIVEL 1	1	1	1	1	1	0	0.
ARMADURA TP- 1 D	NIVEL 1	2	2	2	2	2	2	4130.
	NIVEL 2	2	2	2	2	2	2	4130.
ARMADURA TP- 1 I	NIVEL 1	2	2	2	2	2	2	4130.
	NIVEL 2	2	2	2	2	2	2	4130.
ARMADURA TP- 1AD	NIVEL 2	1	1	1	1	1	1	2026.
ARMADURA TP- 1AI	NIVEL 2	1	1	1	1	1	1	2026.
ARMADURA TP- 2	NIVEL 1	7	7	7	7	7	7	6496.
	NIVEL 2	7	7	7	7	7	7	6495.
ARMADURA TP- 2A	NIVEL 2	1	1	1	1	1	0	1025.
ARMADURA TP- 3 D	NIVEL 1	1	1	1	1	1	1	2051.
	NIVEL 2	1	1	1	1	1	1	2051.
ARMADURA TP- 3 I	NIVEL 1	1	1	1	1	1	1	2051.
	NIVEL 2	1	1	1	1	1	1	2051.
ARMADURA TP- 3AD	NIVEL 1	2	2	2	2	2	2	4184.
	NIVEL 2	2	2	2	2	2	2	4184.
ARMADURA TP- 3AI	NIVEL 1	2	2	2	2	2	2	4184.
ARMADURA TP- 3BD	NIVEL 1	1	1	1	1	1	1	2090.
	NIVEL 2	1	1	1	1	1	1	2090.
ARMADURA TP- 3BI	NIVEL 1	1	1	1	1	1	1	2090.
	NIVEL 2	1	1	1	1	1	1	2090.
ARMADURA TP- 4 D	NIVEL 1	2	2	2	2	1	1	4630.
ARMADURA TP- 4 I	NIVEL 1	2	2	2	2	0	0	4630.
ARMADURA TP- 4AD	NIVEL 1	1	1	1	1	1	1	2309.
ARMADURA TP- 4AI	NIVEL 1	1	1	1	1	1	1	2309.
ARMADURA TP- 4BD	NIVEL 1	3	3	3	3	3	3	6873.
	NIVEL 2	3	3	3	3	3	3	6873.
ARMADURA TP- 4BI	NIVEL 1	3	3	3	3	3	3	6873.
	NIVEL 2	2	2	2	2	2	2	4592.
ARMADURA TP- 4CD	NIVEL 1	3	3	3	3	3	3	6726.
	NIVEL 2	3	3	3	3	3	3	6726.
ARMADURA TP- 4CI	NIVEL 1	3	3	3	3	3	3	6725.
	NIVEL 2	2	2	2	2	2	2	4484.
ARMADURA TP- 5	NIVEL 1	2	2	2	2	2	2	6238.
	NIVEL 2	1	1	1	1	1	1	3119.
ARMADURA TP- 5A	NIVEL 1	2	2	2	2	2	2	5556.
	NIVEL 2	1	1	1	1	1	1	2978.
ARMADURA TP- 6 D	NIVEL 1	2	2	2	2	2	2	2406.
	NIVEL 2	2	2	2	2	2	2	2406.
ARMADURA TP- 6 I	NIVEL 1	2	2	2	2	2	2	2406.
	NIVEL 2	2	2	2	2	2	2	2406.
ARMADURA TP-10 D	NIVEL 1	1	1	1	1	1	1	2018.
	NIVEL 2	1	1	1	1	1	1	2018.
ARMADURA TP-10 I	NIVEL 1	1	1	1	1	1	1	2018.
	NIVEL 2	1	1	1	1	1	1	2018.
ARMADURA TP-10AD	NIVEL 1	1	1	1	1	1	1	1972.

	NIVEL 2	1	1	1	1	1	1	1972.
ARMADURA TP-15AI	NIVEL 1	1	1	1	1	1	1	1972.
	NIVEL 2	1	1	1	1	1	1	1972.
ARMADURA TP-15B	NIVEL 1	4	4	4	4	4	4	8404.
	NIVEL 2	2	2	2	2	2	2	4202.
ARMADURA TP-15C	NIVEL 2	1	1	1	1	1	1	2181.
ARMADURA TP-15I	NIVEL 2	1	1	1	1	1	1	2181.
ARMADURA TP-17	NIVEL 2	1	1	1	1	1	1	2706.
ARMADURA TP-17A	NIVEL 2	1	1	1	1	1	1	2765.
ARMADURA TP-17B	NIVEL 2	1	1	1	1	1	1	2771.
ARMADURA TP-17C	NIVEL 2	1	1	1	1	0	0	2756.
ARMADURA TP-17D	NIVEL 2	1	1	1	1	1	1	2769.
ARMADURA TP-17E	NIVEL 2	1	1	1	1	1	1	2771.
ARMADURA TP-19 D	NIVEL 1	1	1	1	1	1	1	1854.
ARMADURA TP-19 I	NIVEL 1	1	1	1	1	1	1	1854.
	NIVEL 2	1	1	1	1	1	1	1854.
ARMADURA TP-20 D	NIVEL 1	1	1	1	1	0	0	2234.
ARMADURA TP-20 I	NIVEL 1	1	0	0	0	0	0	0.
	NIVEL 2	1	1	1	1	0	0	2266.
ARMADURA TP-21 D	NIVEL 1	1	1	1	1	1	1	1715.
	NIVEL 2	1	1	1	1	1	1	1715.
ARMADURA TP-21 I	NIVEL 1	1	1	1	1	1	1	1715.
	NIVEL 2	1	1	1	1	1	1	1715.
ARMADURA TP-22 D	NIVEL 1	2	2	1	1	1	1	2567.
ARMADURA TP-22 I	NIVEL 1	2	2	2	2	2	2	5134.
ARMADURA TP-22AD	NIVEL 1	2	1	1	1	1	1	2591.
ARMADURA TP-22AI	NIVEL 1	2	2	2	2	1	1	5182.
ARMADURA TP-22BD	NIVEL 2	2	1	1	1	1	1	2606.
ARMADURA TP-22BI	NIVEL 2	2	1	1	1	1	1	2606.
ARMADURA TP-22CD	NIVEL 2	2	1	1	1	1	1	2595.
ARMADURA TP-22CI	NIVEL 2	2	2	2	2	2	2	5190.
ARMADURA TP-22D	NIVEL 2	1	0	0	0	0	0	0.
ARMADURA TP-23 D	NIVEL 1	1	1	1	1	0	0	2166.
	NIVEL 2	1	1	1	1	0	0	2166.
ARMADURA TP-23 I	NIVEL 1	1	1	1	1	0	0	2166.
ARMADURA TP-23AD	NIVEL 1	1	1	1	1	0	0	2164.
	NIVEL 2	1	1	1	1	0	0	2164.
ARMADURA TP-23AI	NIVEL 1	1	1	1	1	1	1	2154.
ARMADURA TP-24 D	NIVEL 1	4	4	4	4	4	4	5396.
	NIVEL 2	2	2	2	2	2	2	2698.
ARMADURA TP-24 I	NIVEL 1	4	4	4	4	4	4	5396.
	NIVEL 2	2	2	2	2	2	2	2598.
ARMADURA TP-24A	NIVEL 1	1	1	1	1	0	0	1392.
ARMADURA TP-24B	NIVEL 1	1	1	0	0	0	0	0.
	NIVEL 2	1	0	0	0	0	0	0.
ARMADURA TP-24CD	NIVEL 2	2	2	2	2	2	2	2782.
ARMADURA TP-24CI	NIVEL 2	2	2	2	2	2	2	2782.
ARMADURA TP-24D	NIVEL 2	1	1	1	1	0	0	1415.
ARMADURA TP-27	NIVEL 2	1	1	0	0	0	0	0.
ARMADURA TP-27A	NIVEL 2	1	1	0	0	0	0	0.
ARMADURA TP-28	NIVEL 2	1	1	1	1	1	1	2307.
ARMADURA TP-28A	NIVEL 2	1	1	1	1	1	1	2318.
ARMADURA TP-28B	NIVEL 2	1	1	1	1	0	0	2309.
ARMADURA TP-29	NIVEL 2	1	1	1	1	1	1	3597.
ARMADURA TP-29A	NIVEL 2	1	1	1	1	1	1	3746.

ARMADURA 3T- 1 D	NIVEL 3	2	2	2	2	2	2	2684.
ARMADURA 3T- 1 I	NIVEL 3	2	2	2	2	2	2	2684.
ARMADURA 3T- 2 D	NIVEL 3	1	1	1	1	1	1	2247.
ARMADURA 3T- 2 I	NIVEL 3	1	1	1	1	1	1	2247.
ARMADURA 3T- 3	NIVEL 3	1	1	1	1	1	1	1980.
ARMADURA 3T- 4 D	NIVEL 3	2	2	2	2	2	2	4248.
ARMADURA 3T- 4 I	NIVEL 3	2	2	2	2	2	2	4248.
ARMADURA 3T- 5 D	NIVEL 3	1	1	1	1	1	1	2759.
ARMADURA 3T- 5 I	NIVEL 3	1	1	1	1	1	1	2759.
ARMADURA 3T- 6	NIVEL 3	1	1	1	1	1	1	1414.
ARMADURA 3T- 7 D	NIVEL 3	5	4	4	4	3	3	6052.
ARMADURA 3T- 7 I	NIVEL 3	2	2	2	2	2	2	3026.
ARMADURA 3T- 8	NIVEL 3	2	2	2	2	2	2	3676.
ARMADURA 3T- 9	NIVEL 3	1	1	1	1	1	1	2341.
ARMADURA 3T-10	NIVEL 3	1	1	1	1	1	1	2299.
ARMADURA 3T-11	NIVEL 3	1	1	1	1	1	1	2226.
ARMADURA 3T-12	NIVEL 3	6	6	6	6	5	6	11574.
ARMADURA 3T-13 D	NIVEL 3	2	2	2	2	2	2	4062.
ARMADURA 3T-13 I	NIVEL 3	2	2	2	2	2	2	4062.
ARMADURA 3T-14 D	NIVEL 3	2	2	2	2	2	2	4192.
ARMADURA 3T-14 I	NIVEL 3	2	2	2	2	2	3	4192.
ARMADURA 3T-15	NIVEL 3	6	6	6	6	6	6	8160.
ARMADURA 3T-16 D	NIVEL 3	6	5	5	5	4	4	10055.
ARMADURA 3T-16 I	NIVEL 3	5	5	4	4	3	3	6264.
ARMADURA 3T-17 D	NIVEL 3	3	2	2	2	2	2	4586.
ARMADURA 3T-17 I	NIVEL 3	2	2	2	2	1	2	4586.
ARMADURA 3T-18 D	NIVEL 3	1	1	1	1	1	1	2246.
ARMADURA 3T-18 I	NIVEL 3	1	1	1	1	1	1	2246.
ARMADURA 3T-19 D	NIVEL 3	1	1	1	1	1	1	1827.
ARMADURA 3T-19 I	NIVEL 3	1	1	1	1	1	1	1827.
ARMADURA 3T-20 D	NIVEL 3	1	1	1	1	1	1	2702.
ARMADURA 3T-20 I	NIVEL 3	1	1	1	1	1	1	2702.
ARMADURA 3T-21	NIVEL 3	1	1	1	1	1	1	2449.
ARMADURA 3T-22 D	NIVEL 3	2	2	2	2	2	1	5404.
ARMADURA 3T-22 I	NIVEL 3	2	2	2	2	2	1	5404.
ARMADURA 3T-23 D	NIVEL 3	2	0	0	0	0	0	0.
ARMADURA 3T-23 I	NIVEL 3	2	2	1	1	1	1	2460.
ARMADURA 3T-24	NIVEL 3	1	1	1	0	0	0	0.
ARMADURA 3T-25	NIVEL 3	1	1	1	1	1	1	3065.
ARMADURA 3T-26	NIVEL 3	1	1	1	1	1	0	2946.
ARMADURA 3T-27	NIVEL 3	1	0	0	0	0	0	0.
	TOTAL	246	232	226	225	205	206	447637.

MAYO 22 DE 1979

REPORTE DE AVANCE DE FABRICACION Y MONTAJE

4

CONCEPTO		NO. TOTAL DE PIEZAS	FABRICACION PIEZAS ARMADAS	FABRICACION PIEZAS SOLDADAS	FABRICACION PIEZAS PINTADAS	MONTAJE PIEZAS COLOCADAS	MONTAJE PIEZAS SOLDADAS	PESO DE PIEZAS FABRICADAS (KGS)
ARMADURA TS- 1 D	NIVEL 1	2	2	2	2	2	2	1924.
	NIVEL 2	2	2	2	2	2	2	1924.
ARMADURA TS- 1 I	NIVEL 1	2	2	2	2	2	2	1924.
	NIVEL 2	2	2	2	2	2	2	1924.
ARMADURA TS- 1A	NIVEL 1	7	7	7	7	7	7	6531.
	NIVEL 2	7	7	7	[illegible]	7	6	6531.
ARMADURA TS- 1B	NIVEL 1	24	24	23	23	21	21	22194.
	NIVEL 2	21	21	21	21	21	21	19438.
ARMADURA TS- 1C	NIVEL 1	28	24	24	24	19	17	[illegible]
	NIVEL 2	16	17	16	16	15	14	[illegible]
ARMADURA TS- 1D	NIVEL 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	NIVEL 2	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7224.
ARMADURA TS- 1ED	NIVEL 1	2	2	2	2	2	2	1976.
	NIVEL 2	1	1	1	1	1	1	955.
ARMADURA TS- 1EI	NIVEL 1	2	2	2	2	2	2	1971.
	NIVEL 2	1	1	1	1	1	1	[illegible]
ARMADURA TS- 1FD	NIVEL 1	2	2	2	2	2	2	1976.
	NIVEL 2	1	1	1	1	1	1	939.
ARMADURA TS- 1FI	NIVEL 1	2	2	2	2	2	2	1978.
	NIVEL 2	1	1	1	1	1	1	959.
ARMADURA TS- 1GD	NIVEL 1	6	6	6	6	6	5	5274.
	NIVEL 2	5	5	5	5	5	5	4395.
ARMADURA TS- 1GI	NIVEL 1	6	6	6	6	6	5	5274.
	NIVEL 2	5	6	5	5	5	5	4395.
ARMADURA TS- 1H	NIVEL 1	12	12	10	12	2	2	9370.
	NIVEL 2	3	3	3	3	2	2	2811.
ARMADURA TS- 1ID	NIVEL 1	2	2	2	2	2	2	1958.
	NIVEL 2	2	2	2	2	2	2	[illegible]
ARMADURA TS- 1II	NIVEL 1	2	2	2	2	2	2	1858.
	NIVEL 2	2	2	2	2	2	2	1858.
ARMADURA TS- 1J	NIVEL 2	6	5	3	3	3	3	2525.
ARMADURA TS- 1K	NIVEL 1	1	1	1	1	1	0	927.
	NIVEL 2	1	1	1	1	1	0	927.
ARMADURA TS- 1LD	NIVEL 2	1	1	1	1	1	1	879.
ARMADURA TS- 1LI	NIVEL 2	1	1	1	1	1	1	879.
ARMADURA TS- 1M	NIVEL 1	1	1	1	1	1	0	528.
	NIVEL 2	1	0	0	0	0	[illegible]	0.
ARMADURA TS- 2	NIVEL 1	18	17	15	15	9	9	[illegible]
	NIVEL 2	12	12	12	12	6	6	[illegible]
ARMADURA TS- 2A	NIVEL 1	6	6	6	6	6	5	5772.
	NIVEL 2	6	6	5	6	6	5	5772.
ARMADURA TS- 2B	NIVEL 1	6	6	6	6	3	3	5765.
	NIVEL 2	3	3	3	3	0	3	2883.
ARMADURA TS- 2CD	NIVEL 1	2	2	2	2	2	2	2030.
	NIVEL 2	2	2	2	2	2	2	2030.
ARMADURA TS- 2CI	NIVEL 1	2	2	2	2	2	2	2030.

	NIVEL 2	2	2	2	2	2	2	2232.
ARMADURA TS- 2D	NIVEL 2	6	6	6	6	5	6	5772.
ARMADURA TS- 25D	NIVEL 2	1	1	1	1	1	1	963.
ARMADURA TS- 25I	NIVEL 2	1	1	1	1	1	1	963.
ARMADURA TS- 22	NIVEL 2	4	4	4	4	4	4	3842.
ARMADURA TS- 23	NIVEL 2	2	2	2	2	1	1	2034.
ARMADURA TS- 3	NIVEL 1	6	6	6	6	6	6	10020.
	NIVEL 2	6	6	6	6	6	6	10020.
ARMADURA TS- 3A	NIVEL 2	4	4	4	4	0	0	6680.
ARMADURA TS- 3B	NIVEL 2	1	1	1	1	0	0	1718.
ARMADURA TS- 4 D	NIVEL 2	1	1	1	1	0	0	2119.
ARMADURA TS- 4 I	NIVEL 2	1	0	0	0	0	0	0.
ARMADURA TS- 6 D	NIVEL 2	1	1	1	1	1	1	1743.
ARMADURA TS- 6 I	NIVEL 2	1	1	1	1	1	1	1743.
ARMADURA TS- 6A	NIVEL 2	1	1	1	1	1	1	1822.
ARMADURA TS- 6B	NIVEL 2	2	2	2	2	1	1	3490.
ARMADURA TS- 9	NIVEL 1	1	1	1	1	1	0	1057.
ARMADURA TS- 9A	NIVEL 2	6	6	6	6	3	3	5244.
ARMADURA 3V- 1 D	NIVEL 3	2	2	2	2	2	2	1904.
ARMADURA 3V- 1 I	NIVEL 3	1	1	1	1	1	1	952.
ARMADURA 3V- 2	NIVEL 3	9	9	9	9	9	9	7920.
ARMADURA 3V- 3 D	NIVEL 3	2	2	2	2	2	2	1774.
ARMADURA 3V- 3 I	NIVEL 3	1	1	1	1	1	1	887.
ARMADURA 3V- 5 D	NIVEL 3	2	2	2	2	2	2	1898.
ARMADURA 3V- 6 I	NIVEL 3	2	2	2	2	2	2	1898.
ARMADURA 3V- 7	NIVEL 3	16	16	16	16	16	16	14064.
ARMADURA 3V- 8 D	NIVEL 3	2	2	2	2	2	2	1774.
ARMADURA 3V- 8 I	NIVEL 3	2	2	2	2	2	2	1774.
ARMADURA 3V- 9	NIVEL 3	6	6	6	6	6	6	5280.
ARMADURA 3V-10	NIVEL 3	1	1	1	1	1	1	888.
ARMADURA 3V-11	NIVEL 3	29	29	29	29	19	19	25520.
ARMADURA 3V-12	NIVEL 3	1	1	1	1	1	1	952.
ARMADURA 3V-13	NIVEL 3	4	4	4	4	4	4	3808.
ARMADURA 3V-14 D	NIVEL 3	6	6	6	6	6	6	5322.
ARMADURA 3V-14 I	NIVEL 3	6	6	6	6	6	6	5322.
ARMADURA 3V-15	NIVEL 3	18	18	18	18	18	18	15858.
ARMADURA 3V-16	NIVEL 3	20	4	4	4	4	4	2568.
ARMADURA 3V-17	NIVEL 3	2	2	2	2	2	1	4266.
ARMADURA 3V-18	NIVEL 3	2	2	2	2	2	1	4266.
ARMADURA 3V-19	NIVEL 3	6	6	6	6	6	3	12744.
ARMADURA 3V-20	NIVEL 3	20	15	14	14	5	5	12306.
ARMADURA 3V-21 D	NIVEL 3	2	1	1	1	0	0	1773.
ARMADURA 3V-21 I	NIVEL 3	2	1	1	1	0	0	1773.
ARMADURA 3V-22	NIVEL 3	6	6	5	5	0	0	2980.
ARMADURA 3V-23	NIVEL 3	2	0	0	0	0	0	0.
	TOTAL	472.	439	430	430	349	342	419495.

```
                                                    MAYO-22-DE-1979
            REPORTE DE AVANCE DE FABRICACION Y/O MONTAJE

                        TOTAL       FABRICACION          MONTAJE             PESO           PESO
          CONCEPTO      PIEZAS.. ARM.... SOLD.... PINT... COL.   SOLD.      FABRICADO       MONTADO
                                 (PCT)   (PCT)   (PCT)   (PCT)  (PCT)        (KGS)          (KGS)

COLUMNAS EXTERIORES        72   100.00  100.00  100.00  100.00 100.00       149062.         149062.
COLUMNAS INTERIORES        72   100.00  100.00  100.00  100.00 100.00       147613.         147613.
TRABES PRINCIPALES        246    94.30   91.86   91.46   83.33  83.73       447607.         405264.
TRABES SECUNDARIAS        472    93.00   91.10   91.10   73.94  72.45       419495.         326566.


                                                            TOTAL  1163777.        1028505.
```

6

```
                                                                     1
                                             2     4     6     8     0
                            PORCENTAJE       0     0     0     0     0
                                       ...............................


ARMADO  DE COLUMNAS EXTERIORES         -------------------------------
SOLDADO DE COLUMNAS EXTERIORES         -------------------------------
PINTADO DE COLUMNAS EXTERIORES         -------------------------------


ARMADO  DE COLUMNAS INTERIORES         -------------------------------
SOLDADO DE COLUMNAS INTERIORES         -------------------------------
PINTADO DE COLUMNAS INTERIORES         -------------------------------


ARMADO  DE TRABES PRINCIPALES          -----------------------------
SOLDADO DE TRABES PRINCIPALES          ----------------------------
PINTADO DE TRABES PRINCIPALES          ----------------------------


ARMADO  DE TRABES SECUNDARIAS            --------------------------
SOLDADO DE TRABES SECUNDARIAS            --------------------------
PINTADO DE TRABES SECUNDARIAS            --------------------------
```

```
                                   MAYO-22-DE-1979
                REPORTE DE AVANCE DE FABRICACION Y/O MONTAJE DE ACUERDO CON EL PROGRAMA

                    +----------HASTA LA PRESENTE SEMANA----------+-----------DURANTE ESTA SEMANA-------------+
                     TOTAL       FABRICACION          MONTAJE       TOTAL       FABRICACION           MONTAJE
                     PIEZAS   ARM.   SOLD.  PINT.  COL.    SOLD.    PIEZAS   ARM.    SOLD.  PINT.  COL.    SOLD.

COLUMNAS EXTERIORES    72      72      72     72     72      72       0        0       0      0      0       0
                     (100.0)  (100.0)(100.0)(100.0)(100.0)(100.0)   (100.0)  (  0.0)(  0.0)(  0.0)(  0.0)(  0.0)
COLUMNAS INTERIORES    72      72      72     72     72      72       0        0       0      0      0       0
                     (100.0)  (100.0)(100.0)(100.0)(100.0)(100.0)   (100.0)  (  0.0)(  0.0)(  0.0)(  0.0)(  0.0)
TRABES PRINCIPALES    198     232     226    225    205     206       6       40      34     33     13      14
                     (100.0)  (117.1)(114.1)(113.6)(103.5)(104.0)   (100.0)  (666.6)(566.6)(550.0)(216.6)(233.3)
TRABES SECUNDARIAS    333     439     430    430    349     342      15      121     112    112     31      24
                     (100.0)  (131.8)(129.1)(129.1)(104.8)(102.7)   (100.0)  (806.6)(746.6)(746.6)(206.6)(160.0)
```

CINCO PUNTOS EN LOS QUE HAY QUE FIJAR LA ATENCION PARA ASEGURAR UNA BUENA CALIDAD DE LA SOLDADURA.

1) SELECCION DEL PROCESO DE UNA SOLDADURA.

   A) SOLDADURA DE OPERACION MANUAL

   B) SOLDADURA SEMI AUTOMATICA

   C) SOLDADURA AUTOMATICA

2) PREPARACION DE LAS JUNTAS.

3) ESTUDIO EN DETALLE DEL PROCEDIMIENTO.

   A) IDENTIFICACION DE LA JUNTA

   B) DETALLES Y TOLERANCIA DE LA JUNTA

   C) IDENTIFICACION DEL PROCEDIMIENTO

   D) TIPO Y TAMAÑO DEL ELECTRODO

   E) TIPO DE FUNDENTE (CUANDO SE REQUIERE)

   F) CORRIENTE Y VOLTAJE

   G) PRECALENTAMIENTO

   H) SECUENCIA DE PASES

   I) COMENTARIOS O INDICACIONES ADICIONALES

4) PERSONAL (CALIFICACION Y SELECCION)

5) PRUEBAS PREVIAS.

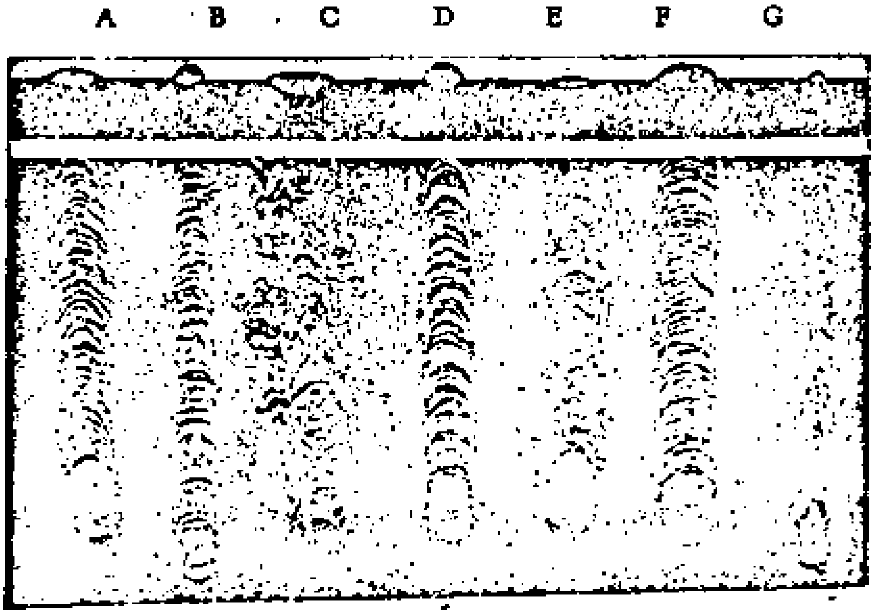


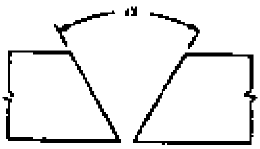
Fig. 2-77. Plan and elevation views of welds made with an E6010 type electrode under various conditions. Conditions are accentuated to illustrate differences. Iron powder type electrodes when used minimize variations shown here. (A) Current, voltage and speed normal. (B) Current too low. (C) Current too high. (D) Arc length too short. (E) Arc length too long. (F) Speed too low. (G) Speed too high.

LISTA DE DETALLES QUE INFLUYEN EN LA CALIDAD DE UNASOLDADURA.

REVISION ANTES DE LA SOLDADURA ● ○ ○
REVISION DURANTE LA SOLDADURA ○ ● ○
REVISION DESPUES DE LA SOLDADURA ○ ○ ●

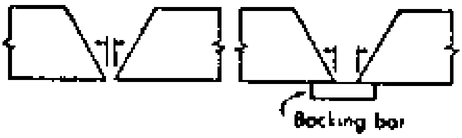
1) ANGULO DE LA PREPARACION

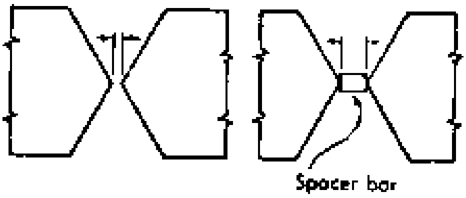
● ○ ○

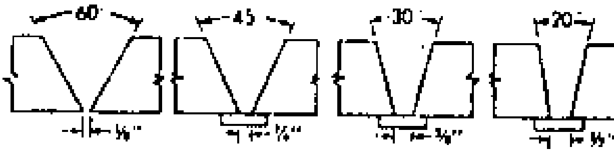


2) ABERTURA DE LA RAIZ.

● ○ ○

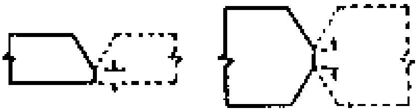


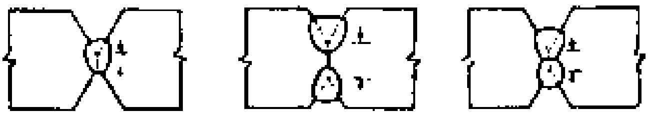




3) PERFIL DE LA RAIZ.

● ○ ○

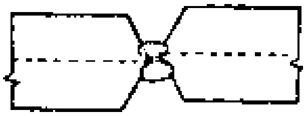




(a) Too small root face, burn-through (b) Too large root face, lack of penetration (c) Proper root face; proper penetration

4) ALINEAMIENTO DE LAS PLACAS

● ○ ○



5) LIMPIEZA DE LA JUNTA

● ● ●

6) TIPO Y TAMAÑO DE ELECTRODO

○ ● ○

7) INTENSIDAD Y POLARIDAD DE LA CORRIENTE

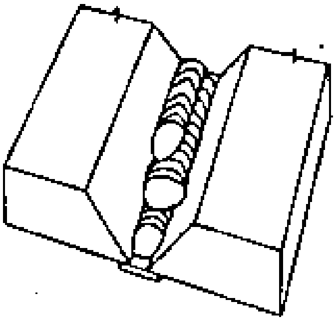
○ ● ○

8) PUNTOS DE SOLDADURA.

○ ● ○

9) FUSION ADECUADA

○ ● ●

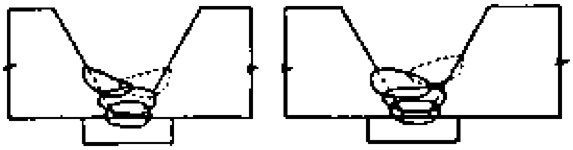


10) PRECALENTAMIENTO

○ ● ○

II) SECUENCIA ADECUADA DE PASES

○ ● ○

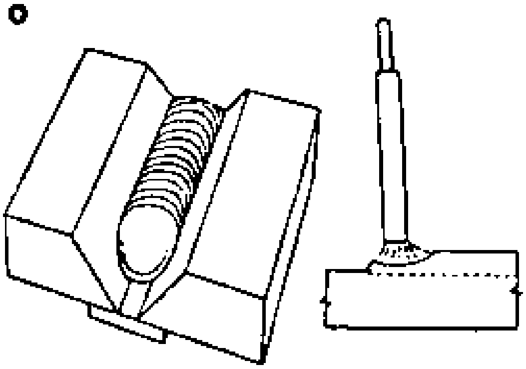


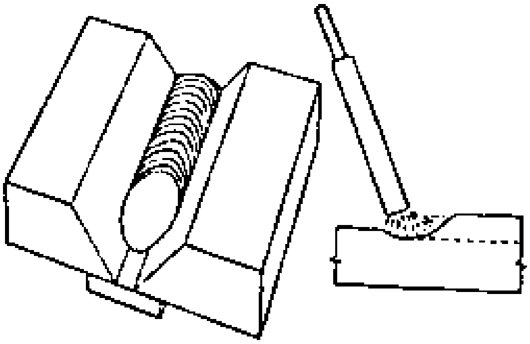
(a) No problem for next pass to fuse properly into side of joint and weld

(b) Not enough room left between side of joint and last pass, will not fuse properly; may trap slag

I2) VELOCIDAD CORRECTA DE MOVIMIENTO DEL ELECTRODO

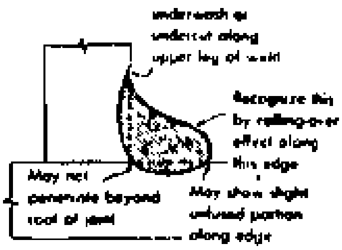
○ ● ○

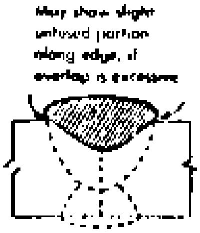


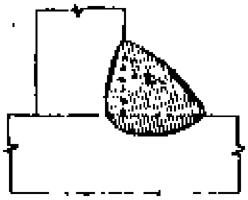


I3) AUSENCIA DE SOLAPADURAS (OVERLAP)

○ ● ●





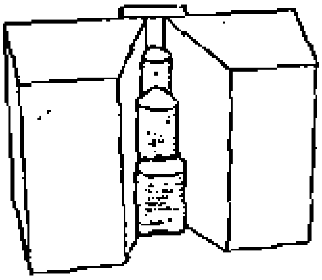


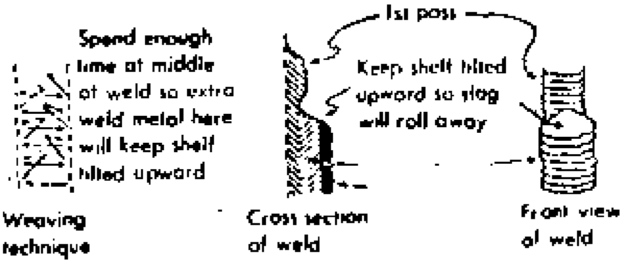
No overlap

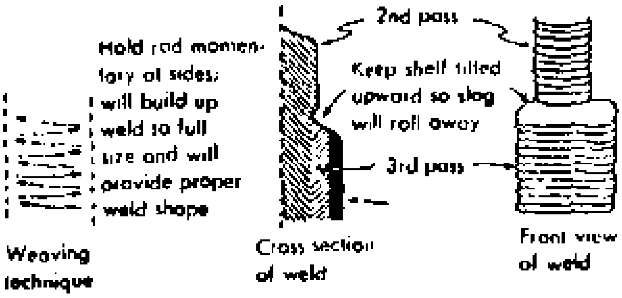
No overlap

14) INCLINACION DEL CRATER EN SOLDADURAS VERTICALES

○ ● ○

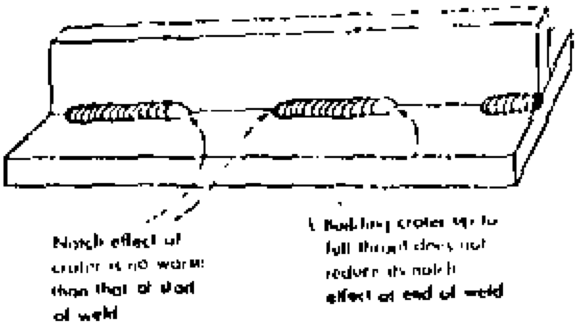






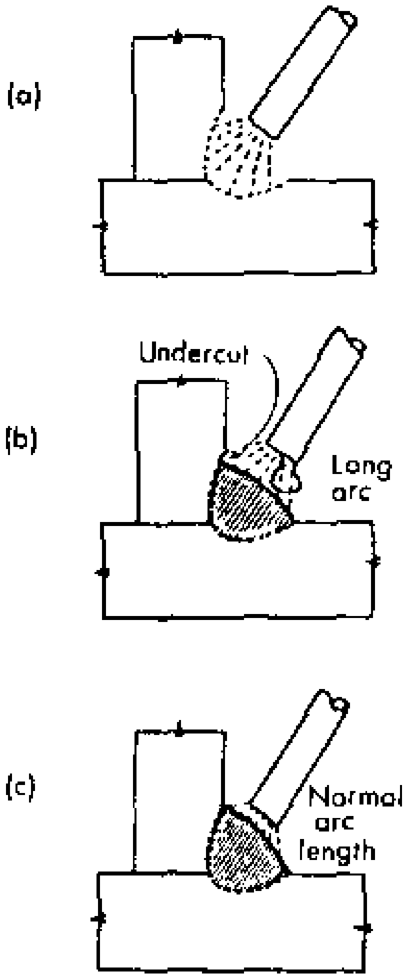
15) RELLENO DE CRATERES

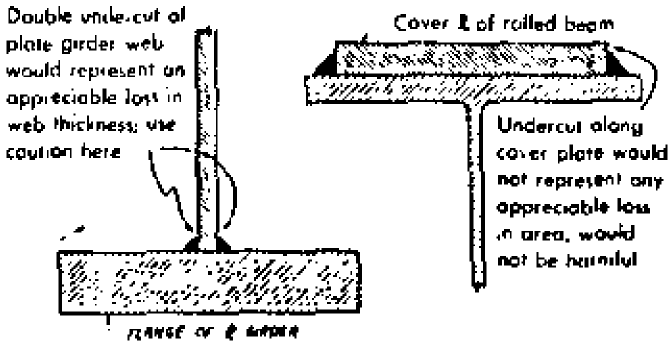
○ ● ●



16) AUSENCIA DE SOCAVACIONES

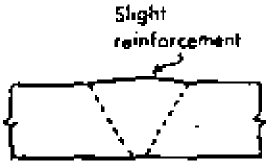
○ ● ●





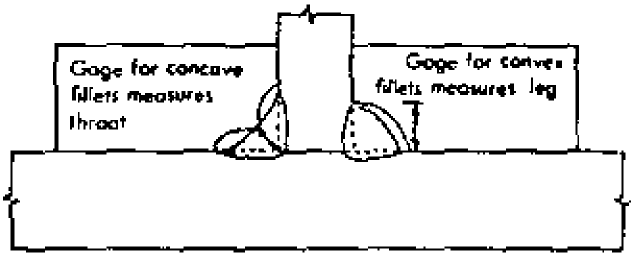
I7) REFUERZO ADECUADO EN SOLDADURAS A TOPE

○ ● ●



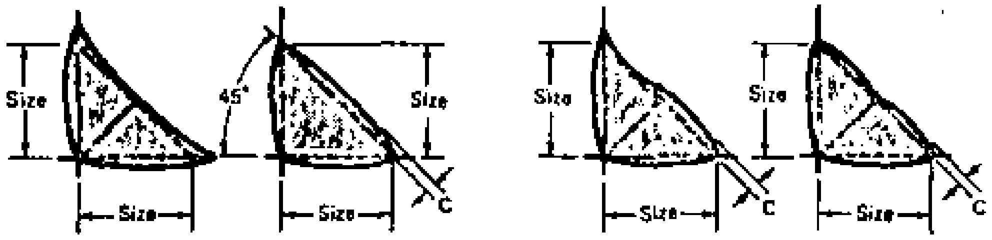
I8) TAMAÑO CORRECTO DE SOLDADURAS DE FILETE.

○ ○ ●



I9) AUSENCIA DE GRIETAS

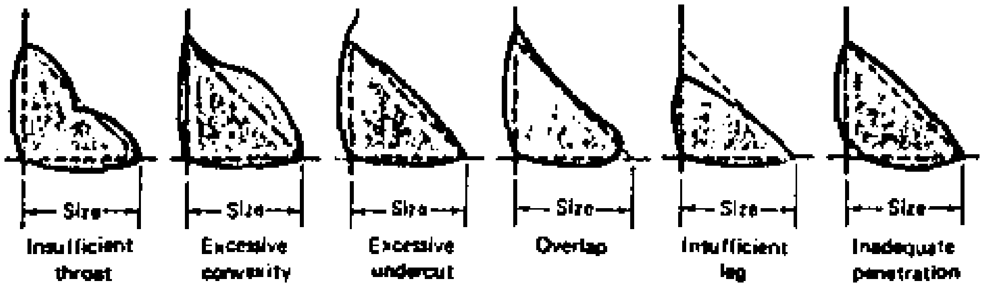
○ ● ○



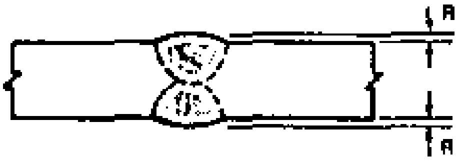
Note: Convexity C shall not exceed 0.1 actual size + 0.03 in.

(A) Desirable fillet weld profiles

(B) Acceptable fillet weld profiles

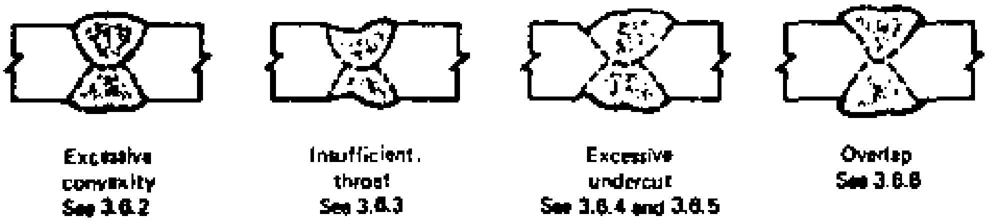


(C) Unacceptable fillet weld profiles



Note: Reinforcement R shall not exceed 1/8 in. See 3.6.2.

(D) Acceptable butt weld profile



(E) Unacceptable butt weld profiles

Fig. 3.6—Acceptable and unacceptable weld profiles

GRIETAS EXTERIORES

CAUSAS PROBABLES

GRAN RESTRICCION DE LAS PARTES POR SOLDAR

ENFRIAMIENTO BRUSCO

EL PRIMER CORDON MUY PEQUEÑO

FALTA DE PRECALENTAMIENTO

ALTO CONTENIDO DE AZUFRE EN LA PLACA ACENTUADO POR EXCESO DE PENETRACION

ALTO CONTENIDO DE CARBONO

CONSECUENCIAS

FALLA COMPLETA DE LA JUNTA

REDUCCION DE LA RESISTENCIA

GRIETAS EN EL CRATER DE UNA SOLDADURA DE FILETE

GRIETA LONGITUDINAL EN UNA SOLDADURA A TOPE

GRIETA EN UNA SOLDADURA DE TRASLAPE

GRIETA EN UNA SOLDADURA DE FILETE POR FALTA DE PENETRACION

GRIETA POR PENETRACION EXCESIVA

POROSIDAD EXTERIOR

CAUSAS PROBABLES

CONTENIDO EXCESIVO DE AZUFRE EN EL ELECTRODO O EN EL METAL BASE
SE NOTAN TAMBIEN BURBUJAS Y POROSIDADES TUBULARES

CONSECUENCIAS

REDUCCION DE LA RESISTENCIA (NO ES MUY GRAVE SI LA POROSIDAD NO ES EXCESIVA)

APARIENCIA IRREGULAR

POROSIDAD EXCESIVA
POR EXCESO DE AZUFRE.

QUEMADURAS

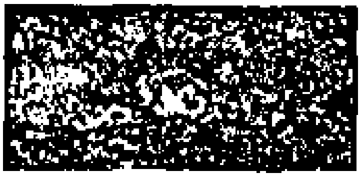
CAUSAS

INICIO INCORRECTO DEL ARCO ELECTRICO (SOBRE LA PLACA)

CONSECUENCIAS

POSIBLES GRIETAS EN ACEROS DE ALEACION

REDUCCION DE LA RESISTENCIA POR EFECTO DE MUESCA



QUEMADURA (PLANTA)

(CORTE)

SOLAPADURAS (OVERLAP)

CAUSAS

MANEJO INADECUADO DEL ELECTRODO

BAJA CORRIENTE

BAJA VELOCIDAD

MUCHO DEPOSITO EN UN SOLO CORDON

CONSECUENCIAS

REDUCCION DE LA RESISTENCIA POR CONCENTRACION DE ESFUERZOS

SOLDADURA DE FILETE SOLAPADA.

SOCAVACIONES

CAUSAS	CONSECUENCIAS
CORRIENTE EXCESIVA	REDUCCION DE LA RESISTENCIA EN ALGUNOS CASOS.
ALTA VELOCIDAD	
LONGITUD DEL ARCO MUY GRANDE	
ANGULO DEL ELECTRODO INCORRECTO	
ELECTRODO INADECUADO	
HUMEDAD EN EL ELECTRODO	

SOCAVACION EN LA PARTE SUPERIOR DE LA PLACA

SOCAVACION EN LA PARED DE UNA SOLDADURA A TOPE SIN PREPARACION Y CON PLACA DE RESPALDO

SOCAVACION EN LAS PAREDES DE LA RAIZ DE UNA SOLDADURA A TOPE DE BISEL

PLANTA Y CORTE DE UNA UNION A TOPE. (NOTESE LA REDUCCION DE LA SECCION.)

TAMAÑO INADECUADO

CAUSAS

BAJA CORRIENTE

ALTA CORRIENTE

BAJA VELOCIDAD

MANEJO INADECUADO DEL ELECTRODO

POSICION DIFICIL

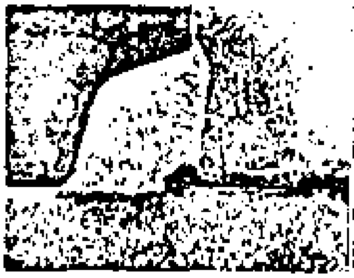
MALA PREPARACION

CONSECUENCIAS

REDUCCION DE RESISTENCIA

CONCENTRACION DE ESFUERZOS

SOLDADURAS DE FILETE



CONVEXIDAD EXCESIVA POR BAJA CORRIENTE

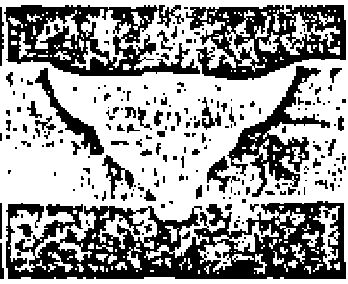
TAMAÑO INSUFICIENTE POR EXCESO DE CORRIENTE

TAMAÑO INSUFICIENTE POR POSICION INADECUADA DEL ELECTRODO

PERFIL IRREGULAR POR BAJA CORRIENTE Y ELECTRODO MUY PEQUEÑO

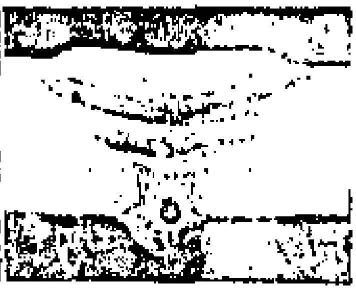
SOLDADURAS A TOPE

REFUERZO EXCESIVO



GARGANTA INSUFICIENTE

REFUERZO IRREGULAR



PENETRACION EXCESIVA

QUEMADURAS EN LA ORILLA DEL METAL BASE

CAUSAS

ELECTRODO MUY GRANDE

MANEJO INADECUADO DEL ELECTRODO

CONSECUENCIAS

REDUCCION DE LA RESISTENCIA

QUEMADURA EN LA ORILLA DE UNA SOLDADURA DE FILETE

CORTE QUE MUESTRA EL DEFECTO

CORDON REPARADO

ESQUEMA EXPLICATIVO

APARIENCIA IRREGULAR

CAUSAS

1) ONDULACIONES

MANEJO INADECUADO DEL ELECTRODO

ACCESO DIFICIL

BAJA CORRIENTE

ALTA CORRIENTE

LONGITUD INADECUADA DEL ARCO

2) SALPICADURAS

ALTA CORRIENTE

LONGITUD GRANDE DEL ARCO

INTERRUPCION DEL ARCO

ELECTRODOS DAÑADOS

3) OTRO TIPO DE IRREGULARIDAD

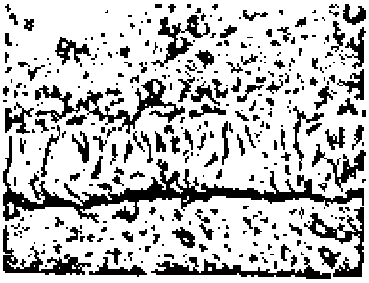
ARRANQUE EN FRIO CUANDO
SE EMPLEAN MAQUINAS DE GASOLINA.

CONSECUENCIAS

REDUCCION DE LA RESISTENCIA

APARIENCIA DESAGRADABLE

ONDULACIONES



ONDULACION Y SALPICADURAS.

DEFECTOS INTERNOS

PENETRACION INCOMPLETA

CAUSAS

PREPARACION INADECUADA

TAMAÑO INADECUADO DEL ELECTRODO

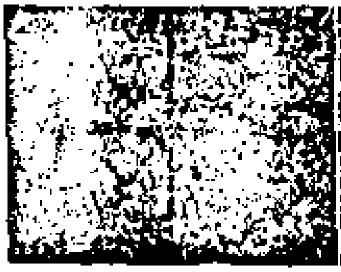
BAJA CORRIENTE

VELOCIDAD EXCESIVA

CONSECUENCIAS

REDUCCION IMPORTANTE DE LA RESISTENCIA

ROTURA DE LA RAIZ

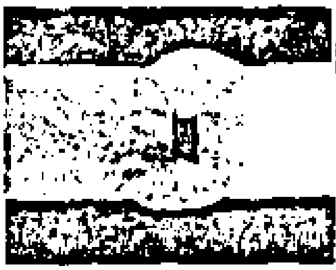


RADIOGRAFIA DE UNA UNION A TOPE CON FALTA DE PENETRACION

FALTA DE PENETRACION POR CORRIENTE BAJA

FALTA DE PENETRACION CON INCLUSION DE ESCORIA

RADIOGRAFIA DE UNA FALLA POR FALTA DE PENETRACION



FALTA DE PENETRACION POR MALA PREPARACION

RADIOGRAFIA DE UNA UNION A TOPE CON FALTA DE PENETACION

FALTA DE PENETRACION EN SOLDADURAS DE FILETE

GRIETAS INTERIORES

CAUSAS

COMPOSICION QUIMICA DEL MATERIAL BASE

ENFRIAMIENTO BRUSCO

ALTA VELOCIDAD

CORDON INICIAL PEQUEÑO

LAPSOS GRANDES ENTRE LA COLOCACION DE DOS CORDONES CONSECUTIVOS

PENETRACION INCOMPLETA

FALTA DE FUSION

INCLUSION DE ESCORIA

CONSECUENCIAS

FALLA TOTAL DE LA JUNTA DEPENDIENDO DEL TAMAÑO DE LAS GRIETAS

GRIETA EN LA RAIZ POR EXCESO DE AUSTENITA

GRIETA EN LA RAIZ DE UNA SOLDADURA A TOPE

GRIETA EN UNA UNION A TOPE ASOCIADA CON INCLUSION DE ESCORIA

GRIETA EN LA ZONA AFECTADA POR EL CALOR

GRIETA EN LA RAIZ EN LA ZONA AFECTADA POR EL CALOR

GRIETA EN LA RAIZ EN MATERIAL MUY GRUESO

GRIETA POR INCLUSION DE ESCORIA

INCLUSION DE ESCORIA

CAUSAS

LIMPIEZA DEFICIENTE ENTRE CORDONES

PRESENCIA DE ESCAMAS, PINTURA, ETC.

SUPERFICIES IRREGULARES

ELECTRODO HUMEDO, CON RECUBRIMIENTO ROTO, ETC.

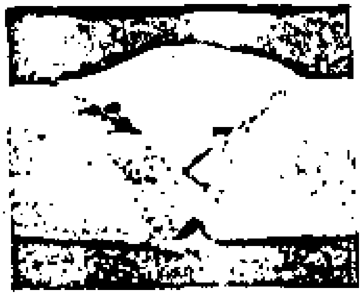
CORRIENTE INADECUADA

CONSECUENCIAS

REDUCCION DE RESISTENCIA SI LAS INCLUSIONES SON GRANDES Y NUMEROSAS

POSIBILIDAD DE GRIETAS SI SE LOCALIZAN EN LA UNION DE SOLDADURA Y EL METAL BASE.

INCLUSION DE ESCORIA EN SOLDADURA DE VARIOS PASES



INCLUSION DE ESCORIA EN RAIZ Y PAREDES

LINEAS DE ESCORIA EN LA RAIZ DE UNA UNION A TOPE

FALTA DE FUSION

CAUSAS

PRESENCIA DE ESCAMAS, OXIDOS

FALTA DE REMOCION DE LA ESCORIA ENTRE DOS CORDONES CONSECUTIVOS

CORRIENTE BAJA

ALTA VELOCIDAD

COMPOSICION QUIMICA

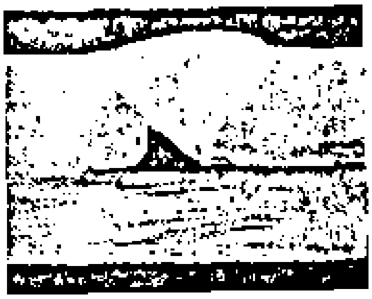
CONSECUENCIAS

REDUCCION IMPORTANTE DE LA RESISTENCIA

FALTA DE FUSION ENTRE CORDONES DE ACERO AUSTENITICO

FALTA DE FUSION EN LA RAIZ

FALTA DE FUSION EN UNA SOLDADURA A TOPE



FALTA DE LA FUSION EN LA RAIZ

FALTA DE FUSION EN LAS CAPAS DE LA RAIZ

RADIOGRAFIA DE UNA REPARACION LOCAL

POROS Y BURBUJAS INTERIORES

CAUSAS

ALTO CONTENIDO DE AZUFRE

HUMEDAD EN EL ELECTRODO

LONGITUD DEL ARCO INCORRECTA

POLARIDAD EQUIVOCADA

CONSECUENCIAS

POROSIDADES TUBULARES
REDUCEN LA RESISTENCIA

POROSIDADES EN UNA
UNION A TOPE

POROSIDAD TUBULAR EN
UNA SOLDADURA DE FILETE

POROSIDAD TUBULAR EN
UNA SOLDADURA DE FILETE

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

PROCEDIMIENTOS DE CONSTRUCCION DE ESTRUCTURAS DE ACERO

TABLAS Y ESPECIFICACIONES

MANUAL OF STELL CONSTRUCCION

JUNIO,1979.

PART 4

Connections

RIVETS AND THREADED FASTENERS

Tension

Allowable loads in kips

Unfinished Bolts and Threaded Parts

Tension on tensile stress area

ASTM Designation or Yield Stress		Allowable Tensile Stress F_t ksi	Nominal Diameter, in.							
			5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
			Tensile Stress Area, sq. in.							
			0.2260	0.3345	0.4617	0.6057	0.7633	0.9691	1.1549	1.4053
A307 Bolts		20.0	4.52	6.69	9.23	12.11	15.27	19.38	23.10	28.11
Threaded Parts F_y, ksi	36	22.0	4.97	7.36	10.16	13.33	16.79	21.32	25.41	30.92
	42	25.2	5.70	8.41	11.64	15.27	19.23	24.42	29.23	35.53
	45	27.0	6.10	9.03	12.47	16.35	20.61	26.17	31.18	37.94
	50	30.0	6.78	10.04	13.85	18.17	22.90	29.07	34.65	42.16
	55	33.0	7.46	11.04	15.24	19.99	25.19	31.98	38.11	46.37
	60	36.0	8.14	12.04	16.62	21.81	—	—	—	—

The definition of tensile stress area is given in the AISC Specification, Section 1.5.2.1. Values are based on UNC thread dimensions.

Nuts must meet specifications compatible with threaded parts.

For Upset Rods see AISC Specification, Section 1.5.2.1.

Rivets and High Strength Bolts

Tension on gross (nominal) area

ASTM Designation		Allowable Tensile Stress F_t ksi	Nominal Diameter, in.							
			5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
			Gross (Nominal) Area, sq. in.							
			0.3068	0.4418	0.6013	0.7854	0.9940	1.2272	1.4849	1.7671
Rivets	A502-1	20.0	6.14	8.84	12.03	15.71	19.88	24.54	29.70	35.34
	A502-2	27.0	8.28	11.93	16.24	21.21	26.84	33.13	40.09	47.71
Bolts	A325	40.0	12.27	17.67	24.05	31.42	39.76	49.09	59.40	70.68
	A490	54.0*	16.57*	23.86*	32.47*	42.41*	53.68*	66.27*	80.18*	95.42*

* For static loading only.

For allowable combined shear and tension loads, see AISC Specification, Section 1.6.3.

RIVETS AND THREADED FASTENERS

Shear

Allowable loads in kips

Power Driven Shop and Field Rivets

Diam. — Area	5/8 in. — 0.3068 sq. in.		3/4 in. — 0.4418 sq. in.	
ASTM Designation	A502-1	A502-2	A502-1	A502-2
Shear F_v, ksi	15.0	20.0	15.0	20.0
Single Shear, kips Double Shear, kips	4.60 9.20	6.14 12.27	6.63 13.25	8.84 17.67

Unfinished Bolts, ASTM A307, and Threaded Parts, F_y = 36 ksi[a]

Diam. — Area	5/8 in. — 0.3068 sq. in.		3/4 in. — 0.4418 sq. in.	
ASTM Designation or Yield Stress, ksi	A307	F_y = 36	A307	F_y = 36
Shear F_v, ksi	10.0	10.8[a]	10.0	10.8[a]
Single Shear, kips Double Shear, kips	3.07 6.14	3.31 6.63	4.42 8.84	4.77 9.54

High Strength Bolts in Friction Type Connections and in Bearing Type Connections with Threads in Shear Planes

Diam. — Area	5/8 in. — 0.3068 sq. in.			3/4 in. — 0.4418 sq. in.		
[b]ASTM Designation	A325-F A325-N	A490-F	A490-N	A325-F A325-N	A490-F	A490-N
Shear F_v, ksi	15.0	20.0	22.5	15.0	20.0	22.5
Single Shear, kips Double Shear, kips	4.60 9.20	6.14 12.27	6.90 13.81	6.63 13.25	8.84 17.67	9.54 19.08

High Strength Bolts in Bearing Type Connections with Threads Excluded from Shear Planes

Diam. — Area	5/8 in. — 0.3068 sq. in.		3/4 in. — 0.4418 sq. in.	
[b]ASTM Designation	A325-X	A490-X	A325-X	A490-X
Shear F_v, ksi	22.0	32.0	22.0	32.0
Single Shear, kips Double Shear, kips	6.75 13.50	9.82 19.64	9.72 19.44	14.14 28.28

[a] For threaded parts of material other than F_y = 36 ksi steel, use $F_v = 0.30 F_y$.

[b] The letter suffixes following the ASTM Designations A325 and A490 represent the following:
F: Friction type connection
N: Bearing type connection with threads included in shear plane
X: Bearing type connection with threads excluded from shear plane

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RIVETS AND THREADED FASTENERS

Bearing

Allowable loads in kips

All rivets and bolts in bearing type connections

	Diam., in.	5/8								3/4							
	F_y, ksi	36	42	45	50	55	60	65	100	36	42	45	50	55	60	65	100
	Bearing F_p, ksi	48.6	56.7	60.8	67.5	74.3	81.0	87.8	135	48.6	56.7	60.8	67.5	74.3	81.0	87.8	135
MATERIAL THICKNESS	1/8	3.80	4.43	4.75	5.27	5.80	6.33	6.86	10.5	4.56	5.31	5.70	6.33	6.97	7.59	8.23	12.7
	3/16	5.70	6.64	7.13	7.91	8.71	9.49	10.3	15.8	6.83	7.97	8.55	9.49	10.4	11.4	12.3	19.0
	1/4	7.59	8.86	9.50	10.6	11.6	12.7	13.7	21.1	9.11	10.6	11.4	12.7	13.9	15.2	16.5	25.3
	5/16	9.49	11.1	11.9	13.2	14.5	15.8	17.1	26.4	11.4	13.3	14.3	15.8	17.4	19.0	20.6	31.6
	3/8	11.4	13.3	14.3	15.8	17.4	19.0	20.6	31.6	13.7	15.9	17.1	19.0	20.9	22.8	24.7	38.0
	7/16	13.3	15.5	16.6	18.5	20.3	22.1		36.5	15.9	18.6	19.9	22.1	24.4	26.6	28.8	44.3
	1/2	15.2	17.7	19.0	21.1				42.2	18.2	21.3	22.8	25.3	27.9	30.4		50.6
	9/16	17.1	19.9	21.4					47.5	20.5	23.9	25.7	28.5	31.3			57.0
	5/8	19.0							52.7	22.8	26.6	28.5					63.3
	11/16	20.9							58.0	25.1	29.2						69.6
	3/4								63.3	27.3							75.9
	13/16								68.6	29.6							82.3
	7/8								73.8								88.6
	15/16								79.1								94.9
	1	30.4	35.4	38.0	42.2	46.4	50.6	54.9	84.4	36.5	42.5	45.6	50.6	55.7	60.8	65.9	101

This table not applicable to fasteners in friction type connections.

F_y is the yield stress of the connected material; see AISC Specification, Sect. 1.5.2.2.

F_p, the unit bearing stress, applies equally to conditions of single shear and enclosed bearing.

Values for thicknesses not listed may be obtained by multiplying the unlisted thickness by the value given for a 1" thickness in the appropriate F_y column.

Values for F_y's not listed may be obtained by multiplying the value given for F_y = 100 ksi by the unlisted F_y and dividing by 100.

RIVETS AND THREADED FASTENERS

Shear

Allowable loads in kips

Power Driven Shop and Field Rivets

Diam. — Area	7/8 in. — 0.6013 sq. in.		1 in. — 0.7854 sq. in.	
ASTM Designation	A502-1	A502-2	A502-1	A502-2
Shear F_v, ksi	15.0	20.0	15.0	20.0
Single Shear, kips Double Shear, kips	9.02 18.04	12.03 24.05	11.78 23.56	15.71 31.42

Unfinished Bolts, ASTM A307, and Threaded Parts, F_y = 36 ksi[*]

Diam. — Area	7/8 in. — 0.6013 sq. in.		1 in. — 0.7854 sq. in.	
ASTM Designation or Yield Stress, ksi	A307	F_y = 36	A307	F_y = 36
Shear F_v, ksi	10.0	10.8[*]	10.0	10.8[*]
Single Shear, kips Double Shear, kips	6.01 12.03	6.49 12.99	7.85 15.71	8.48 16.96

High Strength Bolts in Friction Type Connections and in Bearing Type Connections with Threads in Shear Planes

Diam. — Area	7/8 in. — 0.6013 sq. in.			1 in. — 0.7854 sq. in.		
[†]ASTM Designation	A325-F A325-N	A490-F	A490-N	A325-F A325-N	A490-F	A490-N
Shear F_v, ksi	15.0	20.0	22.5	15.0	20.0	22.5
Single Shear, kips Double Shear, kips	9.02 18.04	12.03 24.05	13.53 27.06	11.78 23.56	15.71 31.42	17.67 35.34

High Strength Bolts in Bearing Type Connections with Threads Excluded from Shear Planes

Diam. — Area	7/8 in. — 0.6013 sq. in.		1 in. — 0.7854 sq. in.	
[†]ASTM Designation	A325-X	A490-X	A325-X	A490-X
Shear F_v, ksi	22.0	32.0	22.0	32.0
Single Shear, kips Double Shear, kips	13.23 26.46	19.24 38.48	17.28 34.56	25.13 50.27

[*] For threaded parts of material other than F_y = 36 ksi steel, use F_v = 0.30 F_y.

[†] The letter suffixes following the ASTM Designations A325 and A490 represent the following:
F: Friction type connection
N: Bearing type connection with threads included in shear plane
X: Bearing type connection with threads excluded from shear plane

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RIVETS AND THREADED FASTENERS

Bearing

Allowable loads in kips
All rivets and bolts in bearing type connections

	Diam., in.	7/8								1							
	F_y, ksi	36	42	45	50	55	60	65	100	36	42	45	50	55	60	65	100
	Bearing F_p, ksi	48.6	56.7	60.8	67.5	74.3	81.0	87.8	135	48.6	56.7	60.8	67.5	74.3	81.0	87.8	135
MATERIAL THICKNESS	1/8	5.32	6.20	6.65	7.38	8.13	8.86	9.60	14.8	6.08	7.09	7.60	8.44	9.29	10.1	11.0	16.9
	3/16	7.97	9.30	9.98	11.1	12.2	13.3	14.4	22.1	9.11	10.6	11.4	12.7	13.9	15.2	16.5	25.3
	1/4	10.6	12.4	13.3	14.8	16.3	17.7	19.2	29.5	12.2	14.2	15.2	16.9	18.6	20.3	22.0	33.8
	5/16	13.3	15.5	16.6	18.5	20.3	22.1	24.0	36.9	15.2	17.7	19.0	21.1	23.2	25.3	27.4	42.2
	3/8	15.9	18.6	20.0	22.1	24.4	26.6	28.8	44.3	18.2	21.3	22.8	25.3	27.9	30.4	32.9	50.6
	7/16	18.6	21.7	23.3	25.8	28.4	31.0	33.6	51.7	21.3	24.8	26.6	29.5	32.5	35.4	38.4	59.1
	1/2	21.3	24.8	26.6	29.5	32.5	35.4	38.4	59.1	24.3	28.4	30.4	33.8	37.2	40.5	43.9	67.5
	9/16	23.9	27.9	29.9	33.2	36.6	39.9	43.2	66.4	27.3	31.9	34.2	38.0	41.8	45.6	49.4	75.9
	5/8	26.6	31.0	33.3	36.9	40.6			73.8	30.4	35.4	38.0	42.2	46.4	50.6	54.9	84.4
	11/16	29.2	34.1	36.6	40.6				81.2	33.4	39.0	41.8	46.4	51.1			92.8
	3/4	31.9	37.2	39.9					88.6	36.5	42.5	45.6	50.6				101
	13/16	34.6	40.3						96.0	39.5	46.1	49.4					110
	7/8	37.2							103	42.5	49.6	53.2					118
	15/16	39.9							111	45.6	53.2						127
	1	42.5	49.6	53.2	59.1	65.0	70.9	76.8	118	48.6	56.7	60.8	67.5	74.3	81.0	87.8	135
	1 1/8								126	51.6							143

This table not applicable to fasteners in friction type connections.

F_y is the yield stress of the connected material; see AISC Specification, Sect. 1.5.2.2.

F_p, the unit bearing stress, applies equally to conditions of single shear and enclosed bearing.

Values for thicknesses not listed may be obtained by multiplying the unlisted thickness by the value given for a 1" thickness in the appropriate F_y column.

Values for F_y's not listed may be obtained by multiplying the value given for F_y = 100 ksi by the unlisted F_y and dividing by 100.

RIVETS AND THREADED FASTENERS

Shear

Allowable loads in kips

Power Driven Shop and Field Rivets

Diam. — Area	1⅛ in. — 0.9940 sq. in.		1¼ in. — 1.2272 sq. in.	
ASTM Designation	A502-1	A502-2	A502-1	A502-2
Shear F_v, ksi	15.0	20.0	15.0	20.0
Single Shear, kips Double Shear, kips	14.91 29.82	19.88 39.76	18.41 36.82	24.54 49.09

Unfinished Bolts, ASTM A307, and Threaded Parts, F_y = 36 ksi*

Diam. — Area	1⅛ in. — 0.9940 sq. in.		1¼ in. — 1.2272 sq. in.	
ASTM Designation or Yield Stress, ksi	A307	F_y = 36	A307	F_y = 36
Shear F_v, ksi	10.0	10.8*	10.0	10.8*
Single Shear, kips Double Shear, kips	9.94 19.88	10.74 21.47	12.27 24.54	13.25 26.51

High Strength Bolts in Friction Type Connections and in Bearing Type Connections with Threads in Shear Planes

Diam. — Area	1⅛ in. — 0.9940 sq. in.			1¼ in. — 1.2272 sq. in.		
‡ASTM Designation	A325-F A325-N	A490-F	A490-N	A325-F A325-N	A490-F	A490-N
Shear F_v, ksi	15.0	20.0	22.5	15.0	20.0	22.5
Single Shear, kips Double Shear, kips	14.91 29.82	19.88 39.76	22.37 44.73	18.41 36.82	24.54 49.09	27.61 55.22

High Strength Bolts in Bearing Type Connections with Threads Excluded from Shear Planes

Diam. — Area	1⅛ in. — 0.9940 sq. in.		1¼ in. — 1.2272 sq. in.	
‡ASTM Designation	A325-X	A490-X	A325-X	A490-X
Shear F_v, ksi	22.0	32.0	22.0	32.0
Single Shear, kips Double Shear, kips	21.87 43.74	31.81 63.62	27.00 54.00	39.27 78.54

* For threaded parts of material other than F_y = 36 ksi steel, use $F_v = 0.30 F_y$.

‡ The letter suffixes following the ASTM Designations A325 and A490 represent the following:
F: Friction type connection
N: Bearing type connection with threads included in shear plane
X: Bearin- -pe connection with threads excluded from shear plane

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Bearing

Allowable loads in kips
All rivets and bolts in bearing type connection

	Diam., in.	1⅛								1¼							
	F_y, ksi	36	42	45	50	55	60	65	100	36	42	45	50	55	60	65	100
	Bearing F_p, ksi	48.6	56.7	60.8	67.5	74.3	81.0	87.8	135	48.6	56.7	60.8	67.5	74.3	81.0	87.8	135
MATERIAL THICKNESS	⅛	6.83	7.97	8.55	9.49	10.4	11.4	12.3	19.0	7.59	8.86	9.50	10.6	11.6	12.7	13.7	21.1
	3/16	10.2	12.0	12.8	14.2	15.7	17.1	18.5	28.5	11.4	13.3	14.3	15.8	17.4	19.0	20.6	31.6
	¼	13.7	15.9	17.1	19.0	20.9	22.8	24.7	38.0	15.2	17.7	19.0	21.1	23.2	25.3	27.4	42.2
	5/16	17.1	19.9	21.4	23.7	26.1	78.5	30.9	47.5	19.0	22.1	23.7	26.4	29.0	31.6	34.3	52.7
	⅜	20.5	23.9	25.7	28.5	31.3	34.2	37.0	57.0	22.8	26.6	28.5	31.6	34.8	38.0	41.2	63.3
	7/16	23.9	27.9	29.9	33.2	36.6	39.9	43.2	66.4	26.6	31.0	33.3	36.9	40.6	44.3	48.0	73.8
	½	27.3	31.9	34.2	38.0	41.8	45.6	49.4	75.9	30.4	35.4	38.0	42.2	46.4	50.6	54.9	84.4
	9/16	30.8	35.9	38.5	42.7	47.0	51.3	55.6	85.4	34.2	39.9	42.7	47.5	52.2	57.0	61.7	94.9
	⅝	34.2	39.9	42.7	47.5	52.2	57.0	61.7	94.9	38.0	44.3	47.5	52.7	58.1	63.3	68.5	105
	11/16	37.6	43.9	47.0	52.2	57.5	62.6	67.9	104	41.8	48.7	52.5	58.0	63.9	69.6	75.5	116
	¾	41.0	47.8	51.3	57.0	62.7	68.3		114	45.6	53.2	57.0	63.3	69.7	75.9	82.3	127
	13/16	44.4	51.8	55.6	61.7	67.9			123	49.4	57.6	61.7	68.6	75.5	82.3		137
	⅞	47.8	55.8	59.9	66.4				133	53.2	62.0	66.5	73.8	81.3			148
	15/16	51.3	59.8	64.1					142	57.0	66.4	71.3	79.1				158
	1	54.7	63.8	68.4	75.9	83.6	91.1	98.8	152	60.8	70.9	76.0	84.4	92.9	101	110	169
	1 1/16	58.1							161	64.5	75.3	80.7					179
	1⅛	61.5							171	68.3	79.7						190
	1 3/16	64.9							180	72.1							200
	1¼									75.9							211
	1 5/16									79.7							221

This table not applicable to fasteners in friction type connections.

F_y is the yield stress of the connected material; see AISC Specification, Sect. 1.5.2.2.

F_p, the unit bearing stress, applies equally to conditions of single shear and enclosed bearing.

Values for thicknesses not listed may be obtained by multiplying the unlisted thickness by the value given for a 1" thickness in the appropriate F_y column.

Values for F_y's not listed may be obtained by multiplying the value given for F_y = 100 ksi by the unlisted F_y and dividing by 100.

Shear

Allowable load in kips

Power Driven Shop and Field Rivets

Diam. — Area	1⅜ in. — 1.4849 sq. in.		1½ in. — 1.7671 sq. in.	
ASTM Designation	A502-1	A502-2	A502-1	A502-2
Shear F_v, ksi	15.0	20.0	15.0	20.0
Single Shear, kips Double Shear, kips	22.27 44.55	29.70 59.40	26.51 53.01	35.34 70.68

Unfinished Bolts, ASTM A307, and Threaded Parts, F_y = 36 ksi[a]

Diam. — Area	1⅜ in. — 1.4849 sq. in.		1½ in. — 1.7671 sq. in.	
ASTM Designation or Yield Stress, ksi	A307	F_y = 36	A307	F_y = 36
Shear F_v, ksi	10.0	10.8[a]	10.0	10.8[a]
Single Shear, kips Double Shear, kips	14.85 29.70	16.04 32.07	17.67 35.34	19.08 38.17

High Strength Bolts in Friction Type Connections and in Bearing Type Connections with Threads in Shear Planes

Diam. — Area	1⅜ in. — 1.4849 sq. in.			1½ in. — 1.7671 sq. in.		
[b]ASTM Designation	A325-F A325-N	A490-F	A490-N	A325-F A325-N	A490-F	A490-N
Shear F_v, ksi	15.0	20.0	22.5	15.0	20.0	22.5
Single Shear, kips Double Shear, kips	22.27 44.55	29.70 59.40	33.41 66.82	26.51 53.01	35.34 70.68	39.76 79.52

High Strength Bolts in Bearing Type Connections with Threads Excluded from Shear Planes

Diam. — Area	1⅜ in. — 1.4849 sq. in.		1½ in. — 1.7671 sq. in.	
[b]ASTM Designation	A325-X	A490-X	A325-X	A490-X
Shear F_v, ksi	22.0	32.0	22.0	32.0
Single Shear, kips Double Shear, kips	32.67 65.34	47.52 95.03	38.[illegible] 77.75	56.55 113.09

[a] For threaded parts of material other than F_y = 36 ksi steel, use $F_v = 0.30\ F_y$.

[b] The letter suffixes following the ASTM Designations A325 and A490 represent the following:

F: Friction type connection
N: Bearing type connection with threads included in shear plane
X: Bearing type connection with threads excluded from shear plane

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Bearing

Allowable loads in kips

All rivets and bolts in bearing type connections

	Diam., in.	1⅜								1½							
	F_y, ksi	36	42	45	50	55	60	65	100	36	42	45	50	55	60	65	100
	Bearing F_p, ksi	48.6	56.7	60.8	67.5	74.3	81.0	87.8	135	48.6	56.7	60.8	67.5	74.3	81.0	87.4	135
MATERIAL THICKNESS	⅛	8.35	9.75	10.5	11.6	12.8	13.9	15.1	23.2	9.11	10.6	11.4	12.7	13.9	15.2	16.5	25.3
	3/16	12.5	14.6	15.7	17.4	19.2	20.9	22.6	34.8	13.7	15.9	17.1	19.0	20.9	22.8	24.7	38.0
	¼	16.7	19.5	20.9	23.2	25.5	27.8	30.2	46.4	18.2	21.3	22.8	25.3	27.9	30.4	32.9	50.6
	5/16	20.9	24.4	26.1	29.0	31.9	34.8	37.7	58.0	22.8	26.6	28.5	31.6	34.8	38.0	41.2	63.3
	⅜	25.1	29.2	31.3	34.8	38.3	41.8	45.3	69.6	27.3	31.9	34.2	38.0	41.8	45.6	49.4	75.9
	7/16	29.2	34.1	36.6	40.6	44.7	48.7	52.8	81.2	31.9	37.2	39.9	44.3	48.8	53.2	57.6	88.6
	½	33.4	39.0	41.8	46.4	51.1	55.7	60.4	92.8	36.5	42.5	45.6	50.6	55.7	60.8	65.9	101
	9/16	37.6	43.9	47.0	52.2	57.5	62.6	67.9	104	41.0	47.8	51.3	57.0	62.7	68.3	74.1	114
	⅝	41.8	48.7	52.3	58.0	63.9	69.6	75.5	116	45.6	53.2	57.0	63.3	69.7	75.9	82.3	127
	11/16	45.9	53.6	57.5	63.8	70.2	76.6	83.0	128	50.1	58.5	62.7	69.6	76.6	83.5	90.5	139
	¾	50.1	58.5	62.7	69.6	76.6	83.5	90.5	139	54.7	63.8	68.4	75.9	83.6	91.1	98.8	152
	13/16	54.3	63.3	67.9	75.4	83.0	90.5	98.1	151	59.2	69.1	74.1	82.3	90.6	98.7	107	165
	⅞	58.5	68.2	73.1	81.2	89.4	97.5		162	63.8	74.4	79.8	88.6	97.5	106	115	177
	15/16	62.7	73.1	78.4	87.0	95.8			174	68.3	79.7	85.5	94.9	104	114		190
	1	66.8	78.0	83.6	92.8	102	111	121	186	72.9	85.1	91.2	101	111	122	132	203
	1 1/16	71.0	82.8	88.8	98.6				197	77.5	90.4	96.9	108	118			215
	1⅛	75.2	87.7	94.1					209	82.0	95.7	103	114				228
	1 3/16	79.4	92.6	99.3					220	86.6	101	108					240
	1¼	83.5	97.5						232	91.1	106	114					253
	1 5/16	87.7							244	95.7	112						266
	1⅜	91.9							255	100	117						278
	1 7/16	96.1							267	105							291
	1½									109							304
	1 9/16									114							316

This table not applicable to fasteners in friction type connections.

F_y is the yield stress of the connected material; see AISC Specification, Sect. 1.5.2.2.

F_p, the unit bearing stress, applies equally to conditions of single shear and enclosed bearing.

Values for thicknesses not listed may be obtained by multiplying the unlisted thickness by the value given for a 1" thickness in the appropriate F_y column.

Values for F_y's not listed may be obtained by multiplying the value given for F_y = 100 ksi by the unlisted F_y and dividing by 100.

FRAMED BEAM CONNECTIONS
and
HEAVY FRAMED BEAM CONNECTIONS
Bolted or Riveted

TABLES I and II

BEAM REACTIONS

For economical connections, the beam reactions should be shown on the contract drawings. If these reactions are not shown, connections shall be selected to support half the total uniform load capacity shown in Tables for Allowable Loads on Beams for the given shape, span and steel specified. The effect of concentrated loads must be accounted for.

Beam reactions must be shown on contract drawings for composite beam construction and continuous beam framing.

TYPE OF CONNECTION

Tables are developed for allowable reactions from simple beam (Type 2) framing. No eccentricity or moment resistance is considered in determining tabulated values. Inherent rigidity of the connections is a factor the designer should be aware of and consider where critical.

FASTENERS

Bolts and rivets are listed in AISC Specification Sect. 1.4.4, Bolts, and Sect. 1.4.3, Rivets. Applications should comply with Sect. 1.5.2, Rivets, Bolts and Threaded Parts, and Sect. 1.15.12, Field Connections.

Type of high strength bolt is indicated as follows:

A 325-F and A 490-F: Friction type connection
A 325-N and A 490-N: Bearing type connections with threads included in shear plane
A 325-X and A 490-X: Bearing type connections with threads excluded from shear plane

TABLE I-A AND TABLE II-A

These tables give allowable connection capacities based on:

(a) Vertical shear capacity of the fastener group
(b) Bearing capacity of F_y = 36 ksi steel framing angles of the listed thickness, shear or capacity on the longitudinal gross area of the F_y = 36 ksi framing angles
(c) An arbitrary thickness limitation of $\frac{5}{8}$" for framing angles to assure flexibility

TABLE I-B AND TABLE II-B

These capacities are based on the bearing capacity for the specific group of fasteners in the designated steel for 1" thickness. Bearing capacity of a beam web can be determined by using the web thickness of the supported beam as a multiplier with the appropriate tabular load. Bearing values for unlisted values of F_y may be obtained by multiplying the value given for F_y = 100 ksi by the unlisted yield strength divided by 100.

DETAILS

(a) Connection angle lengths vary from a maximum equal to the T dimension to a minimum equal to half the T dimension of the supported beam.

(b) Vertical fastener spacing is arbitrarily chosen as 3" for these tables. This may be varied, providing requirements for shear in the connection angles and for Specification Sect. 1.16.4, Minimum Pitch, are met.

(c) Edge distance at ends of framing angles is set at $1\frac{1}{4}$" as permitted in Sect. 1.16.5 of the AISC Specification for sizes of fasteners included.

(d) Standard gage for the supporting column should be followed when practical with the angle gage selected to meet requirements of Sect. 1.16.4, Minimum Pitch, and Sect. 1.16.5, Minimum Edge Distance.

(f) Clearance for assembly is essential in all cases.

COMBINATION OF WELDED AND BOLTED FRAMED BEAM CONNECTION

Either the bolted framing angle connection to the supported beam web or the outstanding leg bolted connection may be used with the appropriate welded connection. See FRAMED BEAM CONNECTIONS—WELDED.

OTHER FRAMED CONNECTIONS

These tables are not intended to preclude the use of other designed adequate connections.

EXAMPLES

The purpose of the following examples is to illustrate the primary use of Tables I and II. This primary use is to provide shear and bearing values along with minimum connection angle thickness for selected groups of fasteners.

(a) Given: *Beam:* W 36 × 230, t_w = 0.761"
ASTM A572 grade 45 steel (F_y = 45 ksi)
Bolts: 1" ϕ high-strength ASTM A490-X
(Bearing type—threads excluded)
Reaction: 320 kips

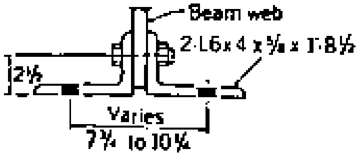
Solution, design: Table I-A7 gives a shear value of 352 kips with the use of $\frac{5}{8}$" thick angles for 1" ϕ A490 bolts in a bearing type connection with no threads in the shear plane. This is for seven fasteners, permitted for all W 36 beams.

Conditions affecting the bearing value from Table I-B7 are F_y = 45 ksi and seven 1" ϕ bolts. These correspond to a value from the table of 425 kips for 1" thick, F_y = 45 ksi steel. The web thickness of 0.761" governs the bearing conditions and gives a bearing value of 0.761 × 425 = 323 kips.

Solution, detail: A quick check for clearance and distance indicates a 4" leg will be adequate for attachment to . eam web compatible with the suggested 2¼″ gage shown. It will not be sufficient for the outstanding legs. A minimum gage for the outstanding legs is developed as follows:

Angle thickness required:	⅝″
Washer thickness (web bolt):	3/16″
Nut thickness (web bolt):	1″
Bolt projection (web bolts):	¼″
Impact wrench clearance:	1 7/16″
	3½″.

A minimum leg gage of 3½″ allows bolts in both legs to be placed on the same horizontal rows and also gives sufficient clearance for the impact wrench. AISC Specification Table 1.16.5 specifies a minimum edge distance of 1¼″ for 1″ϕ bolts. Thus, the minimum angle leg width for the outstanding legs will be 3½″ + 1¼″ = 4¾″. Use either 6 × 4 × ⅝″ × 1′-8½″ angles or 6 × 5 × ⅝″ × 1′-8½″ angles.



Detail for Example (a)
Angles of F_y = 36 ksi material

The use of two 6 × 4 × ⅝″ angles gives a slightly greater option for gage on the outstanding legs. The minimum needed is (2 × 3½″) + ¾″ web = 7¾″. The maximum that may be used is (2 × 6″) + ¾″ web − (2 × 1¼″ edge distance) = 10¼″. The gage chosen may be anywhere between these two limits; selection may be dependent upon gage lines established in the connecting member.

(b) Given: *Beam:* W12 × 14, t_w = 0.198″
ASTM A36 steel (F_y = 36 ksi)
Bolts: ¾″ϕ ASTM A307
Reaction: 20 kips

Solution, design: A glance at the shear values in Table I-A3 indicates that the end reaction can be satisfied by using a single vertical row containing three ¾″ϕ A307 bolts. This group has a shear value of 26.5 kips and the table also shows a minimum thickness angle of ¼″. A compatibility check indicates a three bolt group will provide a suitable angle length for use with a W12 shape.

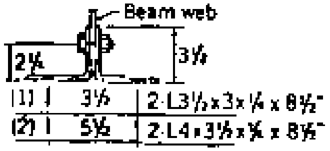
Conditions governing the bearing value found in Table I-B3 are F_y = 36 ksi and three ¾″ϕ bolts. This table shows a value of 109 kips for 1″ thick steel under these conditions. The W12 × 14 has a 0.198″ web thickness. The bearing value for the group is then 0.198 × 109 = 21.6 kips.

The allowable shear and bearing values of 26.5 kips and 21.6 kips are each greater than the reaction of 20 kips and the selected connection is satisfactory.

Solution, detail:

(1) Consider that the W12 × 14 is to frame into the flange of a W8 × 28. From AISC Manual Part 1, the usual gage for this flange is 3½″. Using the 3½″ gage in the column flange will result in a gage of (½ × 3½) − ⅛ (for ½ the web thickness) = 1⅝″. AISC Specification Table 1.16.5 requires a minimum edge distance of 1″, making the minimum width of angle 1⅝″ + 1 = 2⅝″. The outstanding angle leg width chosen would then be 3″. If a 3″ web leg is used it will not allow enough edge distance with the suggested 2¼″ gage shown in the sketch accompanying Table I-A3 and there will be insufficient clearance. Increase the angle size; choose two angles 3½ × 3 × ¼″ × 0′-8½″.

(2) Consider that the W12 × 14 is to frame into the flange of a W8 × 31, which has a usual gage of 5½″. This will result in a gage of (½ × 5½) − ⅛ = 2⅝″. The edge distance of 1″ still prevails and gives a minimum leg width of 2⅝ + 1 = 3⅝″. Use 4 × 3½ × ¼″ × 0′-8½″ angles to adequately satisfy this condition. The 2¼″ gage is still satisfactory for the web legs.



Detail for Example (b)
Beam and angles of F_y = 36 ksi material

(c) Given: *Beam:* W18 × 60, t_w = 0.416″
ASTM A572 grade 50 steel (F_y = 50 ksi)
Bolts: ⅞″ϕ ASTM A325-X (Bearing type—threads excluded)
Reaction: 150 kips

Solution, design: Table I-A5 gives a shear value of 132 kips for five bolts and Table I-A6 shows 159 kips for six bolts. However, consulting the limit of sections indicated for Table I-A6, it is seen that six horizontal rows of fasteners cannot be used without reducing the 3″ fastener spacing or going to a heavy framed (double vertical row) connection. A third solution would be to increase the size of fasteners; in most instances this would be undesirable. Arbitrarily, use the heavy framed connection. Table II-A4 gives a value of 159 kips using four horizontal rows and a total of six ⅞″ϕ A325 bolts. It also indicates that a minimum angle thickness of ⅝″ is needed to maintain this shear value.

Conditions affecting the bearing value selected from Table II-B4 are F_y = 50 ksi and six ⅞″ ϕ bolts. These correspond to a value from the table of 354 kips for 1″ steel, F_y = 50 ksi. The web thickness of 0.416″ governs the bearing condition and gives a bearing value of 0.416 × 354 = 147 kips. Use a seven bolt group.

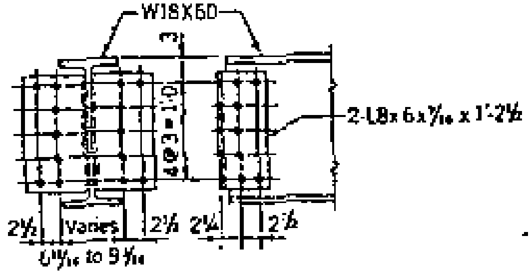
Table II does not include a seven fastener connection; however, the five row, eight fastener tables can be used, and one fastener dropped, provided the shear and bearing check and the symmetry of the connection is maintained. Table II-A5 gives a shear value of 212 kips for eight ⅞"φ A325-X bolts: for seven bolts the shear will be 212 × ⅞ = 186 kips. The angle thickness required for eight bolts is $\frac{5}{16}$". 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 ⅜" 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 × ⅞ = 172 kips. The bearing in the two ⅜" angles (A36 steel) is not critical.

Solution, detail: Using the 2¼"-2½" 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 1⅛". This gives a minimum width of leg 2¼" + 2½" + 1⅛" = 5⅞" or 6". A minimum gage for the outstanding legs is developed as follows:

Angle thickness required:	⅜"
Washer thickness (web bolt):	$\frac{5}{16}$"
Nut thickness (web bolt):	⅞"
Bolt projection (web bolt):	¼"
Impact wrench clearance:	1⅝"
	$3\frac{1}{16}$"

A minimum leg gage of $3\frac{1}{16}$" 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 1⅛" for ⅞"φ bolts. Thus, the minimum angle leg width for the outstanding leg will be $3\frac{1}{16} + 2\frac{1}{2} + 1\frac{1}{8} = 6\frac{11}{16}''$.

Since a 6" leg must be used with the web and at least $6\frac{11}{16}$" is needed on the outstanding legs, use two angles 8 × 6 × $\frac{7}{16}$" × 1'-2½". (This size angle is not rolled in a ⅜" thickness; therefore, a $\frac{7}{16}$" angle is selected.) The minimum inside gage that may be used across the outstanding legs is $2 \times (3\frac{1}{16} + \frac{1}{16}) + \frac{7}{16}$ beam web $= 6\frac{11}{16}''$. The maximum inside gage that may be used across the outstanding legs is $(2 \times 8) + \frac{7}{16}$ web $- 2\,(2\frac{1}{2}''$ gage $+ 1\frac{1}{8}''$ edge distance$) = 9\frac{5}{16}''$. 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

FRAMED BEAM CONNECTIONS

Bolted or riveted

TABLE I Allowable loads in kips

10 ROWS

W 36

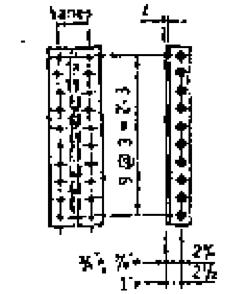


TABLE I-A10 Total Shear, kips

[a]Fastener Designation	F_v ksi	Fastener Diameter					
		¾		⅞		1	
		Load	t[b]	Load	t[b]	Load	t[b]
A307	10.0	88.4	¼	120	¼	157	¼
A325-F A325-N A502-1	15.0	133	¼	180	¼	236	$\frac{5}{16}$
A490-F A502-2	20.0	177	¼	241	$\frac{5}{16}$	314	⅜
A325-X	22.0	194	$\frac{5}{16}$	265	$\frac{5}{16}$	346	$\frac{7}{16}$
A490-N	22.5	199	$\frac{5}{16}$	271	⅜	353	$\frac{7}{16}$
A490-X	32.0	283	$\frac{7}{16}$	385	½	503	⅝

TABLE I-B10 Total Bearing,[c] kips, 10 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	365	425	456	506	557	608	658	1010
	⅞	425	496	532	591	650	709	768	1180
	1	486	567	608	675	743	810	878	1350

9 ROWS

W 36, 33

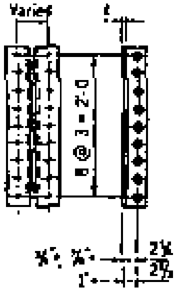


TABLE I-A9 Total Shear, kips

[a]Fastener Designation	F_v ksi	Fastener Diameter					
		¾		⅞		1	
		Load	t[b]	Load	t[b]	Load	t[b]
A307	10.0	79.6	¼	108	¼	141	¼
A325-F A325-N A502-1	15.0	119	¼	162	¼	212	$\frac{5}{16}$
A490-F A502-2	20.0	159	¼	216	$\frac{5}{16}$	283	⅜
A325-X	22.0	175	$\frac{5}{16}$	238	$\frac{5}{16}$	311	$\frac{7}{16}$
A490-N	22.5	179	$\frac{5}{16}$	244	⅜	318	$\frac{7}{16}$
A490-X	32.0	255	$\frac{7}{16}$	346	½	452	⅝

TABLE I-B9 Total Bearing,[c] kips, 9 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	328	383	410	456	501	547	592	911
	⅞	383	447	478	532	585	638	691	1060
	1	437	510	547	608	668	729	790	1220

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[a] For description of fastener designation see page 4-12.

[b] Thickness t based on connection angles of F_y = 36 ksi material.

[c] Use decimal thickness of enclosed web material as multiplying factor for these values.

FRAMED BEAM CONNECTIONS

Bolted or riveted

TABLE I Allowable loads in kips

8 ROWS

W 36, 33, 30

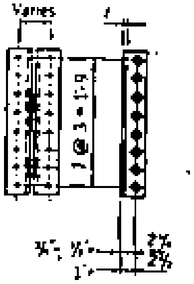

TABLE I-A8 Total Shear, kips

ᵃFastener Designation	F_v ksi	Fastener Diameter ¾ Load	¾ t^b	⅞ Load	⅞ t^b	1 Load	1 t^b
A307	10.0	70.7	¼	96.2	¼	126	¼
A325-F A325-N A502-1	15.0	106	¼	144	¼	189	5/16
A490-F A502-2	20.0	141	¼	192	5/16	251	⅜
A325-X	22.0	156	5/16	212	5/16	276	7/16
A490-N	22.5	159	5/16	216	⅜	283	7/16
A490-X	32.0	226	7/16	308	½	402	⅝

TABLE I-B8 Total Bearing,ᶜ kips, 8 fasteners on 1" thick material

Fastener Diameter	F_y 36	42	45	50	55	60	65	100
¾	292	340	364	405	446	486	527	810
⅞	340	397	425	472	520	567	614	945
1	389	454	486	540	594	648	702	1080

7 ROWS

W 36, 33, 30, 27, 24
S 24ᵈ

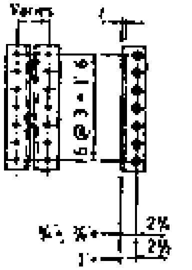

TABLE I-A7 Total Shear, kips

ᵃFastener Designation	F_v ksi	Fastener Diameter ¾ Load	¾ t^b	⅞ Load	⅞ t^b	1 Load	1 t^b
A307	10.0	61.9	¼	84.2	¼	110	¼
A325-F A325-N A502-1	15.0	92.8	¼	126	¼	165	5/16
A490-F A502-2	20.0	124	¼	168	5/16	220	⅜
A325-X	22.0	136	5/16	185	5/16	242	7/16
A490-N	22.5	139	5/16	189	⅜	247	7/16
A490-X	32.0	198	7/16	269	½	352	⅝

TABLE I-B7 Total Bearing,ᶜ kips, 7 fasteners on 1" thick material

Fastener Diameter	F_y 36	42	45	50	55	60	65	100
¾	256	298	319	354	390	425	461	709
⅞	298	347	372	413	455	496	537	827
1	340	397	425	473	520	567	614	945

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[a] For description of fastener designation see page 4-12.
[b] Thickness t based on connection angles of F_y = 36 ksi material.
[c] Use decimal thickness of enclosed web material as multiplying factor for these values.
[d] Limited to S 24 × 79.9, 90, 100.

FRAMED BEAM CONNECTIONS

Bolted or riveted

TABLE I Allowable loads in kips

6 ROWS

W 36, 33, 30, 27, 24, 21
S 24

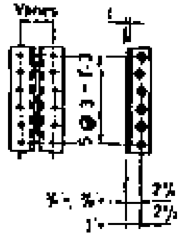

TABLE I-A6 Total Shear, kips

ᵃFastener Designation	F_v ksi	Fastener Diameter ¾ Load	¾ t^b	⅞ Load	⅞ t^b	1 Load	1 t^b
A307	10.0	53.0	¼	72.2	¼	94.3	¼
A325-F A325-N A502-1	15.0	79.5	¼	108	¼	141	5/16
A490-F A502-2	20.0	106	¼	144	5/16	189	⅜
A325-X	22.0	117	5/16	159	⅜	207	7/16
A490-N	22.5	119	5/16	162	⅜	212	7/16
A490-X	32.0	170	7/16	231	½	302	⅝

TABLE I-B6 Total Bearing,ᶜ kips, 6 fasteners on 1" thick material

Fastener Diameter	F_y 36	42	45	50	55	60	65	100
¾	219	255	273	304	334	365	395	608
⅞	255	298	319	354	390	425	461	709
1	292	340	365	405	446	486	527	810

5 ROWS

W 30, 27, 24, 21, 18
S 24, 20, 18
MC 18

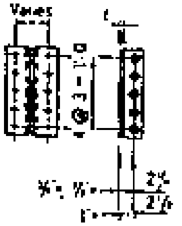

TABLE I-A5 Total Shear, kips

ᵃFastener Designation	F_v ksi	Fastener Diameter ¾ Load	¾ t^b	⅞ Load	⅞ t^b	1 Load	1 t^b
A307	10.0	44.2	¼	60.2	¼	78.6	¼
A325-F A325-N A502-1	15.0	66.3	¼	90.2	¼	118	5/16
A490-F A502-2	20.0	88.4	¼	120	5/16	157	⅜
A325-X	22.0	97.2	5/16	132	⅜	173	7/16
A490-N	22.5	99.4	5/16	135	⅜	177	7/16
A490-X	32.0	141	7/16	192	½	251	⅝

TABLE I-B5 Total Bearing,ᶜ kips, 5 fasteners on 1" thick material

Fastener Diameter	F_y 36	42	45	50	55	60	65	100
¾	182	213	228	253	278	304	329	506
⅞	213	248	266	295	325	354	384	591
1	243	284	304	336	371	405	439	675

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[a] For description of fastener designation see page 4-12.
[b] Thickness t based on connection angles of F_y = 36 ksi material.
[c] Use decimal thickness of enclosed web material as multiplying factor for these values.

FRAMED BEAM CONNECTIONS
Bolted or riveted
TABLE I Allowable loads in kips

4 ROWS

W 24, 21, 18, 16
M 14
S 24, 20, 18, 15
C 15; MC 18

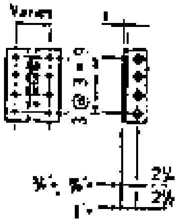

TABLE I-A4 Total Shear, kips

[a]Fastener Designation	F_v ksi	Fastener Diameter					
		¾		⅞		1	
		Load	t[b]	Load	t[b]	Load	t[b]
A307	10.0	35.4	¼	48.1	¼	62.8	¼
A325-F A325-N A502-1	15.0	53.0	¼	72.2	¼	94.2	5/16
A490-F A502-2	20.0	70.7	¼	96.2	5/16	126	7/16
A325-X	22.0	77.8	5/16	106	⅜	138	7/16
A490-N	22.5	79.5	5/16	108	⅜	141	7/16
A490-X	32.0	113	7/16	154	½	201	⅝

TABLE I-B4 Total Bearing,[c] ksi, 4 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	146	170	182	203	223	243	263	405
	⅞	170	198	213	236	260	284	307	473
	1	194	227	243	270	297	324	351	540

3 ROWS

W 18, 16, 14, 12, 10*
M 14, 12
S 18, 15, 12
C 15, 12, 10*
MC 12, 10

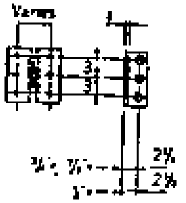

TABLE I-A3 Total Shear, kips

[a]Fastener Designation	F_v ksi	Fastener Diameter					
		¾		⅞		1	
		Load	t[b]	Load	t[b]	Load	t[b]
A307	10.0	26.5	¼	36.1	¼	47.1	¼
A325-F A325-N A502-1	15.0	39.8	¼	54.1	¼	70.7	5/16
A490-F A502-2	20.0	53.0	¼	72.2	5/16	94.3	7/16
A325-X	22.0	58.3	5/16	79.4	⅜	104	7/16
A490-N	22.5	59.6	5/16	81.2	⅜	106	7/16
A490-X	32.0	84.8	7/16	115	½	151	⅝

TABLE I-B3 Total Bearing,[c] kips, 3 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	109	128	137	152	167	182	197	304
	⅞	128	149	159	177	195	213	230	354
	1	146	170	182	203	223	243	263	405

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[a] For description of fastener designation see page 4-12.
[b] Thickness t based on connection angles of F_y = 36 ksi material.
[c] Use decimal thickness of enclosed web material as multiplying factor for these values.
[d] Lie to W 10 × 11.5, 15, 17, 19, 21, 25, 29; C 10 × 15.3, 20, 25, 30.

FRAMED BEAM CONNECTIONS
Bolted or riveted
TABLE I Allowable loads in kips

2 ROWS

W 12, 10, 8
S 12, 10, 8
C 12, 10, 9, 8

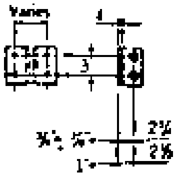

TABLE I-A2 Total Shear, kips

[a]Fastener Designation	F_v ksi	Fastener Diameter					
		¾		⅞		1	
		Load	t[b]	Load	t[b]	Load	t[b]
A307	10.0	17.7	¼	24.1	¼	31.4	¼
A325-F A325-N A502-1	15.0	26.5	¼	36.1	¼	47.1	5/16
A490-F A502-2	20.0	35.3	¼	48.1	5/16	62.8	7/16
A325-X	22.0	38.9	5/16	52.9	⅜	69.1	7/16
A490-N	22.5	39.8	5/16	54.1	⅜	70.7	½
A490-X	32.0	56.6	7/16	77.0	½	99.7*	⅝

TABLE I-B2 Total Bearing,[c] kips, 2 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	72.9	85.1	91.1	101	111	122	132	203
	⅞	85.1	99.2	106	118	130	142	154	236
	1	97.2	113	122	135	149	162	176	270

1 ROW

W 6, 5
M 6, 5
S 8, 7, 6, 5
C 7, 6, 5

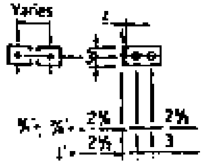

TABLE I-A1 Total Shear, kips

[a]Fastener Designation	F_v ksi	Fastener Diameter					
		¾		⅞		1	
		Load	t[b]	Load	t[b]	Load	t[b]
A307	10.0	8.8	¼	12.0	¼	15.7	¼
A325-F A325-N A502-1	15.0	13.3	¼	18.0	¼	23.6	5/16
A490-F A502-2	20.0	17.7	¼	24.1	5/16	31.4	⅜
A325-X	22.0	19.4	5/16	26.5	5/16	34.6	7/16
A430-N	22.5	19.9	5/16	27.1	⅜	35.3	7/16
A490-X	32.0	28.3	7/16	38.5	½	50.3	⅝

TABLE I-B1 Total Bearing,[c,d] kips, on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	72.9	85.1	91.1	101	111	122	132	203
	⅞	85.1	99.2	106	118	130	142	154	236
	1	97.2	113	122	135	149	162	176	270

---

[a] For description of fastener designation see page 4-12.
[b] Thickness t based on connection angles of F_y = 36 ksi material.
[c] Use decimal thickness of enclosed web material as multiplying factor for these values.
[d] Values shown are for 1 bolt in each outstanding leg or 2 bolts in web leg.
* Indicates shear values are limited by shear capacity of ⅝" angle of F_y = 36 ksi material (arbitrary limit for flexibility), and length of angle assumed to be c/c outside fa [illegible] plus 2½".

EAVY FRAMED BEAM CONNECTIONS

Bolted or riveted

TABLE II Allowable loads in kips

10 ROWS

W 36

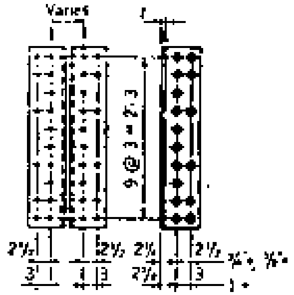

TABLE II-A10 Total Shear, kips, 16 fasteners

*Fastener Designation	F_v ksi	Fastener diameter					
		¾		⅞		1	
		Load	t^b	Load	t^b	Load	t^b
A325-F A325-N A502-1	15.0	212	¼	289	⅜	377	½
A490-F A502-2	20.0	283	⅜	385	½	503	⅝
A325-X	22.0	311	⅜	423	½	535*	⅝
A490-N	22.5	318	⅜	433	9/16		
A490-X	32.0	452	9/16	535*	⅝		

TABLE II-B10 Total Bearing,[c] kips, 16 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	583	680	729	810	891	972	1050	1620
	⅞	680	794	851	945	1040	1130	1230	1890
	1	778	907	972	1080	1190	1300	1400	2160

9 ROWS

W 36, 33

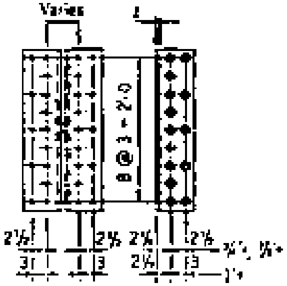

TABLE II-A9 Total Shear, kips, 14 fasteners

*Fastener Designation	F_v ksi	Fastener diameter					
		¾		⅞		1	
		Load	t^b	Load	t^b	Load	t^b
A325-F A325-N A502-1	15.0	186	¼	253	⅜	330	7/16
A490-F A502-2	20.0	247	⅜	337	½	440	⅝
A325-X	22.0	272	⅜	370	½	480*	⅝
A490-N	22.5	278	⅜	379	½		
A490-X	32.0	396	9/16	480*	⅝		

TABLE II-B9 Total Bearing,[c] kips, 14 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	510	595	638	709	780	851	921	1420
	⅞	595	695	744	827	910	992	1080	1650
	1	680	794	851	945	1040	1130	1230	1890

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[a] For description of fastener designation see page 4-12.
[b] Thickness t based on connection angles of F_y = 36 ksi material.
[c] Use decimal thickness of enclosed web material as multiplying factor for these values.
* Indicates shear values are limited by shear capacity of ⅝" angle of F_y = 36 ksi material (arbitrary limit for flexibility), and length of angle assumed to be c/c outside fasteners plus 2½".

HEAVY FRAMED BEAM CONNECTIONS

Bolted or riveted

TABLE II Allowable loads in kips

8 ROWS

W 36, 33, 30

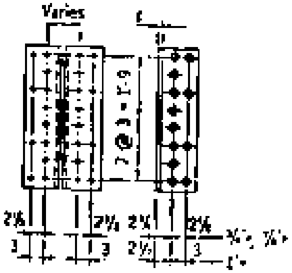

TABLE II-A8 Total Shear, kips, 12 fasteners

*Fastener Designation	F_v ksi	Fastener diameter					
		¾		⅞		1	
		Load	t^b	Load	t^b	Load	t^b
A325-F A325-N A502-1	15.0	159	¼	216	⅜	283	7/16
A490-F A502-2	20.0	212	5/16	289	7/16	377	9/16
A325-X	22.0	233	⅜	318	½	415	⅝
A490-N	22.5	239	⅜	325	½	426*	⅝
A490-X	32.0	339	½	426*	⅝		

TABLE II-B8 Total Bearing,[c] kips, 12 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	437	510	547	608	668	729	790	1220
	⅞	510	595	638	709	780	851	921	1420
	1	583	680	729	810	891	972	1050	1620

7 ROWS

W 36, 33, 30, 27, 24
S 24**

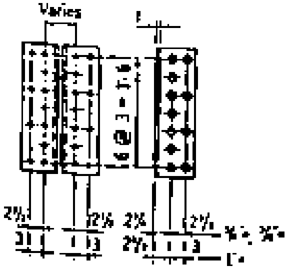

TABLE II-A7 Total Shear, kips, 11 fasteners

*Fastener Designation	F_v ksi	Fastener diameter					
		¾		⅞		1	
		Load	t^b	Load	t^b	Load	t^b
A325-F A325-N A502-1	15.0	146	¼	198	⅜	259	½
A490-F A502-2	20.0	194	⅜	265	½	346	⅝
A325-X	22.0	214	⅜	291	½	372*	⅝
A490-N	22.5	219	⅜	298	9/16		
A490-X	32.0	311	9/16	372*	⅝		

TABLE II-B7 Total Bearing,[c] kips, 11 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	401	468	501	557	613	668	724	1110
	⅞	468	546	585	650	715	780	845	1300
	1	535	624	668	743	817	891	955	1490

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[a] For description of fastener designation see page 4-12.
[b] Thickness t based on connection angles of F_y = 36 ksi material.
[c] Use decimal thickness of enclosed web material as multiplying factor for these values.
* Indicates shear values limited by shear capacity of ⅝" angle of F_y = 36 ksi material (arbitrary limit for flexibility), and length of angle assumed to be c/c of outside fasteners plus 2½".
** Limited to S 24 × 79.9, 90, 100.

HEAVY FRAMED BEAM CONNECTIONS

Bolted or riveted

TABLE II Allowable loads in kips

6 ROWS

W 36, 33, 30,
27, 24, 21
S 24

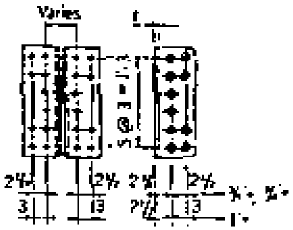

TABLE II-A6 Total Shear, kips, 10 fasteners

[a]Fastener Designation	F_v ksi	Fastener diameter					
		¾		⅞		1	
		Load	t^b	Load	t^b	Load	t^b
A325-F A325-N A502-1	15.0	133	5/16	180	⅜	236	½
A490-F A502-2	20.0	177	⅜	241	½	314	⅝
A325-X	22.0	194	7/16	265	9/16	317*	⅝
A490-N	22.5	199	7/16	271	9/16		
A490-X	32.0	283	9/16	317*	⅝		

TABLE II-B6 Total Bearing,[c] kips, 10 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	365	425	456	506	557	608	658	1010
	⅞	425	496	532	591	650	709	768	1180
	1	486	567	608	675	743	810	878	1350

5 ROWS

W 30, 27, 24, 21, 18
S 24, 20, 18
MC 18

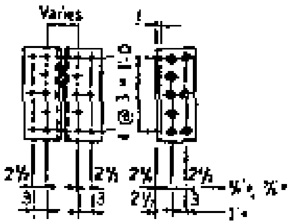

TABLE II A5 Total Shear, kips, 8 fasteners

[a]Fastener Designation	F_v ksi	Fastener diameter					
		¾		⅞		1	
		Load	t^b	Load	t^b	Load	t^b
A325-F A325-N A502-1	15.0	106	5/16	144	⅜	188	½
A490-F A502-2	20.0	141	⅜	192	½	251	⅝
A325-X	22.0	156	⅜	212	9/16	263*	⅝
A490-N	22.5	159	7/16	216	9/16		
A490-X	32.0	226	9/16	263*	⅝		

TABLE II-B5 Total Bearing,[c] kips, 8 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	292	340	365	405	446	486	527	810
	⅞	340	397	425	473	520	567	614	945
	1	389	454	486	540	594	648	702	1080

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[a] For description of fastener designation see page 4-12.
[b] Thickness t based on connection angles of F_y = 36 ksi material.
[c] Use decimal thickness of enclosed web material as multiplying factor for these values.
[d] Indicates shear values limited by shear capacity of ⅝" angle of F_y = 36 ksi material (arbitrary limit for flexibility), and length of angle assumed to be c/c of outside fasteners plus 2½".

HEAVY FRAMED BEAM CONNECTIONS

Bolted or riveted

TABLE II Allowable loads in kips

4 ROWS

W 24, 21, 18, 16
M 14
S 24, 20, 18, 15
C 15; MC 18

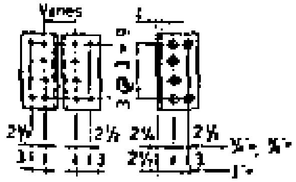

TABLE II-A4 Total Shear, kips, 6 fasteners

[a]Fastener Designation	F_v ksi	Fastener diameter					
		¾		⅞**		1	
		Load	t^b	Load	t^b	Load	t^b
A325-F A325-N A502-1	15.0	79.5	[illegible]	108	⅜	141	7/16
A490-F A502-2	20.0	106	[illegible]	144	7/16	189	⅝
A325-X	22.0	117	[illegible]	159	½	207	⅝
A490-N	22.5	119	[illegible]	152	½	208*	⅝
A490-X	32.0	170	[illegible]	208*	⅝		

TABLE II-B4 Total Bearing,[c] kips, 6 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	219	255	273	304	334	365	395	608
	⅞	255	298	319	354	[illegible]	425	461	709
	1	292	340	365	405	[illegible]	486	527	810

3 ROWS

W 18, 16, 14, 12, 10**
M 14, 12
S 18, 15, 12
C 15, 12; MC 12, 10

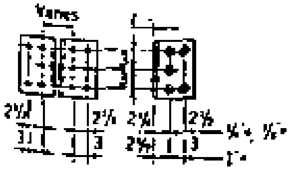

TABLE II-A3 Total Shear, kips, 5 fasteners

[a]Fastener Designation	F_v ksi	Fastener diameter					
		¾		⅞		1	
		Load	t^b	Load	t^b	Load	t^b
A325-F A325-N A502-1	15.0	66.3	[illegible]	90.2	⅜	118	½
A490-F A502-2	20.0	88.4	⅜	120	½	154*	⅝
A325-X	22.0	97.2	7/16	132	9/16		
A490-N	22.5	99.4	7/16	135	7/16		
A490-X	32.0	141	[illegible]	154*	⅝		

TABLE II-B3 Total Bearing,[c] kips, 5 fasteners on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	¾	182	213	228	253	278	304	329	506
	⅞	213	248	266	295	325	354	384	591
	1	243	284	304	338	371	405	439	675

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[a] For description of fastener designation see page 4-12.
[b] Thickness t based on connection angles of F_y = 36 ksi material.
[c] Use decimal thickness of enclosed web material as multiplying factor for th[illegible] values.
[d] Indicates shear values limited by shear capacity of ⅝" angle of F_y = 36 [illegible] erial (arbitrary limit for flexibility), and length of angle assumed to be c/c of outside [illegible] ers plus 2½".
** Limited to W 10 × 11.5, 15, 17, 19, 21, 25, 29.

HEAVY FRAMED BEAM CONNECTIONS

Bolted or riveted

TABLE II Allowable loads in kips

2 ROWS

W 12, 10, 8
S 12, 10, 8
C 12, 10, 9, 8

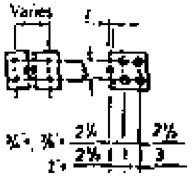


TABLE II-A2 Total Shear, kips, 4 fasteners

[a]Fastener Designation	F_v ksi	Fastener Diameter					
		3/4		7/8		1	
		Load	t[b]	Load	t[b]	Load	t[b]
A325-F A325-N A502-1	15.0	26.5	1/4	36.1	1/4	47.1	5/16
A490-F A502-2	20.0	35.4	1/4	48.1	5/16	62.8	7/16
A325-X	22.0	38.9	1/4	52.9	3/8	69.2	7/16
A490-N	22.5	39.8	1/4	54.1	3/8	70.7	1/2
A490-X	32.0	56.6	3/8	77.0	1/2	100[e]	5/8

TABLE II-B2 Total Bearing,[c,d] kips, on 1" thick material

	F_y	36	42	45	50	55	60	65	100
Fastener Diameter	3/4	146	170	182	203	223	243	263	405
	7/8	170	198	213	236	260	284	307	473
	1	194	227	243	270	297	324	351	540

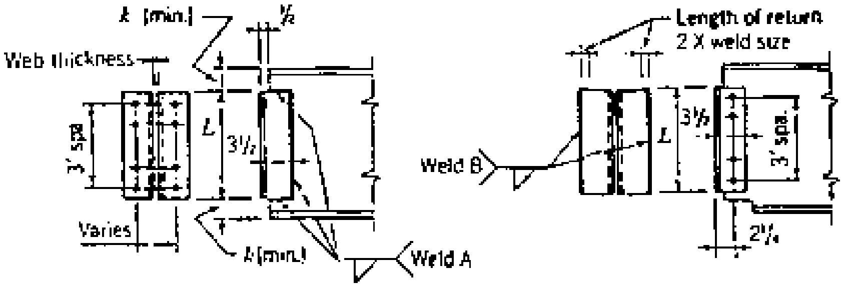
---

[a] For description of fastener designation see page 4-12.
[b] Thickness t based on connection angles of $F_y = 36$ ksi material.
[c] Use decimal thickness of enclosed web material as multiplying factor for these values.
[d] Values shown are for 2 bolts in each outstanding leg or 4 bolts in web legs.
[e] Indicates shear values limited by shear capacity of 5/8" angle of $F_y = 36$ ksi material (arbitrary limit for flexibility), and length of angle assumed to be c/c of outside fasteners plus 2 1/2".

Notes

FRAMED BEAM CONNECTIONS
Welded—E70XX electrodes
for combination with Table I connections

TABLE III



Case I Case II

Table III is arranged to permit substitution of welds for rivets or bolts in the connections shown in Table I which fall within the weld capacities. Welds A replace fasteners in the beam web legs (Case I). Welds B replace fasteners in the outstanding legs (Case II).

To accommodate usual gages, angle leg widths will generally be 4 × 3½″, with the 4″ leg outstanding. Width of web legs in Case I may be reduced optionally from 3½″ to 3″. Width of outstanding legs in Case II may be reduced optionally from 4″ to 3″ for values of L = 5½″ through 1′-5½″. When 3″ legs are used, tabular capacities of welds A and B are conservative.

Angle thickness is equal to weld size plus $\frac{1}{16}$″, or thickness of angle from applicable Table I-A, whichever is greater.

Angle length L must be as tabulated in Table III.

Holes for erection bolts may be placed as required in legs to be field welded (optional).

When rivets or bolts in bearing type connections are used in outstanding legs, investigate bearing capacity of supporting member.

Although it is permissible to use welds A and B in combination to obtain all-welded connections, it is recommended that such connections be chosen from Table IV. This table will usually provide greater economy and allow increased flexibility in selection of angle lengths and connection capacities.

EXAMPLES CASE I

(a) Given: *Beam:* W36 × 150; t_w = 0.625
F_y = 36 ksi; F_v = 14.5 ksi
Reaction: 200 kips
Bolts: ⅞″ ϕ, ASTM A325-X
Welds: E70XX

Solution: Enter Table III under Weld A and note that the value most nearly satisfying the reaction is 217 kips. This requires $\frac{5}{16}$ in. welds and 1′-11½″ long angles. Use ⅜″ thick angles to meet the weld requirement stipulated in AISC Specification Sect. 1.17.6. The 0.625″ web thickness exceeds the minimum required 0.54″, so no reduction in capacity is necessary.

Note in Table I-A8 that the angle length is compatible for the 36″ deep beam and that 8 rows of ⅞″ ϕ ASTM A325-X bolts have a capacity of 212 kips. The $\frac{5}{16}$″ required angle thickness is less than the ⅜″ angle thickness required due to Weld A.

Detail Data: Two L 4 × 3½ × ⅜ × 1′-11½″
F_y = 36 ksi
Sixteen ⅞″ ϕ ASTM A325-X bolts (threads excluded from shear plane)
$\frac{5}{16}$ in. fillet weld, E70XX

(b) Given: *Beam:* W16 × 26; t_w = 0.25
F_y = 36 ksi; F_v = 14.5 ksi
Reaction: 48 kips
Bolts: ⅞″ ϕ ASTM A307
Welds: E70XX

Solution: See Table I-A4 and note 4 rows of bolts with 11½″ long angles are compatible with a 16″ deep section. Capacity of the ⅞″ ϕ ASTM A307 bolts with ¼″ thick angles is 48.1 kips.

Note in Table III that 59.4 kips capacity is designated for $\frac{3}{16}$ in. Weld A and 11½″ long angles. The 0.25″ web thickness is less than the minimum 0.29″ listed. The reduced capacity is 0.25/0.29 times 59.4 kips, or 51.2 kips. The ¼″ angle thickness required for bolts is satisfactory for the $\frac{3}{16}$ in. weld.

Detail Data: Two L 4 × 3½ × ¼ × 0′-11½″
F_y = 36 ksi
Eight ⅞″ ϕ ASTM A307 bolts
$\frac{3}{16}$ in. fillet weld, E70XX

EXAMPLES CASE II

(c) **Given:** *Beam:* W36×150; t_w = 0.625"
F_y = 36 ksi; F_v = 14.5 ksi
Reaction: 150 kips
Bolts: 7/8" ϕ ASTM A490-F (friction type)
Welds: E70XX

Solution: Enter Table III under Weld B and note that the value most nearly satisfying the reaction is 152 kips. This requires 3/8 in. Weld B and 1'-5½" long 7/16" thick angles. However, Table I-A6 shows a bolt capacity for this connection of 144 kips, which is less than the 150 kips required. Therefore a 1'-8½" long angle is selected from Table III. This angle requires a 5/16 in. Weld B and 3/8" thick angles with a capacity of 156 kips.

Note in Table I-A7 that 7 rows of 7/8" ϕ ASTM A490-F bolts have a capacity of 168 kips. The 5/16" angle thickness required is less than the thickness required by Weld B. Bearing on the web need not be checked since a friction-type connection is used.

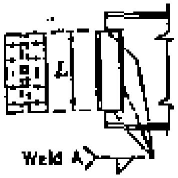
Detail Data: Two L 4 × 3½ × 3/8 × 1'-8½"
F_y = 36 ksi
Seven 7/8" ϕ ASTM A490-F bolts
5/16 in. fillet weld, E70XX

(d) **Given:** *Beam:* W16×31; t_w = 0.275"
F_y = 50 ksi; F_v = 20 ksi
Reaction: 39 kips
Bolts: 3/4" ϕ ASTM A325-N (threads included in shear plane)
Welds: E70XX

Solution: Enter Table III under Weld B and note that the value most nearly satisfying the reaction is 40.3 kips. This requires 5/16 in. Weld B and 8½" long, 3/8" thick angles.

Enter Table I-A3 for 3 rows of fasteners and note that the angle length is compatible with beam size. Capacity of three 3/4" ϕ ASTM A325 bolts acting in bearing is 39.8 kips. Check web bearing on bolts. Bearing capacity for 1" material from Table I-B3 is 152 kips. For this beam, web capacity = 152 × 0.275 = 41.8 kips.

Detail Data: Two L 4 × 3½ × 3/8 × 0'-8½"
F_y = 36 ksi
Three 3/4" ϕ ASTM A325-N bolts
5/16 in. fillet weld, E70XX



FRAMED BEAM CONNECTIONS
Welded—E70XX electrodes
for combination with Table I connections

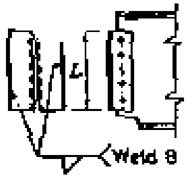


TABLE III Allowable loads in kips

Weld A		Weld B		Angle Length L	[a]Minimum Web Thickness for Welds A		Number of Fasteners in One Vertical Row (Table I)
Capacity Kips	[b]Size In.	[c]Capacity Kips	[b]Size In.		F_y = 36 ksi F_v = 14.5 ksi	F_y = 50 ksi F_v = 20 ksi	
276	5/16	296	3/8	2'- 5½	.56	.41	10
221	1/4	247	5/16	2'- 5½	.46	.33	
166	3/16	197	1/4	2'- 5½	.34	.25	
246	5/16	261	3/8	2'- 2½	.55	.40	9
197	1/4	217	5/16	2'- 2½	.45	.32	
148	3/16	173	1/4	2'- 2½	.33	.24	
217	5/16	223	3/8	1'-11½	.54	.39	8
173	1/4	186	5/16	1'-11½	.44	.32	
130	3/16	149	1/4	1'-11½	.33	.24	
186	5/16	187	3/8	1'- 8½	.53	.39	7
149	1/4	156	5/16	1'- 8½	.43	.31	
112	3/16	125	1/4	1'- 8½	.32	.23	
157	5/16	152	3/8	1'- 5½	.52	.38	6
125	1/4	126	5/16	1'- 5½	.42	.30	
94.1	3/16	101	1/4	1'- 5½	.31	.23	
128	5/16	115	3/8	1'- 2½	.50	.36	5
102	1/4	95.7	5/16	1'- 2½	.41	.29	
76.6	3/16	76.6	1/4	1'- 2½	.30	.22	
99.0	5/16	80.1	3/8	11½	.48	.35	4
79.2	1/4	66.9	5/16	11½	.39	.28	
59.4	3/16	53.4	1/4	11½	.29	.21	
71.2	5/16	48.2	3/8	8½	.46	.33	3
57.0	1/4	40.3	5/16	8½	.37	.27	
42.8	3/16	32.2	1/4	8½	.28	.20	
44.9	5/16	21.9	3/8	5½	.44	.32	2
35.9	1/4	18.3	5/16	5½	.35	.25	
27.0	3/16	14.6	1/4	5½	.26	.19	

[a] When the beam web thickness is less than the minimum, multiply the connection capacity furnished by Weld A by the ratio of the actual web thickness to the tabulated minimum thickness. Thus, if 5/16 in. Weld A, with a connection capacity of 128 kips and a 1'-2½" long angle, is considered for a beam of web thickness of 0.375" with F_y = 36 ksi, the connection capacity must be multiplied by 0.375/0.50, giving 96.0 kips.

[b] Should the thickness of material to which connection angles are welded exceed the limits set by AISC Specifications, Sect. 1.17.5, for weld sizes specified, increase the weld size as required, but not to exceed the angle thickness.

[c] When welds are used on outstanding legs, connection capacity may be limited by the shear capacity of the supporting member as stipulated by AISC Specification Sect. 1.17.6. See Examples (d) and (e), pages 4-34 and 4-35.

Note 1: Connection Angles: Two L 4 × 3½ × Thickness × L; F_y = 36 ksi. See page 4-28 for limiting values of thickness and optional width of legs.

Note 2: Capacities shown in this table apply only when the material welded is F_y = 36 ksi or F_y = 50 ksi steel.

Notes

FRAMED BEAM CONNECTIONS

Welded—E70XX electrodes

TABLE IV

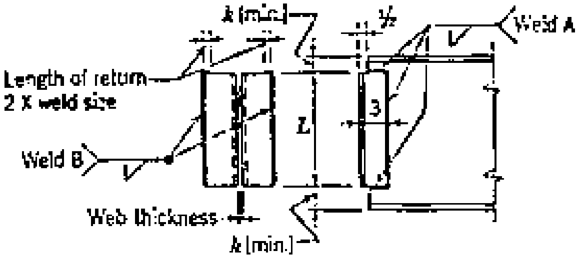


Table IV lists capacities and connection details for angle connections welded to both the beam web and the supporting member.

Holes for erection bolts may be placed as required in legs to be field welded (optional).

EXAMPLES

(a) **Given:** *Beam:* W36 × 150; t_w = 0.625"; T = 32$\frac{1}{8}$"
F_y = 36 ksi; F_v = 14.5 ksi
Weld: E70XX
Reaction: 180 kips

Solution: Enter Table IV and select a Weld A capacity of 181 kips (weld size = $\frac{3}{16}$ in.). Weld B has a capacity of 217 kips and is satisfactory. The angle length (32") is slightly less than T for the W36 × 150 and is satisfactory. The beam web thickness (0.625") exceeds the minimum web thickness (0.34"), so no reduction in Weld A capacity is required.

Detail Data: Two L 4 × 3 × $\frac{5}{16}$ × 2'-8"; F_y = 36 ksi;
Weld A = $\frac{3}{16}$"; Weld B = $\frac{1}{4}$"; E70XX

(b) **Given:** Same data as Example (a) except the reaction is 144 kips.

Solution: Enter Table IV and select a Weld A capacity of 144 kips (weld size = $\frac{3}{16}$"). Weld B has a capacity of 148 kips and is satisfactory. The angle length (16") is less than T and is satisfactory. The beam web thickness (0.625") exceeds the minimum web thickness (0.51"), so no reduction in Weld A capacity is required.

Unless framing details require this short angle length, longer angles with less deposited weld metal may be desirable. The 26" long angles with Weld A capacity of 145 kips (weld size = $\frac{3}{16}$ in.) and Weld B capacity of 169 kips are also satisfactory and may be selected.

Detail Data: Two L 4 × 3 × $\frac{5}{16}$ × 2'-2"; F_y = 36 ksi;
Weld A = $\frac{3}{16}$ in.; Weld B = $\frac{1}{4}$ in.; E70XX

(c) G' : *Beam:* W 16 × 26; t_w = 0.25"; T = 13¾";
F_y = 50 ksi; F_v = 20 ksi
Weld: E70XX
Reaction: 35 kips

Solution: Enter Table IV and select a Weld B capacity of 35.5 kips (weld size = ¼"). Angle length (8") is less than T and is satisfactory. Weld A has a capacity of 40.0 kips and is satisfactory. The beam web thickness (0.25") exceeds the minimum web thickness (0.20"), so no reduction in Weld A capacity is required.

Note: Had this beam been of F_y = 36 ksi steel, the beam web thickness (0.25") would have been less than the minimum web thickness and the capacity of Weld A would have to be reduced. Multiplying 40 kips by 0.25/0.28 gives a reduced capacity of 35.7 kips, which would still be adequate for this reaction. (See note (a) below Table IV.)

Detail Data: Two L 3 × 3 × $\frac{5}{16}$ × 0'-8"; F_y = 36 ksi;
Weld A = $\frac{5}{16}$ in.; Weld B = ¼ in.; E70XX

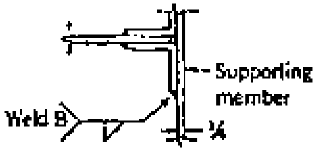
WELDS TO SUPPORTING MEMBERS

Selection of connections tabulated herein is based on and limited by the requirement that Welds B will be applied in accordance with AISC Specification Sect. 1.17.5, which stipulates minimum welds for various material thicknesses.

With respect to Welds B it should be noted that supporting members with limited shear capacity, or which support opposed connections, may be subject to a reduction in connection capacity. See AISC Specification Sect. 1.17.6.

EXAMPLES

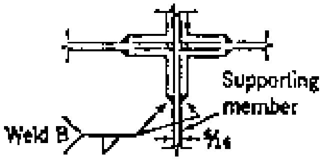
(d) **Given:** Weld B = $\frac{5}{16}$ in. fillet weld, E70XX, fully loaded on one side of ¼" thick supporting member web of F_y = 36 ksi steel.



Solution: Shear value of one $\frac{5}{16}$ in. fillet weld = 0.3125" × 0.707 × 21.0 ksi = 4.64 kips/lin. inch. Shear value of ¼" thick web = 0.25" × 14.5 ksi = 3.63 kips/lin. inch.

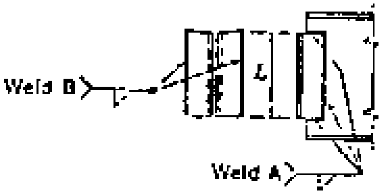
Because of this deficiency in web shear capacity, the total capacity selected from the Weld B column for $\frac{5}{16}$ in. weld size must be multiplied by the ratio 3.63/4.64.

Given: Two floor beams with end reactions of 15.0 kips each be supported by a beam of F_y = 36 ksi steel with a $\frac{5}{16}$" thick web.



Solution: ¼ in. Weld B with 5" long angles has a capacity of 15.7 kips and would be almost fully stressed. Maximum shear developed in the two ¼ in. fillet Welds B on opposite sides of the supporting beam web = 2 × 0.25 × 0.707 × 21.0 × 15/15.7 = 7.09 kips/lin. inch. Shear capacity of $\frac{5}{16}$" web = 0.3125 × 14.5 = 4.53 kips/lin. inch. A longer connection is required to reduce the web shear. Required Weld B capacity is 15.7 kips × 7.09/4.53 = 24.6. Two 7" long angles with ¼ in. Weld B have a tabulated capacity of 28.3 kips and are adequate.

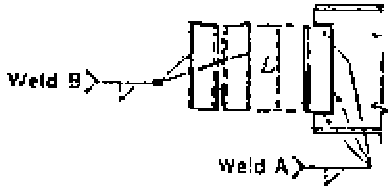
FRAMED BEAM CONNECTIONS
Welded—E70XX electrodes
TABLE IV



Weld A		Weld B		Angle Length L In.	Angle Size F_y = 36 ksi	[a]Minimum Web Thickness for Weld A	
Capacity Kips	[b]Size In.	[c]Capacity Kips	[b]Size In.			F_y = 36 ksi F_v = 14.5 ksi	F_y = 50 ksi F_v = 20 ksi
302	5/16	326	3/8	32	4 × 3 × 7/16	.57	.42
242	1/4	271	5/16	32	4 × 3 × 3/8	.46	.33
181	3/16	217	1/4	32	4 × 3 × 5/16	.34	.25
282	5/16	302	3/8	30	4 × 3 × 7/16	.57	.41
226	1/4	251	5/16	30	4 × 3 × 3/8	.46	.33
169	3/16	201	1/4	30	4 × 3 × 5/16	.34	.25
262	5/16	278	3/8	28	4 × 3 × 7/16	.56	.41
210	1/4	231	5/16	28	4 × 3 × 3/8	.45	.33
157	3/16	185	1/4	28	4 × 3 × 5/16	.34	.24
242	5/16	254	3/8	26	4 × 3 × 7/16	.55	.40
194	1/4	211	5/16	26	4 × 3 × 3/8	.45	.32
145	3/16	169	1/4	26	4 × 3 × 5/16	.33	.24
221	5/16	230	3/8	24	4 × 3 × 7/16	.55	.40
178	1/4	191	5/16	24	4 × 3 × 3/8	.44	.32
133	3/16	153	1/4	24	4 × 3 × 5/16	.33	.24
202	5/16	206	3/8	22	4 × 3 × 7/16	.54	.39
162	1/4	171	5/16	22	4 × 3 × 3/8	.44	.31
121	3/16	137	1/4	22	4 × 3 × 5/16	.32	.24
182	5/16	181	3/8	20	4 × 3 × 7/16	.53	.39
146	1/4	152	5/16	20	4 × 3 × 3/8	.43	.31
110	3/16	121	1/4	20	4 × 3 × 5/16	.32	.23
162	5/16	157	3/8	18	4 × 3 × 7/16	.52	.38
130	1/4	131	5/16	18	4 × 3 × 3/8	.42	.30
97.7	3/16	105	1/4	18	4 × 3 × 5/16	.31	.23
144	5/16	148	3/8	16	3 × 3 × 7/16	.51	.37
114	1/4	123	5/16	16	3 × 3 × 3/8	.41	.30
85.9	3/16	98.8	1/4	16	3 × 3 × 5/16	.31	.22
123	5/16	124	3/8	14	3 × 3 × 7/16	.50	.36
98.8	1/4	103	5/16	14	3 × 3 × 3/8	.40	.29
74.0	3/16	82.5	1/4	14	3 × 3 × 5/16	.30	.22
104	5/16	99.6	3/8	12	3 × 3 × 7/16	.48	.35
83.2	1/4	83.1	5/16	12	3 × 3 × 3/8	.39	.28
62.5	3/16	66.5	1/4	12	3 × 3 × 5/16	.29	.21

For footnotes, see pg. 4 - 37.

FRAMED BEAM CONNECTIONS
Welded—E70XX electrodes
TABLE IV



Weld A		Weld B		Angle Length L In.	Angle Size F_y = 36 ksi	[a]Minimum Web Thickness for Weld A	
Capacity Kips	[b]Size In.	[c]Capacity Kips	[b]Size In.			F_y = 36 ksi F_v = 14.5 ksi	F_y = 50 ksi F_v = 20 ksi
85.1	5/16	75.9	3/8	10	3 × 3 × 7/16	.47	.34
68.1	1/4	63.3	5/16	10	3 × 3 × 3/8	.38	.27
51.0	3/16	50.5	1/4	10	3 × 3 × 5/16	.28	.21
75.9	5/16	64.3	3/8	9	3 × 3 × 7/16	.46	.34
60.6	1/4	53.7	5/16	9	3 × 3 × 3/8	.38	.27
45.5	3/16	42.9	1/4	9	3 × 3 × 5/16	.28	.20
66.7	5/16	53.2	3/8	8	3 × 3 × 7/16	.46	.33
53.3	1/4	44.4	5/16	8	3 × 3 × 3/8	.37	.27
40.0	3/16	35.5	1/4	8	3 × 3 × 5/16	.28	.20
57.8	5/16	42.5	3/8	7	3 × 3 × 7/16	.45	.32
46.3	1/4	35.5	5/16	7	3 × 3 × 3/8	.36	.26
34.7	3/16	28.3	1/4	7	3 × 3 × 5/16	.27	.19
49.2	5/16	32.6	3/8	6	3 × 3 × 7/16	.44	.32
39.3	1/4	27.1	5/16	6	3 × 3 × 3/8	.36	.26
29.5	3/16	21.7	1/4	6	3 × 3 × 5/16	.27	.19
40.8	5/16	23.4	3/8	5	3 × 3 × 7/16	.43	.32
32.6	1/4	19.5	5/16	5	3 × 3 × 3/8	.35	.25
24.5	3/16	15.7	1/4	5	3 × 3 × 5/16	.26	.19
32.7	5/16	15.4	3/8	4	3 × 3 × 7/16	.43	.31
26.2	1/4	12.9	5/16	4	3 × 3 × 3/8	.35	.25
19.7	3/16	10.4	1/4	4	3 × 3 × 5/16	.26	.19

[a] When the beam web thickness is less than the minimum, multiply the connection capacity furnished by Welds A by the ratio of the actual thickness to the tabulated minimum thickness. Thus, if 5/16 in. Weld A, with a connection capacity of 66.7 kips and an 8" long angle, is considered for a beam of web thickness 0.305" and F_y = 36 ksi, the connection capacity must be multiplied by 0.305/0.46, giving 44.2 kips.

[b] Should the thickness of material to which connection angles are welded exceed the limits set by AISC Specification Sect. 1.17.5 for weld sizes specified, increase the weld size as required, but not to exceed the angle thickness.

[c] For welds on outstanding legs, connection capacity may be limited by the shear capacity of the supporting members, as stipulated by AISC Specification Sect. 1.17.6. See Examples (d) and (e), pages 4 - 34, 4 - 35.

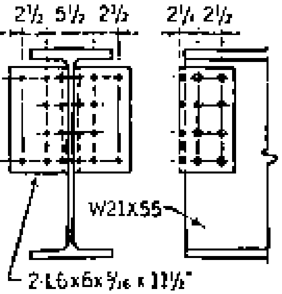
Note 1: Capacities shown in this table apply only when connection angles are F_y = 36 ksi steel and the material to which they are welded is either F_y = 36 ksi or F_y = 50 ksi steel.

SPECIAL FRAMED BEAM CONNECTIONS

In designing framed beam connections there may be cases where Tables I–VIII will not apply. This may occur when bearing governs over single shear or the length of connection angles is limited by framing conditions. The following example outlines the design method recommended when tabulated connections are not applicable.

EXAMPLE 1

Given: Design a connection for a W21 × 55 with a 100 kip end reaction. Beam and connection are F_y = 36 ksi steel. Use ⅞" diam. ASTM A502 Gr 1 rivets in beam web leg, and ⅞" diam. ASTM A325 Friction Type bolts in outstanding leg. The depth of angle is limited to 12 in.



Solution:

1. *Outstanding legs:*
   Single shear value of ⅞" diam. A325-F bolt from shear load tables = 9.02 kips.

$$\text{No. req'd.} = \frac{100}{9.02} = 11.1 \quad \text{Use: 12 bolts}$$

2. *Web legs:*
   Double shear value of ⅞" diam. A502 Gr 1 rivets from shear load tables = 18.04 kips.
   Bearing value of ⅞" diam. A502 Gr 1 rivets in 0.375 in. web from bearing tables = 0.375 × 42.5 = 15.9 kips.

$$\text{Bearing governs.} \quad \text{No. req'd.} = \frac{100}{15.9} = 6.3 \quad \text{Use: 8 rivets}$$

3. *Angle size:*
   Use 2 angles 6 x 6 x *t* x 11½"
   t required by bearing at 42.5 kips per inch thick material

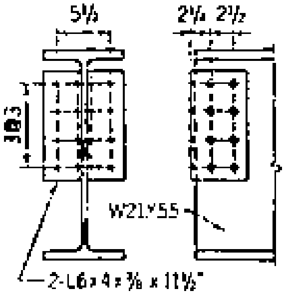
$$= \frac{9.02}{42.5} = 0.21 \text{ in.}$$

t required by gross shear in vertical section

$$= \frac{100}{11.5 \times 14.5 \times 2} = 0.30 \text{ in. (governs)}$$

Use: 2 angles 6 x 6 x 5/16 x 11½"

EXAMPLE 2



Given: Same as Example 1 except use ⅞" diam. A325-X Bearing Type bolts (with threads excluded from the shear planes) in the outstanding legs. Web *t* is 5/16" (ASTM A36).

Solution:

1. *Outstanding legs:*
   Supporting girder web is 5/16" thick A36.
   Bearing value of 5/16" web with ⅞" fasteners = 13.3 kips.
   Single shear value of ⅞" diam A325-X bolts from shear load tables = 13.23 kips (governs).

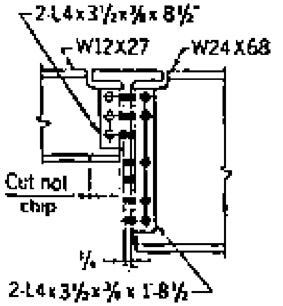
$$\text{No. req'd.} = \frac{100}{13.23} = 7.6 \quad \text{Use: 8 bolts}$$

2. *Web legs:* Same as Example 1
3. *Angle size:* Use: 2 angles 6 x 4 x ⅜ x 11½".

Another case where the tables may not apply is when beams of different depths are framed opposite. Example 3 outlines one design method recommended when tabulated connections are not applicable.

EXAMPLE 3

Given: Design connections for a W12 × 27 with a 27 kip end reaction and a W24 × 68 with an 82 kip end reaction framed opposite to a girder with a ¼" web. Beams, girder and connections are F_y = 36 ksi steel. Use ⅞" diam. A502 Gr 1 rivets in beam web and ⅞" diam. ASTM A325 Bearing Type Bolts, with threads in shear planes in girder web.



Solution:

1. *Web legs:*
   Double shear value of ⅞" diam. A502 Gr 1 rivets from shear load tables = 18.04 kips. Bearing value of ⅞" diam. A502 Gr 1 rivets in 0.24 in. web (W12 × 27) from bearing tables = 0.237 × 42.5 = 10.1 kips; bearing value in 0.416 in. web (W24 × 68) = 0.416 × 42.5 = 17.7 kips. Bearing governs in both beams.

$$\text{W12} \times 27\text{:} \quad \text{No. req'd.} = \frac{27}{10.1} = 2.6 \quad \text{Use: 3 rivets}$$

$$\text{W24} \times 68\text{:} \quad \text{No. req'd.} = \frac{82}{17.7} = 4.6 \quad \text{Use: Minimum of 5 rivets}$$

2. *Outstanding legs:*
   The fasteners in the outstanding legs are governed by two criteria. Where the beams are framed opposite, the fasteners are governed by double shear or bearing on the web, while fasteners that are not framed opposite are governed by single shear or bearing on the web.

   Double shear value of ⅞" diam. ASTM A325 bolts (with threads in shear planes) from allowable load tables = 18.04 kips; single shear = 9.02 kips. Bearing value of ⅞" diam. A325-N bolts in 0.25 in. girder web, from allowable load tables = 0.25 × 42.5 = 10.6 kips. Bearing governs for bolts framed opposite.

   The three-row web pattern of the W12 × 27 makes convenient a 6 bolt connection to the girder, each bolt in girder web being loaded at 27/6 = 4.5 kips. With total allowable bearing at 10.6 kips, girder web capacity available for supporting the W24 × 68 is 10.6 − 4.5 = 6.1 kips per bolt, which is less than single shear and therefore governs. Assuming that all bolts will transmit loads equally to the girder web, the 82 kip load for the W24 × 68 will require 82/6.1 = 13.4.

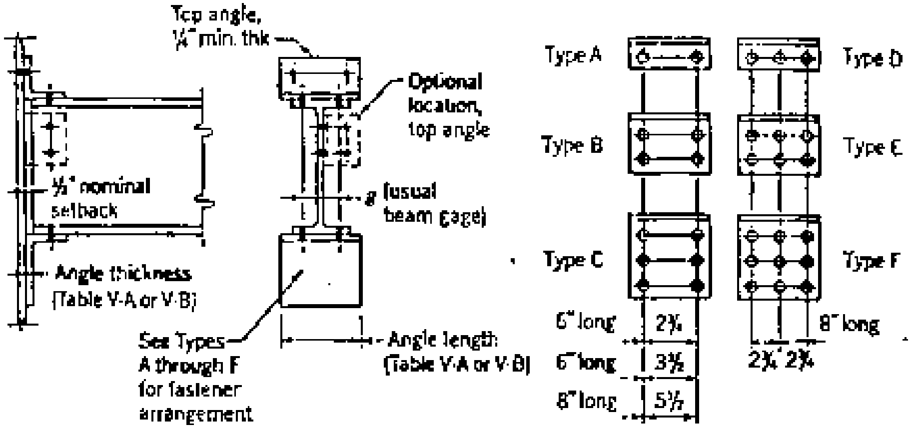
   Use: 14 bolts.

3. *Angle size:*
   Use: Two angles 4 x 3½ x ⅜ x 8½" for W12 × 27
   Use: Two angles 4 x 3½ x ⅜ x 1'-8½" for W24 × 68

SEATED BEAM CONNECTIONS

Bolted or riveted

TABLE V



Seat Angle 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.

Nominal beam setback is 1/2". Allowable loads in Tables V-A and V-B are based on 3/4" setback, which provides for possible mill underrun in beam length.

ASTM A307 bolts may be used in seated connections, provided the stipulations of AISC Specification, Sect. 1.16.12, are observed.

Allowable loads in Table V-A are based on F_y = 36 ksi steel in both beam and seat angle. These values will be conservative when used with beams of F_y greater than 36 ksi. For beams with F_y equal to or greater than 50 ksi, use Table V-B.

Allowable loads in Table V-B are based on F_y = 36 ksi steel in the seat angle and F_y = 50 ksi steel in the beams. For beams with F_y greater than 50 ksi, these values will be conservative.

Vertical spacing of fasteners and gages in seat angles may be arranged to suit conditions, provided they conform to AISC Specification, Sects. 1.16.4 and 1.16.5, with regard to minimum pitch and minimum edge distances. Where thick angles are used, driving clearances may require an increase in the outstanding leg gage and tabulated width.

In the event the thin web of a supporting member limits its bearing capacity, it may be necessary to reduce values listed in Table V-C.

For the most economical seated connection, the reaction values of the beams should be shown on the contract drawings. If the reactions are not shown, the connections shall be selected to support half the total uniform load capacity shown in tables of Allowable Loads on Beams for the given shape, span, and steel specified for the beam in question. The effect of concentrated loads near an end connection must also be considered.

EXAMPLES

(a) *Given:* *Beam:* W16 × 36 (5/16" web)
F_y = 36 ksi material
Reaction: 25 kips
Bolts: 7/8"φ A325-N
Column gage: 5 1/2" in column web

Solution: Enter Table V-A under 8" angle length, for a 5/16" beam web; select a 3/4" angle thickness (capacity = 26.5 kips). Enter Table V-C opposite 7/8"φ A325-N; note that a Type D connection (capacity = 27.1 kips) is required. From Table V-D, with a Type D connection, a 4 × 4 angle is available in 3/4" thickness.

Detail Data: Seat: One L 4 × 4 × 3/4 × 0'-8 with three 7/8"φ A325-N bolts. Top or side support, if required, to be chosen to suit conditions.

(b) Given: Same as Example (a) except connect to a column flange with column gage = 5 1/2".

Solution: As in Example (a), a 3/4" angle thickness is adequate. Enter Table V-C opposite 7/8"φ A325-N; note that a Type B connection (capacity = 36.1 kips) is required. From Table V-D, with a Type B connection, a 6 × 4 angle is available in 3/4" thickness.

Detail Data: Seat: One L 6 × 4 × 3/4 × 0'-8 (4" USL) with four 7/8"φ A325-N bolts. Top or side support, if required, to be chosen to suit conditions.

SEATED BEAM CONNECTIONS

Bolted or riveted

TABLE V Allowable loads in kips

TABLE V-A Outstanding Leg Capacity, kips (based on OSL = 4 inches)

Angle Material		F_y = 36 ksi											
Angle Length		6 Inches						8 inches					
Angle Thickness, In.		3/8	1/2	5/8	3/4	7/8	1	3/8	1/2	5/8	3/4	7/8	1
Beam Web Thickness (in.)	3/16	7.50	10.3	13.1	15.9	18.7	18.8	8.44	11.5	14.6	17.7	18.8	18.8
	1/4	9.57	13.0	16.3	19.7	23.1	26.2	10.6	14.4	18.1	21.8	25.5	26.2
	5/16	11.3	16.3	20.3	24.2	28.1	32.0	13.1	17.9	22.2	26.5	30.8	34.7
	3/8	12.4	19.3	24.3	28.7	33.2	37.6	14.3	21.5	26.3	31.2	36.1	40.9
	7/16	13.4	21.1	28.8	33.7	38.7	43.6	15.5	23.8	30.9	36.3	41.7	47.1
	1/2	14.3	22.8	31.6	39.2	44.6	50.0	16.5	25.7	35.1	41.8	47.7	53.6
F_y = 36 ksi	9/16	15.2	24.4	34.0	43.8	51.0	56.9	17.5	27.5	37.8	47.8	54.1	60.5

TABLE V-B Outstanding Leg Capacity, kips (based on OSL = 4 inches)

Angle Material		F_y = 36 ksi											
Angle Length		6 Inches						8 inches					
Angle Thickness, In.		3/8	1/2	5/8	3/4	7/8	1	3/8	1/2	5/8	3/4	7/8	1
Beam Web Thickness (in.)	3/16	9.14	12.6	16.1	19.5	23.0	26.2	10.2	14.1	17.9	21.7	25.5	26.2
	1/4	11.9	16.1	20.3	24.5	28.7	32.9	13.1	17.7	22.4	27.0	31.6	36.2
	5/16	13.3	20.7	25.6	30.5	35.5	40.4	15.4	22.4	27.8	33.2	38.6	43.9
	3/8	14.6	23.3	31.1	36.7	42.3	47.9	16.9	26.3	33.4	39.5	45.6	51.7
	7/16	15.8	25.5	35.8	43.5	50.0	56.1	18.3	28.8	39.6	46.4	53.2	60.0
	1/2	16.9	27.7	39.0	50.6	57.9	64.8	19.5	31.1	43.2	53.9	61.4	68.8
F_y = 50 ksi	9/16	17.9	29.7	42.2	55.0	66.6	74.3	20.7	33.3	46.6	60.1	70.3	78.4

TABLE V-C Fastener Capacity, kips

*Fastener Specification	Fastener Diameter in.	Connection Type					
		A	B	C	D	E	F
A307	3/4	8.8	17.7	26.5	13.3	26.5	39.8
	7/8	12.0	24.0	36.1	18.0	36.1	54.1
	1	15.7	31.4	47.1	23.6	47.1	70.7
A325-F A325-N A502-1	3/4	13.3	26.5	39.8	19.9	39.8	59.7
	7/8	18.0	36.1	54.1	27.1	54.1	81.2
	1	23.6	47.1	70.7	35.3	70.7	—
A490-F A502-2	3/4	17.7	35.4	53.0	26.5	53.0	79.6
	7/8	24.1	48.1	72.2	36.1	72.2	—
	1	31.4	62.8	94.3	47.1	94.3	—
A325-X	3/4	19.4	38.9	58.3	29.2	58.3	87.5
	7/8	26.5	52.9	79.4	39.7	79.4	—
	1	34.6	69.1	—	51.8	—	—
A490-N	3/4	19.9	39.8	59.6	29.8	59.6	89.5
	7/8	27.1	54.1	81.7	40.6	81.2	—
	1	35.3	70.7	—	53.0	—	—
A490-X	3/4	28.3	56.6	84.8	42.4	84.8	127
	7/8	38.5	77.0	—	57.7	—	—
	1	50.3	101	—	75.4	—	—

* A325-F and A490-F: Friction type connections.
A325-N and A490-N: Bearing type connections with threads included in shear plane.
A325-X and A490-X: Bearing type connections with threads excluded from shear plane.

TABLE V-D Available Seat Angle and Thickness Range

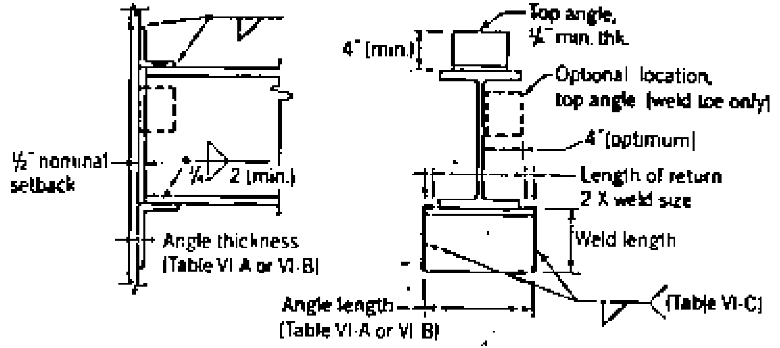
Type	Angle Size In.	t In.
A, D	4 × 3	3/8 – 5/8
	4 × 3½	3/8 – 5/8
	4 × 4	3/8 – 3/4
B, E	6 × 4	3/8 – 5/8
	7 × 4	3/8 – 5/8
	8 × 4	1/2 – 1
C, F	*8 × 4	1/2 – 1
	9 × 4	1/2 – 1

* Suitable for use with 3/4" and 7/8" fasteners only.

SEATED BEAM CONNECTIONS

Welded—E70XX Electrodes

TABLE VI



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 loads in Table VI are based on the use of E70XX electrodes. The table may be used for other electrodes provided the tabular values are adjusted for the electrodes used (e.g., for E60XX electrodes, multiply tabular values by $^{18}/_{21}$, or 0.86, etc.) and the welds and base metal meet the provisions of AISC Specification Sect. 1.5.3.

Welds attaching beams to seat or top angles may be replaced by bolts or rivets, provided the limitations on the use of ASTM A307 bolts stipulated in AISC Specification Sect. 1.15.12 are observed.

In addition to the welds shown, temporary erection bolts may be used to attach beams to seats (optional).

Nominal beam setback is 1/2". Allowable loads in Tables VI-A and VI-B are based on 3/4" setback, which provides for possible mill underrun in beam length.

Allowable loads in Table VI-A are based on F_y = 36 ksi material in both beam and seat angle. These values will be conservative when used for beams with F_y greater than 36 ksi. For beams with F_y equal to or greater than 50 ksi, use Table VI-B.

Allowable loads in Table VI-B are based on F_y = 36 ksi material in the seat angle with beam material of F_y = 50 ksi. These values will be conservative when used with beams of F_y greater than 50 ksi.

Should combinations of material thickness and weld size selected from Tables VI-A or VI-B and VI-C exceed the limits set by AISC Specification Sects. 1.17.5 and 1.17.6, increase the weld size or material thickness as required.

No reduction of the tabulated weld capacity is required when unstiffened seats line up on opposite sides of the supporting web.

For the most economical seated connection, the reaction values of the beams should be shown on the contract drawings. If the reactions are not shown, the connections shall be selected to support half the total uniform load capacity shown in the tables for Allowable Loads on Beams for the given shape, span, and steel specified for the beam in question. The effect of concentrated loads near an end connection shall also be considered.

EXAMPLE

Given: *Beam:* W21 × 62 (3/8" web).
Attach beam flange to seat with bolts.
F_y = 36 ksi material
Reaction: 35 kips
Welds: E70XX electrodes
Column: Column web will permit use of 8" long seat angle.

Solution: Enter Table VI-A opposite 3/8" web thickness; under 8" angle length, read 36.1 kips. Note that a 7/8" angle thickness is required. Enter Table VI-C and note that satisfactory weld capacities appear under 6 through 9 inch leg angles, all of which are shown to be available in 7/8" thickness. In this case the 6 × 4 angle is ruled out because of the rather heavy 7/16" weld required. The 9 × 4 angle is ruled out because the 8 × 4 angle can provide adequate capacity. Angles 8 × 4 (capacity = 35.6 kips, 1/4" weld) and 7 × 4 (capacity = 35.6 kips, 5/16" weld) are equally suitable. Angle 7 × 4 is chosen because the material savings will usually offset the cost differential between welds of 1/16" thickness differential provided that each weld can be made with the same number of passes (5/16" welds and smaller are single pass welds).

Detail Data: One L 7 × 4 × 7/8 × 0'-8, with 5/16 welds (E70XX).
Top or side angle, if required, to be chosen with the same welds.

Had it been required to weld the beam to the seat, the 7/8" seat angle thickness would dictate a 5/16" weld (see AISC Specification Sect. 1.17.5), which is compatible with the 3/8" beam flange thickness (see Sect. 1.17.6). Block beam flange to permit welding to the 8" seat angle or use a longer seat angle if space permits.

SEATED BEAM CONNECTIONS
Welded—E70XX electrodes
TABLE VI Allowable loads in kips

TABLE VI-A Outstanding Leg Capacity, kips (based on OSL = 3½ or 4 inches)

Angle Material		F_y = 35 ksi											
Angle Length		6 inches						8 inches					
Angle Thickness, In.		3/8	1/2	5/8	3/4	7/8	1	3/8	1/2	5/8	3/4	7/8	1
Beam Web Thickness (in.)	3/16	7.50	10.3	13.1	15.9	18.7	18.8	8.44	11.5	14.6	17.7	18.8	18.8
	1/4	9.57	13.0	16.3	19.7	23.1	26.2	10.6	14.4	18.1	21.8	25.5	26.2
	5/16	11.3	16.3	20.3	24.2	28.1	32.0	13.1	17.9	22.2	26.5	30.8	34.7
	3/8	12.4	19.3	24.3	28.7	33.2	37.6	14.3	21.5	26.3	31.2	36.1	40.9
	7/16	13.4	21.1	28.8	33.7	38.7	43.6	15.5	23.8	30.9	36.3	41.7	47.1
F_y = 36 ksi	1/2	14.3	22.8	31.6	39.2	44.6	50.0	16.5	25.7	35.1	41.8	47.7	53.6
	9/16	15.2	24.4	34.0	43.8	51.0	56.9	17.5	27.5	37.8	47.8	54.1	50.5

Note: Values above heavy lines apply only for 4-inch outstanding legs.

TABLE VI-B Outstanding Leg Capacity, kips (based on OSL = 3½ or 4 inches)

Angle Material		F_y = 36 ksi											
Angle Length		6 inches						8 inches					
Angle Thickness, In.		3/8	1/2	5/8	3/4	7/8	1	3/8	1/2	5/8	3/4	7/8	1
Beam Web Thickness (in.)	3/16	9.14	12.6	16.1	19.5	23.0	26.2	10.2	14.1	17.9	21.7	75.5	26.2
	1/4	11.9	16.1	20.3	24.5	28.7	32.9	13.1	17.7	22.4	27.0	31.6	36.2
	5/16	13.3	20.7	25.6	30.5	35.5	40.4	15.4	22.4	27.8	33.2	38.6	43.9
	3/8	14.6	23.3	31.1	36.7	42.3	47.9	16.9	26.3	33.4	39.5	45.6	51.7
	7/16	15.8	25.5	35.8	43.5	50.0	56.1	18.2	28.8	39.6	46.4	53.2	60.0
F_y = 50 ksi	1/2	16.9	27.7	39.0	50.6	57.9	64.8	19.5	31.1	43.2	53.9	61.4	68.8
	9/16	17.9	29.7	42.2	55.0	66.8	74.3	20.7	33.3	46.6	60.1	70.3	78.4

Note: Values above heavy lines apply only for 4-inch outstanding legs.

TABLE VI-C - Weld Capacity, kips

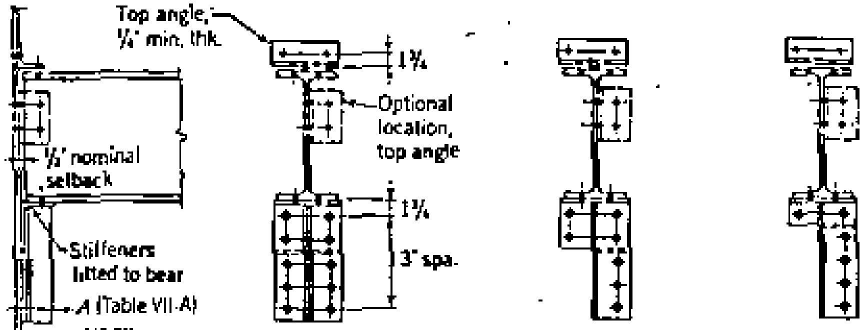
Weld Size In.	E70XX Electrodes					
	Seat Angle Size (long leg vertical)					
	4 × 3½	5 × 3½	6 × 4	7 × 4	8 × 4	9 × 4
1/4	11.5	17.2	21.8	28.5	35.6	43.0
5/16	14.3	21.5	27.3	35.6	44.5	53.8
3/8	17.2	25.8	32.7	42.7	53.4	64.6
7/16	20.1	30.1	38.2	49.8	62.3	75.3
1/2	22.9	34.4	43.6	56.9	71.2	86.1
5/8	—	43.0	54.5	71.2	89.0	—
11/16	—	47.3	60.0	78.3	—	—
3/4	—	—	65.4	85.4	—	—
Range of available seat angle thicknesses						
Minimum	3/8	3/8	3/8	3/8		1/2
Maximum	5/8	3/4	7/8	7/8		1

Notes

STIFFENED SEATED BEAM CONNECTIONS

Bolted or Riveted

TABLE VII



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

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

Type C
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 ¼" 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.

EXAMPLE

Given: Design a stiffened seated beam connection of F_y = 36 ksi steel to support a W30 × 99, also F_y = 36 ksi, with an end reaction of 85 kips. Use ⅞"Φ ASTM A325-F bolts to attach the seat to a column web with a 5½" gage. Assume that a top angle is required.

Solution:

1. From the F_y = 36 ksi beam load tables, under W 30 × 99, note that R = 70 kips and R_i = 14.1 kips. Required length of bearing is:

$$3.5 + \frac{85 - 70}{14.1} = 4.56''$$

From Table VII-A, under F_y = 36 ksi, it will be seen that a 4.56" length of bearing requires that 5" OSL stiffener angles be used. In the outstanding leg column under "5 in.", note that the 85 kip reaction requires stiffener angles of 5⁄16" thickness. Use a seat angle of ⅜" thickness extending beyond the stiffener angle; this requires a 6" leg outstanding.

2. In Table VII-B for a ⅞"Φ A325-F fastener, 5 rows of bolts with a capacity of 90.2 kips will be required for an 85 kip reaction.

Detail Data: Steps 1 and 2 indicate the use of a Type A connection with 5 rows of ⅞"Φ A325-F bolts. Assuming it is possible to employ the suggested spacing of fasteners, detail material will be as follows:

Steel:	F_y = 36 ksi
2 Stiffeners:	L 5 × 5 × 5⁄16 × 1'-2⅝
1 Seat Angle:	L 6 × 6 × ⅜ × 0'-10
1 Filler:	PL ⅜ × 8¾ × 0'-10
1 Top Angle:	L 4 × 3 × ¼ × 0'-8 (4" OSL)

Had the reaction been 45 kips, and all other conditions the same, a 3½" OSL of stiffener and a 6 × 4 × ⅜" seat angle would have been adequate. Using a Type B connection, enter Table VII-A with two times the reaction (or 90 kips) and select ½" stiffeners. From Table VII-B, 5 fasteners per row is still required for ⅞"Φ A325-F bolts (capacity = 90.2 kips).

Components of a Type B connection with 5 rows of ⅞"Φ A325-F bolts are as follows:

Steel:	F_y = 36 ksi
1 Stiffener:	L 4 × 3½ × ½ × 1'-2⅝ (3½" OSL)
1 Seat Angle:	L 6 × 4 × ⅜ × 0'-8 (4" OSL)
1 Filler:	PL ⅜ × 4 × 0'-8¾
1 Top Angle:	L 4 × 3 × ¼ × 0'-8 (4" OSL)

STIFFENED SEATED BEAM CONNECTIONS

Bolted or riveted

TABLE VII

TABLE VII-A Stiffener Angle Capacity, kips

Stiffener Material		F_y = 36 ksi (F_p = 33 ksi)			F_y = 50 ksi (F_p = 45 ksi)		
Stiffener Outstanding Leg, A, In.		3½	4	5	3½	4	5
Max. Length Beam Bearing, In.		3½	4¼	5¼	3½	4¼	5¼
Thickness of Stiffener Outstanding Legs In.	5⁄16	61.9	72.2	92.8	84.4	98.4	127
	⅜	74.3	86.6	111	101	118	152
	7⁄16	86.6	101	130	118	138	177
	½	99.0	116	149	135	158	203
	⅝	124	144	186	169	197	253
	¾	149	173	223	203	236	304

Use ⅜" thick seat angles with vertical legs wide enough to accommodate fastener pattern, and with outstanding legs wide enough to extend beyond outstanding legs of stiffener.

TABLE VII-B Fastener Capacity, kips

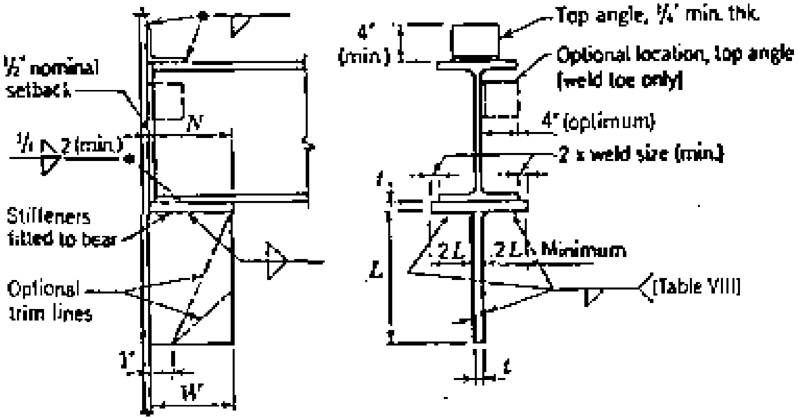
*Fastener Specification	Fastener Diameter In.	Number of Fasteners in One Vertical Row				
		3	4	5	6	7
A307	¾	26.5	35.4	44.2	53.0	61.9
	⅞	36.1	48.1	60.2	72.2	84.2
	1	47.1	62.8	78.6	94.3	110
A325-F A325-N A502-1	¾	39.8	53.0	66.3	79.5	92.8
	⅞	54.1	72.2	90.2	108	126
	1	70.7	94.2	118	141	165
A490-F A502-2	¾	53.0	70.7	88.4	106	124
	⅞	72.2	96.2	120	144	168
	1	94.3	126	157	189	220
A325-X	¾	58.3	77.8	97.2	117	136
	⅞	79.6	106	132	159	185
	1	104	138	173	207	242
A490-N	¾	59.6	79.8	99.4	119	139
	⅞	81.2	108	135	162	189
	1	106	141	177	212	247
A490-X	¾	84.8	113	141	170	198
	⅞	115	154	192	231	269
	1	151	201	251	302	352

* A325-F and A490-F: Friction type connections.
A325-N and A490-N: Bearing type connections with threads included in shear plane.
A325-X and A490-X: Bearing type connections with threads excluded from shear plane.

STIFFENED SEATED BEAM CONNECTIONS

Welded—E70XX Electrodes

TABLE VIII



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 loads in Table VIII are based on the use of E70XX electrodes. The table may be used for other electrodes, provided that the tabular values are adjusted for the electrodes used (e.g., for E60XX electrodes, multiply tabular values by ¹⁸⁄₂₁, or 0.86, etc.) and the welds and base metal meet the provisions of AISC Specification Sect. 1.5.3.

Based on F_y = 36 ksi bracket material, minimum stiffener plate thickness, t, for supported beams with unstiffened webs should not be less than the supported beam web thickness for F_y = 36 ksi beams, and not less than 1.4 times the beam web thickness for beams with F_y = 50 ksi. Based on bracket material of F_y = 50 ksi or greater, the minimum stiffener plate thickness, t, for supported beams with unstiffened webs should be the beam web thickness multiplied by the ratio of F_y of the beam to F_y of the bracket [e.g., F_y (beam) = 65 ksi; F_y (bracket) = 50 ksi; t = t_w (beam) × 65/50, minimum]. The minimum stiffener plate thickness, t, should be at least two times the required E70XX weld size when F_y of bracket is 36 ksi, and should be at least 1.5 times the required E70XX weld size when F_y of the bracket is 50 ksi.

Thickness, t, of the horizontal seat plate, or flange of tee, should not be less than the thickness of the stiffener.

If seat and stiffener are separate plates, fit stiffener to bear against seat. Welds connecting the two plates should have a strength equal to, or greater than, the horizontal welds to the support under the seat plate.

Welds attaching beam to seat may be replaced by bolts or rivets, providing the limitations on the use of ASTM A307 bolts, stipulated in AISC Specification Sect. 1.15.12, are observed.

For stiffener seats in line on opposite sides of a column w F_y = 36 ksi material, select E70XX weld size no greater than 0.50 of column web thickness. For column web of F_y = 50 ksi, select E70XX weld size no greater than 0.67 of column web thickness.

Should combinations of material thickness and weld size selected from Table VIII exceed the limits set by AISC Specification Sects. 1.17.5 and 1.17.6, increase the weld size or material thickness as required.

In addition to the welds shown, temporary erection bolts may be used to attach beams to seats (optional).

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

EXAMPLES

(a) Given: *Beam:* W30 × 116 (flange = 10.5" × 0.85";
web = 0.564")
ASTM A36 steel (F_y = 36 ksi)
Welds: E70XX
Reaction: 100 kips

Design a two-plate welded stiffener seat.

Solution: From the F_y = 36 ksi beam load tables:
R = 78 kips and R_i = 15.2 kips.

$$\text{Required length of bearing: } N = 3.5 + \frac{100 - 78}{15.2} = 4.94''$$

Stiffener width: W = 4.94 + 0.5 (setback) = 5.44"

Use: W = 6"

Table VIII with W = 6" and a reaction of 100 kips; select a ⁵⁄₁₆" weld with L = 15", which has a capacity of 103 kips. From this, the minimum length of weld between seat plate and support is 2 × 0.2L = 6". This also establishes the minimum weld between the seat plate and the stiffener as 6" total, or 3" on each side of stiffener.

Stiffener plate thickness, t, to develop welds = 2 × ⁵⁄₁₆ = ⅝", or 0.625". This is greater than the beam web thickness of 0.564"; thus, the stiffener plate thickness need not be increased.

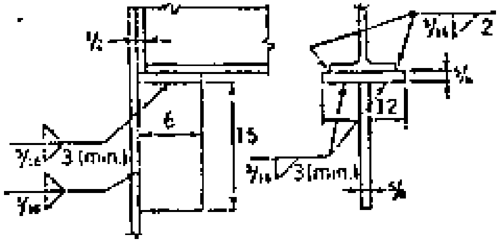
Use: ⅝" plates for the seat and the stiffener.

Welds attaching the beam flange to the seat must be increased from ¼" to ⁵⁄₁₆" to conform to AISC Specification Sect. 1.17.5, due to the 0.85" flange thickness of the W30 × 116 beam.

Seat plate width to permit field welding of beam to seat = flange width + 4 × weld size = 10.5 + 4 (5/16) = 11.75".

Use: 12"

This width is also adequate for the required minimum weld length, horizontal plate to the support.



Use: L 4 × 4 × $\frac{3}{8}$ × 0′-4 top angle (F_y = 36 ksi) with $\frac{5}{16}$ in. welds along toes of angle only (if required).

(b) Given: *Beam:* W21 × 68 (flange = 8.27″ × 0.685″; web = 0.43″)
ASTM A572, Grade 50 steel (F_y = 50 ksi)
Welds: E70XX electrodes
Reaction: 83 kips

Design a two-plate welded stiffener seat using ASTM A36 steel.

Solution: From the F_y = 50 ksi beam load tables, R = 78 kips and R_i = 16.1 kips.

Required length of bearing:

$$N = 3.5 + \frac{83 - 78}{16.1} = 3.80''$$

Stiffener width:
W = 3.9 + 0.5 (setback) = 4.4″

Use: W = 5″

Enter Table VIII with W = 5″ and a reaction of 83 kips; satisfying these requirements are a $\frac{5}{16}$ in. weld, L = 13″ (91.3 kips), or a $\frac{3}{8}$ in. weld, L = 11″ (83.3 kips), or an even larger weld size. Generally, the $\frac{5}{16}$ in. weld is the better selection as this can be made in one pass using manual welding. Select $\frac{5}{16}$ in. weld. From this, the minimum length of $\frac{5}{16}$ in. weld between seat plate and support is 2 × 0.2L = 5.2″.

Use: 6″. This also establishes the minimum weld between the seat plate and the stiffener as 6″ total, or 3″ on each side.

Stiffener plate thickness, t, to develop welds = 2 × $\frac{5}{16}$ = $\frac{5}{8}$″, or 0.625″. The minimum thickness, t, for a bracket of F_y = 36 ksi with a beam of F_y = 50 ksi is 1.4 times the beam web thickness = 1.4 × 0.43 = 0.602″.

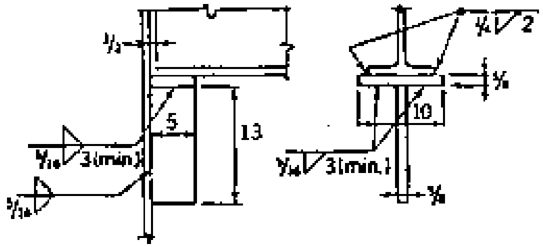
Use: $\frac{5}{8}$″ plates for both the stiffener and the seat.

Welds attaching the beam flange to the seat can be $\frac{1}{4}$ in. for a flange of 0.685″ as per AISC Specification Sect. 1.17.5.

Seat plate width, to permit field welding of beam to seat = flange width + 4 × weld size = 8.27 + (4 × $\frac{1}{4}$) = 9.27″.

Use: 10″. This width is also adequate for the required minimum weld length, horizontal plate to the support.

ail Data:



Use: L 4 × 4 × $\frac{3}{8}$ × 0′-4 top angle (F_y = 36 ksi) with $\frac{5}{16}$ in. welds along toes of angle only (if required).

STIFFENED SEATED BEAM CONNECTIONS

Welded—E70XX electrodes

TABLE VIII Allowable loads in kips

L In.	Width of Seat, W, Inches											
	4				5				6			
	Weld Size, Inches				Weld Size, inches				Weld Size, inches			
	¼	5/16	⅜	7/16	5/16	⅜	7/16	½	5/16	⅜	7/16	½
6	22.7	28.4	34.0	39.7	23.5	28.1	32.8	37.5	19.9	23.9	27.9	31.9
7	29.9	37.4	44.9	52.4	31.2	37.5	43.7	50.0	26.7	32.0	37.3	42.7
8	37.8	47.2	56.7	66.1	39.8	47.8	55.8	63.7	34.3	41.1	48.0	54.8
9	46.1	57.6	69.2	80.7	49.1	59.0	68.8	78.6	42.5	51.1	59.6	68.1
10	54.9	68.6	82.3	96.0	59.0	70.8	82.6	94.4	51.4	61.7	72.0	82.3
11	63.9	79.8	95.8	112	69.4	83.3	97.1	111	60.9	73.1	85.2	97.4
12	73.1	91.4	110	128	80.2	96.2	112	128	70.8	85.0	99.2	113
13	82.5	103	124	144	91.3	110	128	146	81.1	97.4	114	130
14	92.0	115	138	161	103	123	144	164	91.9	110	129	147
15	101	127	152	178	114	137	160	183	103	123	144	165
16	111	139	167	195	126	151	176	202	115	138	160	183
17	121	151	181	212	138	165	193	221	126	151	176	201
18	131	163	196	229	150	180	210	240	137	164	192	219
19	140	175	211	246	162	194	227	259	149	179	208	238
20	150	188	225	263	174	209	243	278	161	193	225	257
21	160	200	240	280	189	223	260	298	173	207	242	276
22	169	212	254	296	198	238	277	317	185	221	258	295
23	179	224	269	313	210	252	294	336	197	236	275	315
24	189	236	283	330	222	267	311	356	209	250	292	334
25	198	248	297	347	234	281	328	375	221	265	309	353
26	208	260	312	364	247	296	345	394	233	279	326	373
27	217	272	326	380	259	310	362	414	245	294	343	392

Note: Loads shown are for E70XX electrodes. For E60XX electrodes, multiply tabular loads by 0.85, or enter table with 1.17 times the given reaction. For E80XX electrodes, multiply tabular loads by 1.14, or enter table with 87.5% of the given reaction.

STIFFENED SEATED BEAM CONNECTIONS

Welded—E70XX electrodes

TABLE VIII Allowable loads in kips

L In.	Width of Seat, W, Inches											
	7				8				9			
	Weld Size, Inches				Weld Size, inches				Weld Size, inches			
	5/16	⅜	7/16	½	5/16	⅜	½	⅝	5/16	⅜	½	⅝
11	54.0	64.8	75.6	86.3	48.4	58.0	77.3	96.6	43.7	52.4	69.9	87.4
12	63.1	75.7	88.4	101	56.7	68.1	90.7	113	51.4	61.7	82.2	103
13	72.7	87.2	102	117	65.5	78.7	105	131	59.6	71.5	95.3	119
14	82.6	99.1	116	132	74.8	89.8	120	149	68.2	81.8	109	136
15	92.9	112	130	149	84.4	101	135	169	77.2	92.6	123	154
16	104	124	145	166	94.4	113	151	189	85.5	104	138	173
17	114	137	160	183	105	126	167	209	95.2	115	154	192
18	126	151	176	201	115	138	184	230	106	127	170	212
19	137	164	192	219	126	151	202	252	117	140	186	233
20	148	178	208	237	137	165	219	274	127	152	203	254
21	160	192	224	256	148	178	237	296	138	165	220	276
22	172	206	240	274	159	192	255	319	149	178	238	297
23	183	220	257	293	171	205	274	342	160	192	256	320
24	195	234	274	312	183	219	292	365	171	205	274	342
25	207	249	290	331	195	233	311	389	182	219	292	365
26	219	263	307	351	206	248	330	412	194	233	310	384
27	231	278	324	370	218	262	349	436	206	247	329	411
28	243	292	341	389	230	276	368	460	217	261	348	435
29	256	307	358	409	242	291	387	484	229	275	367	458
30	268	321	375	428	254	305	406	508	241	289	386	482
31	280	336	392	447	266	319	426	532	253	303	405	506
32	292	350	409	467	278	334	445	556	265	318	424	530

Note: Loads shown are for E70XX electrodes. For E60XX electrodes, multiply tabular loads by 0.86, or enter table with 1.17 times the given reaction. For E80XX electrodes, multiply tabular loads by 1.14, or enter table with 87.5% of the given reaction.

Notes

END PLATE SHEAR CONNECTIONS

TABLE IX

This type of connection consists of a plate, less than the beam depth in length, perpendicular to the longitudinal axis of the beam, welded to the beam web with fillet welds each side of the beam web. The end plate connection compares favorably to the double angle connection and for like thicknesses, gage lines and length of connection will furnish end rotation capacity and strength of connection closely approximating that of the double angle framing connection, within the range listed in the table.

Fabrication of this type of connection requires close control in cutting the beam to length and adequate consideration must be given to squaring the beam ends such that both end plates are parallel and the effect of beam camber does not result in out-of-square end plates which makes erection and field fit-up difficult. Shims may be required on runs of beams to compensate for mill and shop tolerances.

For adequate end rotation capacity, it is suggested that end plates be designed for a plate thickness range of ¼" to ⅜" inclusive. To develop full capacity of the fasteners and welds, the end plate and web thicknesses must equal or exceed the values listed in the table. If the material thickness supplied by either the plate or the web is less than required, the fastener or weld capacity must be reduced by the ratio of thickness supplied to thickness required.

The gage, *g*, should be 3½" to 5½" for average plate thicknesses, with an edge distance of 1¼". Lesser values of edge distance increase bolt prying and should it become necessary to reduce edge distance, it may be necessary to investigate prying action. Plates ¼" thick of $F_y = 36$ ksi steel and a gage of 3" should provide adequate end rotation capacity in the connection. All end plate material thicknesses listed in the table are for $F_y =$ 36 ksi. Use of higher values of F_y should be based on engineering investigation that confirms that adequate end rotation capacity is available.

Weld values listed are for two fillet welds and are based on the use of E70XX electrodes. These weld values have been reduced by considering the effective weld length equal to the plate length minus twice the weld size. Welds should not be returned across the web at the top or bottom of the end plates.

EXAMPLE 1

Given: Select an end plate connection for a W14 × 30 beam
$F_y = 36$ ksi and end reaction = 24 kips.

Solution: Beam web thickness: 0.270"
Usual gage: 3½"

From Table IX for beam depth limits 12" through 18", select a plate length of 8½" with three ¾" diameter A307 bolts per vertical row, with a listed capacity of 26.5 kips and a required minimum plate thickness of $t = 0.121$".

Select a ¼" plate: 0.250 > 0.121 in. o.k.

From Table IX:
Weld Capacity: 8½″ of 3/16 in. fillet = 45.2 kips
Minimum web thickness = 0.389″

$$\frac{0.270}{0.389} \times 45.2 = 31.4 > 24 \text{ kips o.k.}$$

Use: End plate 6″ wide x 8½″ long x ¼″ thick with six ¾″ diameter A307 bolts on 3½″ gage. Weld the plate to the beam web with 3/16 in. fillet welds on each side of the web.

EXAMPLE 2

Given: Select an end plate connection for two W12 × 58 beams framing into both sides of a W30 × 190 girder. Beam reaction = 34 kips for each of the W12 × 58 beams and F_y = 50 ksi for both beams and girder.

Solution: Beam web thickness: 0.359″
Usual gage: 5½″
Girder web thickness: 0.710″

From Table IX for beam depth limits 8″ through 12″, select a plate length of 5½″ with two ¾″ diameter A325 bolts per vertical row, with a listed capacity of 38.9 kips and minimum t = 0.267″.

Try a ¼″ end plate thickness:

$$\frac{0.250}{0.267} \times 38.9 = 36.4 > 34 \text{ kips o.k.}$$

From Table IX:
Weld Capacity: 5½″ of ¼ in. fillet = 37.1 kips
Minimum web t = 0.370″

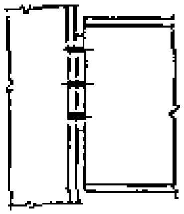
$$\frac{0.359}{0.370} \times 37.1 = 36.0 > 34 \text{ kips o.k.}$$

Since the connection bolts are common to both beams through the girder web, the required girder web thickness must be twice the minimum value shown in the table.

Check girder web:

$$\frac{0.710}{0.740} \times (2 \times 36.4) = 69.8 > 64 \text{ kips o.k.}$$

Use: End plate 8″ wide x 5½″ long x ¼″ thick with four ¾″ diameter A325 bolts on 5½″ gage. Weld the plate to the beam web with ¼ in. fillet welds on each side of the web.



END PLATE SHEAR CONNECTIONS

Welded—E70XX electrodes

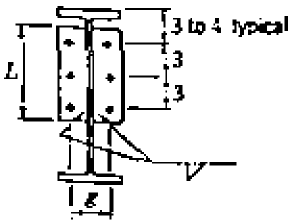


TABLE IX

Fasteners per Vertical Line	Fastener	¾″ Diam. Total Capacity Kips	¾″ Diam. Min. Plate Thickness (t) In.	⅞″ Diam. Total Capacity Kips	⅞″ Diam. Min. Plate Thickness (t) In.	Plate Length (L) Ft-In.	Beam Depth Limits In.
1	ASTM A307 Bolts	8.8	.121	12.0	.141	3	5–8
	[a]ASTM A325 HS Bolts	13.3	.182	18.0	.212		
	[b]ASTM A325 HS Bolts	19.4	.267	26.5	.311		
2	ASTM A307 Bolts	17.7	.121	24.0	.141	5½	8–12
	[a]ASTM A325 HS Bolts	26.5	.182	36.1	.212		
	[b]ASTM A325 HS Bolts	38.9	.267	52.9	.311		
3	ASTM A307 Bolts	26.5	.121	36.1	.141	8½	12–18
	[a]ASTM A325 HS Bolts	39.8	.182	54.1	.212		
	[b]ASTM A325 HS Bolts	58.3	.267	79.4	.311		
4	ASTM A307 Bolts	35.4	.121	48.1	.141	11½	15–24
	[a]ASTM A325 HS Bolts	53.0	.182	72.2	.212		
	[b]ASTM A325 HS Bolts	77.8	.267	105.8	.311		
5	ASTM A307 Bolts	44.2	.121	60.1	.141	1′–2½	18–30
	[a]ASTM A325 HS Bolts	66.3	.182	90.2	.212		
	[b]ASTM A325 HS Bolts	97.2	.267	132.3	.311		
6	ASTM A307 Bolts	53.0	.121	72.1	.141	1′–5½	21–36
	[a]ASTM A325 HS Bolts	79.6	.182	108.2	.212		
	[b]ASTM A325 HS Bolts	116.6	.267	158.8	.311		

[a] Friction type connection, or bearing type with threads in shear planes.
[b] Bearing type connection, threads excluded from shear planes.

WELD CAPACITY

Weld Size	Minimum Web Thickness, In.		Weld Capacity, Kips (2 Fillet Welds)					
	$F_y = 36$	$F_y = 50$	3	5½	8½	11½	1′–2½	1′–5½
3/16	.389	.280	14.7	28.5	45.2	61.9	78.7	95.2
¼	.514	.370	18.6	37.1	59.4	81.6	103.9	126.1
5/16	.646	.465	22.1	45.3	73.1	101.0	128.8	156.7
⅜	.771	.555	25.1	52.9	85.3	119.8	153.4	186.6

ECCENTRIC LOADS ON FASTENER GROUPS

TABLES X—XIII

When a group of fasteners supports an eccentric load, as in Fig. 1, the several fasteners in such a group are not equally stressed. Each supports an equal share of the vertical load P, and each supports additional force due to moment, which is proportional to its distance from the center of gravity of the group. The total force on one fastener is the resultant of the components.

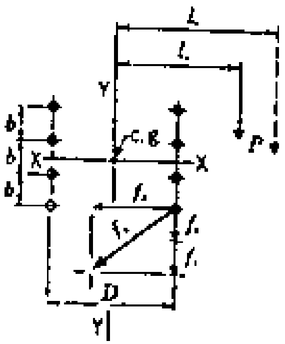


FIG. 1

n = No. of fasteners in a vertical row
m = No. of fasteners in a horizontal row
P = Applied load, kips
r_v = Allowable shear or bearing value for one fastener, kips
I_p = Polar moment of inertia about the center of gravity of fastener group, equal to $I_{xx} + I_{yy}$

$$I_{xx} = \left[\frac{nb^2(n^2 - 1)}{12}\right] \times \text{no. of vertical rows}$$

$$I_{yy} = \left[\frac{mD^2(m^2 - 1)}{12}\right] \times \text{no. of horizontal rows}$$

$L = l_{actual}$ = Actual arm between P and center gravity of fastener group
$l_e = l_{eff.}$ = Effective arm between P and center gravity of fastener group $= L - [(1 + n)/2]$

$$f_1 = \frac{P}{mn} \qquad f_2 = \frac{(Pl_e)D}{2I_p} \qquad f_3 = \frac{(Pl_e)(n - 1)b}{2I_p} \qquad \text{(See Fig. 1)}$$

$$f_R = \sqrt{(f_3)^2 + (f_1 + f_2)^2} \text{ and } f_R = r_v$$

EXAMPLE 1

Given: Find the maximum load that can be supported by the bracket shown in Fig. 2. Column and bracket are F_y = 36 ksi. Use ⅞" ASTM A502 Gr 1 rivets, and assume that the column flange and bracket are at least ¼" thick so that shear will govern. $n = 6$, $m = 2$, $b = 3$, $D = 5\frac{1}{2}$, $L = 16$.

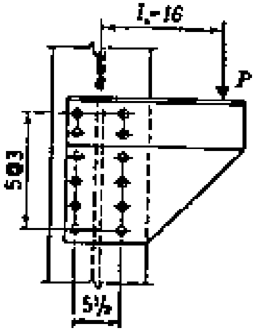


FIG. 2

Solution:

$$I_{xx} = \left[\frac{6 \times 3^2(6^2 - 1)}{12}\right]2 = 315$$

$$I_{yy} = \left[\frac{2 \times 5.5^2(2^2 - 1)}{12}\right]6 = 90.75$$

$$I_p = 315 + 90.75 = 405.75$$

$$l_e = 16 - \left(\frac{1 + 6}{2}\right) = 12.5 \text{ in.}; \quad f_1 = \frac{P}{2 \times 6} = 0.083P$$

$$f_2 = \frac{12.5\,P \times 5.5}{2 \times 405.75} = 0.085P$$

$$f_3 = \frac{12.5\,P \times 5 \times 3}{2 \times 405.75} = 0.231P$$

$$f_R = P\sqrt{(0.231)^2 + (0.083 + 0.065)^2} = 0.285P; \qquad P = f_R/0.285 = 3.51\,f_R$$

A502 Gr 1 rivets, single shear r_v = 9.02 kips.
Since f_R = r_v, P = 3.51 × 9.02 = 31.7 kips.

For any fastener group and any given lever arm of applied load a coefficient C times the allowable value of one fastener equals the total load P permissible on the connection. Thus, $P = C \times r_v$ or, knowing P, and dividing by the allowable fastener value r_v, the necessary coefficient C is obtained, and a fastener group must be employed for which the coefficient is of that magnitude or greater. The coefficients for several fastener groups are given in Tables X to XIII Part 4 of this Manual.

EXAMPLE 2

Given: Using tables, find the maximum load that was found in Example 1 by using the equations given above. $n = 6$, $b = 3$, $D = 5\frac{1}{2}$, $L = 16$.

Solution:

$$l_e = 16 - \left(\frac{1 + 6}{2}\right) = 12.5 \text{ in.}$$

From Table XII, with $n = 6$ and $l_e = 12.5$ by interpolating, $C = 3.51$.

Using r_v = 9.02 kips,
P = 3.51 × 9.02 = 31.7 kips.

EXAMPLE 3

Given: Investigate the rivets in the outer legs of the bracket shown in Fig. 3 for a load P of 29 kips, with L = 12 in., b = 3 in., and using ¾ in. ASTM A502 Gr 1 rivets.

For brackets subjected to eccentric loading as shown, the moment produces a varying amount of tension in the rivets above the neutral axis, coupled with bearing pressure below the neutral axis. There is no definite basis for locating the neutral axis. It lies below the center line of the connection. Example 3 illustrates a simple conservative solution, which is reasonably economical in the case of relatively small brackets, by assuming that the neutral axis is at the centroid of the rivet group, and that the bearing pressure distribution is the same as the tensile stress distribution above the neutral axis.

Solution:

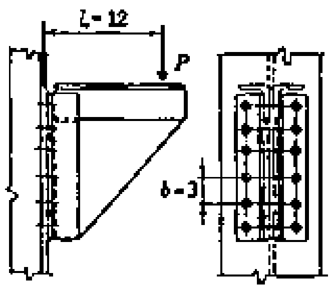


FIG. 3

Moment of Inertia of rivets about the assumed centroid of group =

$$\sum Ad^2 = 0.4418 \times 4(1.5^2 + 4.5^2 + 7.5^2) = 139 \text{ in.}^4$$

$$f_v = \frac{29}{12 \times 0.4418} = 5.47 \text{ ksi}$$

$$F_t = 28.0 - 1.6f_v \leq 20.0 \text{ (Spec. Sect. 1.6.3)}$$
$$= 28.0 - (1.6 \times 5.47) = 19.25 \text{ ksi}$$

$$f_t = \frac{P \times L \times d_{max}}{\sum Ad^2} = \frac{29 \times 12 \times 7.5}{139} = 18.78 < 19.25 \text{ ksi o.k.}$$

Note: The thickness of the bracket connection angles should be ample to resist the bending moment. See page 4-80.

ECCENTRIC LOADS ON FASTENER GROUPS

TABLE X Coefficients *C*

Required minimum $C = \frac{P}{r_v}$

$P = C \times r_v$

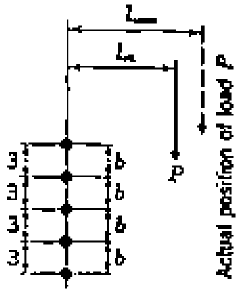
n = Total number of fasteners in the vertical row

P = Permissible load acting with effective lever arm l_{eff}

r_v = Permissible load on one fastener by Specification

$l_{eff} = l_{actual} - \left(\frac{1+2n}{4}\right)$

C = Coefficients tabulated below.



l_{eff} In.	*n*										
	2	3	4	5	6	7	8	9	10	11	12
1½	1.41	2.40	3.43	4.47	5.51	6.55	7.59	8.62	9.65	10.7	11.7
2	1.20	2.12	3.12	4.16	5.21	6.26	7.31	8.36	9.40	10.4	11.5
2½	1.03	1.87	2.83	3.84	4.88	5.94	7.00	8.05	9.10	10.2	11.2
3	.89	1.66	2.56	3.54	4.56	5.60	6.66	7.72	8.78	9.85	10.9
3½	.79	1.49	2.32	3.25	4.24	5.27	6.31	7.37	8.44	9.50	10.6
4	.70	1.34	2.12	3.00	3.95	4.95	5.98	7.03	8.09	9.15	10.2
4½	.63	1.22	1.94	2.77	3.68	4.65	5.66	6.69	7.74	8.80	9.86
5	.57	1.11	1.79	2.57	3.44	4.37	5.35	6.36	7.40	8.45	9.51
5½	.53	1.03	1.66	2.39	3.22	4.12	5.07	6.05	7.07	8.11	9.16
6	.49	.95	1.54	2.24	3.02	3.88	4.80	5.76	6.76	7.78	8.82
6½	.45	.88	1.44	2.10	2.84	3.67	4.55	5.49	6.46	7.46	8.49
7	.42	.82	1.35	1.97	2.68	3.47	4.33	5.23	6.18	7.16	8.17
7½	.39	.77	1.26	1.86	2.54	3.29	4.12	4.99	5.91	6.87	7.86
8	.37	.73	1.19	1.76	2.40	3.13	3.92	4.77	5.67	6.60	7.57
8½	.35	.69	1.13	1.66	2.28	2.98	3.74	4.56	5.43	6.34	7.29
9	.33	.65	1.07	1.58	2.17	2.84	3.58	4.37	5.21	6.10	7.03
10	.30	.59	.97	1.44	1.98	2.60	3.28	4.02	4.82	5.66	6.54
11	.27	.54	.89	1.32	1.82	2.39	3.03	3.72	4.47	5.27	6.10
12	.25	.49	.82	1.21	1.68	2.21	2.81	3.46	4.17	4.92	5.72
14	.21	.42	.70	1.05	1.45	1.92	2.45	3.03	3.66	4.33	5.06
16	.19	.37	.62	.92	1.28	1.70	2.17	2.68	3.25	3.86	4.52
18	.17	.33	.55	.82	1.15	1.52	1.94	2.41	2.92	3.48	4.08
20	.15	.30	.50	.74	1.03	1.37	1.76	2.18	2.65	3.16	3.71
22	.14	.27	.45	.68	.94	1.25	1.60	1.99	2.43	2.89	3.40
24	.12	.25	.41	.62	.87	1.15	1.47	1.84	2.23	2.67	3.14

In general, $C = \dfrac{n}{\sqrt{\left[\dfrac{6l_{eff}}{(n+1)b}\right]^2 + 1}}$

ECCENTRIC LOADS ON FASTENER GROUP

TABLE XI Coefficients *C*

Required minimum $C = \frac{P}{r_v}$

$P = C \times r_v$

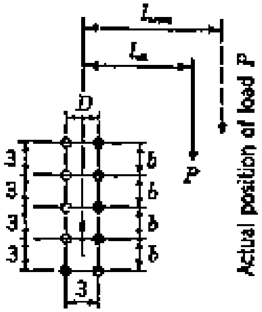
n = Total number of fasteners in any one vertical row

P = Permissible load acting with effective lever arm l_{eff}

r_v = Permissible load on one fastener by Specification

$l_{eff} = l_{actual} - \left(\frac{1+n}{2}\right)$

C = Coefficients tabulated below.



l_{eff} In.	*n*											
	1	2	3	4	5	6	7	8	9	10	11	12
1½	1.00	2.53	4.33	6.30	8.36	10.4	12.5	14.6	16.7	18.8	20.9	23.0
2	.86	2.23	3.88	5.75	7.74	9.80	11.9	14.0	16.1	18.2	20.3	22.4
2½	.75	1.99	3.50	5.24	7.16	9.17	11.2	13.3	15.5	17.6	19.7	21.8
3	.67	1.79	3.17	4.80	6.62	8.56	10.6	12.7	14.8	16.9	19.0	21.1
3½	.60	1.63	2.89	4.41	6.13	8.00	9.97	12.0	14.1	16.2	18.3	20.5
4	.55	1.49	2.66	4.07	5.69	7.48	9.39	11.4	13.4	15.5	17.6	19.8
4½	.50	1.37	2.45	3.77	5.30	7.01	8.85	10.8	12.8	14.8	16.9	19.0
5	.46	1.27	2.28	3.51	4.96	6.58	8.34	10.2	12.2	14.2	16.3	18.4
5½	.43	1.19	2.12	3.28	4.64	6.19	7.88	9.70	11.6	13.6	15.6	17.7
6	.40	1.11	1.99	3.07	4.37	5.84	7.46	9.21	11.1	13.0	15.0	17.0
6½	.37	1.04	1.87	2.89	4.12	5.52	7.08	8.76	10.6	12.4	14.4	16.4
7	.35	.98	1.76	2.73	3.89	5.23	6.72	8.35	10.1	11.9	13.8	15.8
7½	.33	.93	1.66	2.58	3.69	4.97	6.40	7.96	9.64	11.4	13.3	15.2
8	.32	.88	1.58	2.45	3.50	4.72	6.10	7.61	9.23	11.0	12.8	14.6
8½	.30	.84	1.50	2.33	3.33	4.50	5.82	7.28	8.85	10.5	12.3	14.1
9	.29	.80	1.43	2.22	3.18	4.30	5.57	6.97	8.49	10.1	11.8	13.6
10	.26	.73	1.30	2.03	2.91	3.94	5.12	6.43	7.85	9.38	11.0	12.7
11	.24	.67	1.20	1.87	2.68	3.64	4.73	5.95	7.29	8.73	10.3	11.9
12	.22	.62	1.11	1.73	2.48	3.38	4.40	5.54	6.80	8.16	9.61	11.2
14	.19	.54	.97	1.50	2.16	2.95	3.85	4.86	5.98	7.19	8.51	9.91
16	.17	.48	.86	1.33	1.92	2.61	3.41	4.32	5.32	6.42	7.61	8.88
18	.15	.43	.77	1.19	1.72	2.34	3.07	3.88	4.79	5.79	6.88	8.04
20	.14	.39	.70	1.08	1.56	2.12	2.78	3.53	4.36	5.27	6.26	7.34
22	.13	.36	.64	.99	1.42	1.94	2.54	3.23	3.99	4.83	5.75	6.74
24	.12	.33	.59	.91	1.31	1.79	2.34	2.96	3.68	4.46	5.31	6.23

In general, $C = \dfrac{n}{\sqrt{\left[\dfrac{l_{eff}(n-1)b}{D^2 + \frac{1}{3}(n^2-1)b^2}\right]^2 + \left[\dfrac{l_{eff}D}{D^2 + \frac{1}{3}(n^2-1)b^2} + \frac{1}{2}\right]^2}}$

ECCENTRIC LOADS ON FASTENER GROUPS

TABLE XII Coefficients C

Required minimum $C = \frac{P}{r_v}$

$P = C \times r_v$

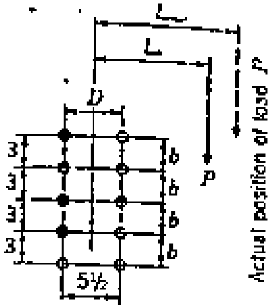
n = Total number of fasteners in any one vertical row

P = Permissible load acting with effective lever arm l_{eff}

r_v = Permissible load on one fastener by Specification

$l_{eff} = l_{actual} - \left(\frac{1+n}{2}\right)$

C = Coefficients tabulated below.



l_{eff} In.	n											
	1	2	3	4	5	6	7	8	9	10	11	12
1½	1.29	2.78	4.46	6.29	8.24	10.3	12.3	14.4	16.5	18.5	20.6	22.7
2	1.16	2.52	4.07	5.81	7.68	9.64	11.7	13.7	15.8	17.9	20.0	22.1
2½	1.05	2.29	3.74	5.37	7.15	9.06	11.0	13.1	15.2	17.2	19.3	21.4
3	.96	2.11	3.45	4.98	6.67	8.51	10.4	12.4	14.5	16.6	18.7	20.8
3½	.88	1.95	3.20	4.63	6.24	7.99	9.87	11.8	13.8	15.9	18.0	20.1
4	.81	1.81	2.98	4.32	5.84	7.52	9.33	11.2	13.2	15.2	17.3	19.4
4½	.76	1.69	2.78	4.05	5.49	7.09	8.83	10.7	12.6	14.6	16.6	18.7
5	.71	1.59	2.61	3.80	5.17	6.70	8.37	10.2	12.0	14.0	16.0	18.0
5½	.67	1.49	2.46	3.58	4.88	6.34	7.94	9.67	11.5	13.4	15.4	17.4
6	.63	1.41	2.32	3.39	4.62	6.01	7.55	9.22	11.0	12.8	14.8	16.8
6½	.59	1.34	2.20	3.21	4.38	5.71	7.19	8.80	10.5	12.3	14.2	16.2
7	.56	1.27	2.09	3.05	4.16	5.44	6.86	8.40	10.1	11.8	13.7	15.6
7½	.54	1.21	1.99	2.90	3.96	5.18	6.55	8.04	9.65	11.4	13.2	15.0
8	.51	1.15	1.90	2.77	3.78	4.95	6.26	7.70	9.26	10.9	12.7	14.5
8½	.49	1.10	1.81	2.64	3.62	4.74	6.00	7.39	8.90	10.5	12.2	14.0
9	.47	1.06	1.74	2.53	3.46	4.54	5.76	7.10	8.56	10.1	11.8	13.5
10	.43	.98	1.60	2.33	3.19	4.19	5.32	6.57	7.94	9.42	11.0	12.6
11	.40	.91	1.48	2.16	2.96	3.88	4.94	6.11	7.40	8.80	10.3	11.9
12	.37	.85	1.38	2.01	2.75	3.62	4.61	5.71	6.92	8.24	9.65	11.2
14	.33	.75	1.22	1.77	2.42	3.18	4.06	5.04	6.12	7.30	8.58	9.94
16	.29	.67	1.09	1.58	2.16	2.84	3.62	4.50	5.48	6.55	7.70	8.94
18	.26	.60	.98	1.42	1.94	2.56	3.26	4.06	4.95	5.92	6.98	8.12
20	.24	.55	.89	1.29	1.77	2.33	2.97	3.70	4.51	5.41	6.38	7.42
22	.22	.51	.82	1.19	1.62	2.13	2.73	3.40	4.14	4.97	5.87	6.84
24	.21	.47	.76	1.10	1.50	1.97	2.52	3.14	3.83	4.59	5.43	6.33

In general, $C = \dfrac{n}{\sqrt{\left[\dfrac{l_{eff}(n-1)b}{D^2 + \frac{1}{6}(n^2-1)b^2}\right]^2 + \left[\dfrac{l_{eff}D}{D^2 + \frac{1}{6}(n^2-1)b^2} + \frac{1}{2}\right]^2}}$

ECCENTRIC LOADS ON FASTENER GROUPS

TABLE XIII Coefficients C

Required minimum $C = \frac{P}{r_v}$

$P = C \times r_v$

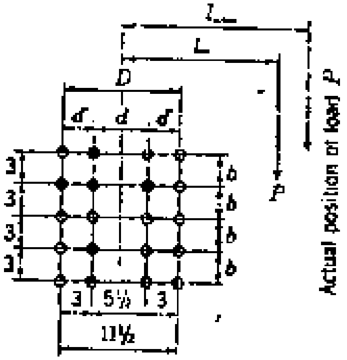
n = Total number of fasteners in any one vertical row

P = Permissible load acting with effective lever arm l_{eff}

r_v = Permissible load on one fastener by Specification

$l_{eff} = l_{actual} - \left(\frac{1+n}{2}\right)$

C = Coefficients tabulated below.



l_{eff} In.	n											
	1	2	3	4	5	6	7	8	9	10	11	12
1½	2.81	5.77	8.96	12.4	16.0	19.8	23.8	27.8	31.9	36.0	40.1	44.2
2	2.55	5.28	8.25	11.5	15.0	18.6	22.5	26.4	30.5	34.6	38.7	42.8
2½	2.34	4.86	7.63	10.7	14.0	17.5	21.3	25.1	29.1	33.2	37.3	41.4
3	2.16	4.50	7.10	9.97	13.1	16.5	20.1	23.9	27.8	31.8	35.9	40.0
3½	2.01	4.20	6.63	9.35	12.3	15.6	19.1	22.7	26.6	30.5	34.5	38.6
4	1.88	3.93	6.22	8.79	11.6	14.8	18.1	21.7	25.4	29.2	33.2	37.2
4½	1.76	3.69	5.86	8.29	11.0	14.0	17.2	20.6	24.3	28.0	31.9	35.9
5	1.66	3.48	5.53	7.84	10.4	13.3	16.4	19.7	23.2	26.9	30.7	34.6
5½	1.56	3.29	5.24	7.44	9.91	12.6	15.6	18.8	22.2	25.8	29.6	33.4
6	1.48	3.12	4.98	7.08	9.43	12.1	14.9	18.0	21.3	24.8	28.5	32.2
6½	1.41	2.97	4.74	6.74	9.00	11.5	14.3	17.3	20.5	23.9	27.4	31.1
7	1.34	2.83	4.52	6.44	8.60	11.0	13.7	16.6	19.7	23.0	26.4	30.1
7½	1.28	2.71	4.33	6.16	8.24	10.6	13.1	15.9	18.9	22.1	25.5	29.0
8	1.22	2.59	4.14	5.91	7.90	10.1	12.6	15.3	18.2	21.3	24.6	28.1
8½	1.17	2.49	3.98	5.67	7.59	9.74	12.1	14.7	17.6	20.6	23.8	27.2
9	1.13	2.39	3.82	5.45	7.30	9.37	11.7	14.2	16.9	19.9	23.0	26.3
10	1.04	2.22	3.55	5.06	6.78	8.71	10.9	13.2	15.8	18.6	21.6	24.7
11	.97	2.07	3.31	4.72	6.33	8.14	10.2	12.4	14.8	17.5	20.3	23.3
12	.91	1.93	3.10	4.42	5.93	7.63	9.53	11.6	13.9	16.4	19.1	21.9
14	.81	1.72	2.75	3.93	5.27	6.78	8.48	10.4	12.4	14.7	17.1	19.7
16	.72	1.54	2.47	3.53	4.73	6.10	7.63	9.33	11.2	13.3	15.5	17.8
18	.66	1.40	2.25	3.21	4.30	5.54	6.93	8.48	10.2	12.1	14.1	16.3
20	.60	1.28	2.06	2.94	3.94	5.07	6.35	7.77	9.34	11.1	12.9	14.9
22	.55	1.18	1.90	2.71	3.63	4.67	5.85	7.17	8.62	10.2	11.9	13.8
24	.51	1.10	1.76	2.51	3.37	4.33	5.43	6.65	8.00	9.48	11.1	12.8

In general, $C = \dfrac{n}{\sqrt{\left[\dfrac{l_{eff}(n-1)b}{d^2 + D^2 + \frac{1}{6}(n^2-1)b^2}\right]^2 + \left[\dfrac{l_{eff}D}{d^2 + D^2 + \frac{1}{6}(n^2-1)b^2} + \frac{1}{4}\right]^2}}$

ECCENTRIC LOADS ON WELD GROUPS

TABLES XIV–XXI

The solution of eccentric loading of weld groups is similar to the method employed for fastener groups, except that for computation of properties, the weld is considered a line coincident with the edge to be fillet welded.

P = Permissible load, kips

A = Distance from vertical weld to P, inches $= l(a + x)$

l = Length of vertical weld, inches

kl = Length of horizontal weld, inches

L = Total length of weld, inches $= l(1 + 2k)$

xl = Distance from vertical weld to center of gravity of weld group, in inches

$$= \frac{(kl)^2}{L} \text{ or } x = \frac{k^2}{(1 + 2k)}$$

I_p = Polar moment of inertia, inches^4

$$= l^3\left[\frac{(1 + 2k)^3}{12} - \frac{k^2(1 + k)^2}{(1 + 2k)}\right]$$

D = Number of sixteenths of an inch in weld size

$0.928D$ = Value of E70XX weld per sixteenth inch of weld per lineal inch, kips

f_1 = Stress on weld at B due to vertical load

$$= P/(l + 2kl) = P/l(1 + 2k)$$

f_2 = Vertical stress on weld at B due to moment

$$= \frac{Pal(kl - xl)}{I_p} = \frac{Pal^2(k - x)}{I_p}$$

f_3 = Horizontal stress on weld at B due to moment

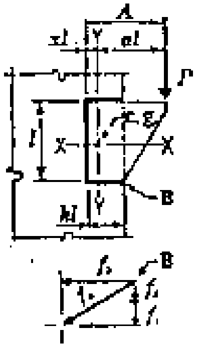
$$= \frac{Pal(l/2)}{I_p} = \frac{Pal^2}{2I_p}$$

f_R = Resultant of stresses on weld at B

$$= \sqrt{(f_1 + f_2)^2 + (f_3)^2}$$

and

f_R = 0.928D (for E70XX electrodes)



FORCES AT B
(most highly stressed point of weld)

FIG. 1

EXAMPLE

Given: Weld group shown in Fig. 1 with l = 10″, kl = 5″ an = 10″. Find the maximum allowable load P for a $\frac{3}{8}$″ weld using E70XX electrodes: (a) with formulas and (b) by using Table XVI, page 4 - 70.

Solution:

(a) $k = \frac{kl}{l} = \frac{5}{10} = 0.5$

$$x = \frac{k^2}{1 + 2k} = \frac{(0.5)^2}{1 + 2(0.5)} = 0.125$$

$xl = (0.125)(10) = 1.25$

$al = A - xl = 10 - 1.25 = 8.75 \qquad a = 0.875$

$$I_p = (10)^3\left[\frac{(1 + 1)^3}{12} - \frac{(0.5)^2(1.5)^2}{(1 + 1)}\right] = 385$$

$$f_1 = \frac{P}{l(1 + 2k)} = \frac{P}{10(1 + 2x.5)} = \frac{P}{20} = 0.05P$$

$$f_2 = \frac{Pal^2(k - x)}{I_p} = \frac{P(.875)(10^2)(0.5 - 0.125)}{385} = 0.085P$$

$$f_3 = \frac{Pal^2}{2I_p} = \frac{P(0.875)(10^2)}{2(385)} = 0.114P$$

$$f_R = \sqrt{(0.05P + 0.085P)^2 + (0.114P)^2} = 0.177P$$

Using $\frac{3}{8}$″ welds (E70XX electrodes):

$f_R = 0.928D = 0.928 \times 6 = 5.568.$ Since f_R also equals $0.177P$,

$$P = \frac{5.568}{0.177} = 31.5 \text{ kips}$$

(b) $l = 10$, $kl = 5$, $k = 0.5$, $A = 10$

Enter Table XVI, page 4 - 70, for $k = 0.5$: $x = 0.125$

$xl = (0.125)(10) = 1.25$

$al = A - xl = 8.75 \qquad a = 0.875$

Interpolating between $a = 0.8$ and $a = 0.9$ for $k = 0.5$, $C = 0.527$

Using $\frac{3}{8}$″ welds, $D = 6$

$C_1 = 1.0$ for E70XX electrodes (see below)

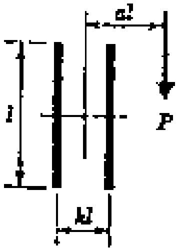
$P = C_1CDl = (1.0)(0.527)(6)(10) = 31.6$ kips

Tables XIV through XXI are based on welds made with E70XX electrodes. Multiply by C_1 values tabulated in table below:

Electrode	E60	E70	E80	E90	E100	E110
F_w (ksi) C_1	18.0 0.857	21.0 1.0	24.0 1.14	27.0 1.29	30.0 1.43	33.0 1.57

ECCENTRIC LOADS ON WELD GROUPS

TABLE XIV Coefficients *C*



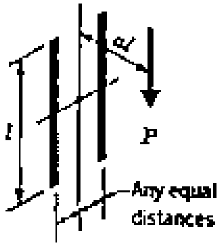
Required Minimum $C = \frac{P}{C_1 D l}$

" " $D = \frac{P}{C C_1 l}$

" " $l = \frac{P}{C C_1 D}$

P = Permissible eccentric load in kips.
l = Length of each weld in inches.
D = Number of sixteenths of an inch in fillet weld size.
C = Coefficients tabulated below.
C_1 = Coefficient for electrode used (see Table on page 4-67).
= 1.0 for E70XX electrodes.

$$P = CC_1Dl$$



SPECIAL CASE*

(Load not in plane of weld group.)

Use *C*-values given in column headed $k = 0$.

a	*k*															
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0
0.1	1.59	1.54	1.51	1.50	1.51	1.52	1.54	1.55	1.57	1.59	1.60	1.63	1.65	1.67	1.68	1.70
0.2	1.19	1.15	1.15	1.16	1.20	1.23	1.27	1.30	1.33	1.36	1.39	1.44	1.48	1.51	1.54	1.56
0.3	.901	.881	.892	.923	.966	1.01	1.06	1.11	1.15	1.19	1.22	1.28	1.33	1.38	1.41	1.45
0.4	.714	.704	.721	.756	.803	.854	.906	.956	1.00	1.05	1.09	1.16	1.21	1.26	1.31	1.34
0.5	.587	.583	.601	.637	.683	.734	.787	.639	.887	.933	.975	1.05	1.11	1.17	1.21	1.25
0.6	.497	.495	.514	.548	.593	.642	.694	.745	.794	.840	.883	.960	1.03	1.08	1.13	1.18
0.7	.430	.430	.449	.481	.523	.570	.620	.659	.717	.763	.806	.883	.951	1.01	1.06	1.11
0.8	.379	.380	.397	.428	.467	.512	.559	.607	.654	.698	.741	.812	.885	.545	.998	1.04
0.9	.338	.340	.357	.385	.422	.464	.509	.555	.600	.644	.685	.761	.828	.888	.941	.989
1.0	.306	.308	.323	.350	.384	.424	.467	.511	.554	.596	.637	.711	.778	.837	.891	.939
1.2	.255	.258	.272	.296	.326	.362	.401	.441	.481	.520	.558	.629	.693	.751	.804	.852
1.4	.219	.222	.235	.256	.283	.316	.351	.387	.424	.460	.496	.563	.625	.681	.732	.779
1.6	.192	.195	.206	.225	.250	.280	.312	.345	.379	.413	.446	.509	.568	.622	.672	.718
1.8	.171	.174	.184	.201	.224	.251	.280	.311	.343	.374	.405	.465	.521	.573	.621	.666
2.0	.154	.157	.166	.182	.203	.227	.255	.283	.313	.342	.371	.428	.481	.531	.577	.620
2.2	.140	.143	.152	.166	.185	.208	.733	.260	.287	.315	.342	.396	.447	.494	.539	.581
2.4	.129	.131	.139	.153	.170	.192	.215	.240	.266	.292	.318	.369	.417	.463	.505	.546
2.6	.119	.121	.129	.141	.158	.178	.200	.223	.247	.272	.296	.345	.391	.435	.476	.515
2.8	.110	.112	.120	.131	.147	.166	.186	.208	.231	.254	.278	.324	.368	.410	.449	.487
3.0	.103	.105	.112	.123	.138	.155	.174	.195	.217	.239	.261	.305	.347	.388	.426	.462

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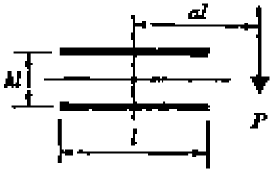
* Valid only when the connection material between the welds is solid and does not bend in the plane of the welds.

ECCENTRIC LOADS ON WELD GROUPS

TABLE XV Coefficients *C*

P = Permissible eccentric load in kips.
l = Length of each weld in inches.
D = Number of sixteenths of an inch in fillet weld size.
C = Coefficients tabulated below.
C_1 = Coefficient for electrode used (see Table on page 4-67).
= 1.0 for E70XX electrodes.



$$P = CC_1Dl$$

Required Minimum $C = \frac{P}{C_1 D l}$

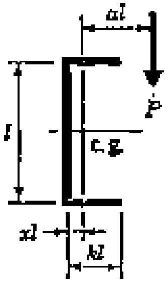
" " $D = \frac{P}{C C_1 l}$

" " $l = \frac{P}{C C_1 D}$

a	*k*															
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0
0.1	1.16	1.17	1.71	1.25	1.31	1.37	1.43	1.48	1.53	1.57	1.60	1.66	1.70	1.73	1.75	1.77
0.2	.844	.856	.891	.944	1.01	1.08	1.15	1.22	1.28	1.34	1.39	1.48	1.55	1.60	1.64	1.67
0.3	.663	.674	.707	.756	.818	.887	.959	1.03	1.10	1.16	1.22	1.33	1.41	1.48	1.54	1.58
0.4	.546	.556	.585	.630	.687	.752	.820	.890	.958	1.02	1.09	1.20	1.29	1.37	1.44	1.50
0.5	.464	.473	.499	.540	.592	.652	.716	.782	.848	.913	.975	1.09	1.19	1.28	1.35	1.41
0.6	.404	.412	.435	.473	.520	.575	.635	.698	.760	.822	.883	.996	1.10	1.19	1.27	1.33
0.7	.357	.364	.386	.420	.464	.515	.571	.629	.688	.748	.806	.917	1.02	1.11	1.19	1.26
0.8	.320	.327	.347	.378	.418	.466	.518	.572	.629	.685	.741	.848	.948	1.04	1.12	1.19
0.9	.290	.296	.315	.343	.381	.425	.474	.525	.578	.632	.685	.788	.886	.975	1.06	1.13
1.0	.265	.271	.288	.315	.350	.391	.436	.485	.535	.586	.637	.736	.830	.919	1.00	1.07
1.2	.226	.231	.246	.270	.300	.337	.377	.420	.465	.511	.558	.649	.737	.821	.900	.973
1.4	.197	.202	.215	.236	.263	.296	.332	.371	.412	.453	.496	.580	.662	.741	.816	.887
1.6	.175	.179	.191	.210	.234	.264	.296	.332	.369	.407	.446	.524	.601	.675	.746	.814
1.8	.157	.161	.172	.189	.211	.238	.268	.300	.334	.369	.405	.477	.549	.619	.686	.751
2.0	.143	.146	.156	.171	.192	.217	.244	.274	.306	.338	.371	.438	.505	.571	.635	.696
2.2	.131	.134	.143	.157	.176	.199	.224	.252	.281	.312	.342	.405	.468	.530	.590	.649
2.4	.121	.123	.132	.145	.163	.184	.208	.233	.261	.289	.318	.377	.436	.494	.551	.607
2.6	.112	.115	.122	.135	.151	.171	.193	.217	.243	.269	.296	.352	.407	.463	.517	.570
2.8	.104	.107	.114	.126	.141	.160	.180	.203	.227	.252	.278	.330	.383	.435	.487	.537
3.0	.0977	.100	.107	.118	.132	.150	.169	.191	.213	.237	.261	.311	.361	.410	.460	.508

ECCENTRIC LOADS ON WELD GROUPS

TABLE XVI Coefficients *C*



P = Permissible eccentric load in kips.
l = Length of weld parallel to load P in inches.
D = Number of sixteenths of an inch in fillet weld size.
C = Coefficients tabulated below.
C_1 = Coefficient for electrode used (see Table on page 4-67).
= 1.0 for E70XX electrodes.
xl = Distance from vertical weld to center of gravity of weld group.

$$P = CC_1Dl$$

Required Minimum $C = \frac{P}{C_1Dl}$

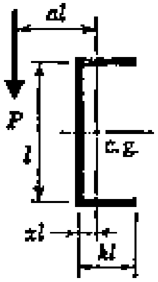
" " $D = \frac{P}{CC_1l}$

" " $l = \frac{P}{CC_1D}$

a	k: 0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0
0.1	.796	.951	1.09	1.23	1.38	1.52	1.66	1.81	1.96	2.11	2.27	2.58	2.90	3.23	3.56	3.90
0.2	.594	.758	.889	1.01	1.13	1.25	1.37	1.50	1.63	1.76	1.89	2.16	2.45	2.74	3.05	3.36
0.3	.451	.608	.730	.840	.946	1.05	1.16	1.27	1.38	1.50	1.61	1.86	2.11	2.38	2.66	2.94
0.4	.357	.499	.611	.711	.807	.901	.997	1.09	1.19	1.30	1.40	1.62	1.86	2.10	2.35	2.62
0.5	.293	.421	.523	.614	.701	.786	.872	.960	1.05	1.14	1.24	1.44	1.65	1.88	2.11	2.35
0.6	.248	.362	.455	.539	.618	.695	.774	.854	.937	1.02	1.11	1.29	1.49	1.70	1.91	2.14
0.7	.215	.317	.402	.479	.551	.623	.695	.769	.844	.922	1.00	1.17	1.35	1.55	1.75	1.96
0.8	.189	.282	.360	.430	.498	.564	.630	.698	.768	.840	.915	1.07	1.24	1.42	1.61	1.81
0.9	.169	.254	.326	.391	.453	.514	.576	.639	.704	.772	.841	.988	1.15	1.31	1.49	1.68
1.0	.153	.230	.297	.358	.416	.473	.530	.589	.650	.713	.778	.916	1.06	1.22	1.39	1.56
1.2	.178	.194	.252	.306	.356	.407	.458	.510	.563	.619	.676	.798	.929	1.07	1.22	1.38
1.4	.110	.168	.219	.267	.312	.357	.402	.449	.496	.546	.598	.707	.825	.952	1.09	1.23
1.6	.096	.148	.194	.236	.277	.318	.359	.400	.444	.489	.536	.635	.742	.857	.981	1.11
1.8	.086	.132	.174	.212	.249	.286	.323	.362	.401	.442	.485	.576	.674	.780	.893	1.01
2.0	.077	.119	.157	.192	.226	.260	.295	.330	.366	.404	.443	.527	.617	.715	.820	.932
2.2	.070	.109	.143	.176	.207	.239	.270	.303	.336	.371	.408	.485	.570	.660	.758	.862
2.4	.064	.100	.132	.152	.191	.220	.259	.280	.311	.344	.378	.450	.529	.613	.705	.802
2.6	.059	.092	.122	.150	.178	.205	.232	.260	.290	.320	.352	.419	.493	.573	.658	.750
2.8	.055	.086	.113	.140	.166	.191	.217	.243	.271	.299	.329	.393	.462	.537	.616	.704
3.0	.051	.080	.107	.131	.155	.175	.203	.228	.254	.281	.309	.369	.435	.505	.582	.663
x	0	.008	.029	.056	.089	.125	.164	.204	.246	.289	.333	.424	.516	.610	.704	.800

ECCENTRIC LOADS ON WELD GROUPS

TABLE XVII Coefficients *C*



P = Permissible eccentric load in kips.
l = Length of weld parallel to load P in inches.
D = Number of sixteenths of an inch in fillet weld size.
C = Coefficients tabulated below.
C_1 = Coefficient for electrode used (see Table on page 4-67).
= 1.0 for E70XX electrodes.
xl = Distance from vertical weld to center of gravity of weld group.

$$P = CC_1Dl$$

Required Minimum $C = \frac{P}{C_1Dl}$

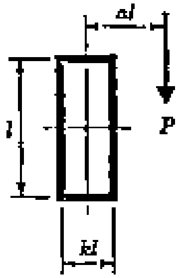
" " $D = \frac{P}{CC_1l}$

" " $l = \frac{P}{CC_1D}$

a	k: 0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0
0.1	.796	1.01	1.19	1.37	1.53	1.69	1.85	2.01	2.17	2.33	2.48	2.80	3.12	3.45	3.78	4.12
0.2	.594	.823	1.01	1.18	1.34	1.49	1.64	1.78	1.92	2.07	2.21	2.49	2.78	3.08	3.38	3.69
0.3	.451	.659	.841	1.01	1.16	1.30	1.44	1.57	1.71	1.84	1.97	2.23	2.50	2.77	3.05	3.33
0.4	.357	.539	.704	.857	1.00	1.14	1.27	1.40	1.52	1.64	1.76	2.01	2.26	2.51	2.77	3.03
0.5	.293	.451	.599	.739	.873	1.00	1.12	1.24	1.36	1.48	1.59	1.82	2.05	2.29	2.53	2.78
0.6	.248	.386	.518	.646	.770	.890	1.01	1.12	1.23	1.34	1.45	1.66	1.88	2.10	2.33	2.57
0.7	.215	.337	.455	.572	.686	.798	.907	1.01	1.12	1.22	1.32	1.53	1.73	1.94	2.16	2.38
0.8	.189	.298	.406	.512	.617	.722	.824	.925	1.02	1.12	1.22	1.41	1.61	1.81	2.01	2.22
0.9	.169	.267	.364	.462	.560	.658	.754	.849	.943	1.04	1.13	1.31	1.50	1.69	1.88	2.08
1.0	.153	.242	.331	.421	.513	.604	.694	.784	.873	.691	1.05	1.22	1.40	1.58	1.76	1.95
1.2	.128	.203	.279	.357	.437	.518	.599	.679	.759	.839	.918	1.08	1.24	1.40	1.57	1.74
1.4	.110	.175	.241	.310	.380	.452	.525	.598	.671	.744	.816	.962	1.11	1.26	1.41	1.57
1.6	.096	.153	.212	.273	.335	.398	.465	.534	.600	.667	.734	.862	1.00	1.14	1.29	1.43
1.8	.086	.137	.189	.242	.295	.350	.408	.458	.531	.599	.666	.790	.916	1.05	1.18	1.32
2.0	.077	.123	.170	.217	.264	.312	.363	.416	.471	.531	.593	.725	.843	.953	1.09	1.22
2.2	.070	.112	.154	.196	.239	.282	.327	.374	.424	.476	.532	.654	.780	.893	1.01	1.13
2.4	.064	.103	.141	.179	.217	.257	.297	.340	.385	.432	.492	.591	.714	.832	.941	1.05
2.6	.059	.095	.130	.165	.200	.236	.273	.311	.352	.395	.442	.540	.651	.775	.892	.989
2.8	.055	.088	.121	.153	.185	.218	.252	.287	.325	.364	.416	.496	.598	.711	.830	.931
3.0	.051	.082	.112	.142	.172	.203	.234	.257	.301	.338	.376	.459	.553	.657	.773	.880
x	0	.008	.029	.056	.089	.125	.164	.204	.246	.289	.333	.424	.516	.610	.704	.800

ECCENTRIC LOADS ON WELD GROUPS

TABLE XVIII Coefficients *C*



P = Permissible eccentric load in kips.
l = Length of longer welds in inches.
D = Number of sixteenths of an inch in fillet weld size.
C = Coefficients tabulated below.
C_1 = Coefficient for electrode used (see Table on page 4-67).
= 1.0 for E70XX electrodes.

$$P = CC_1Dl$$

Required Minimum $C = \frac{P}{C_1Dl}$

" " $D = \frac{P}{CC_1l}$

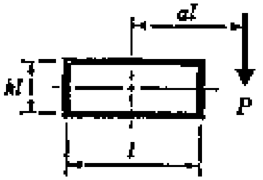
" " $l = \frac{P}{CC_1D}$

Note: When load *P* is perpendicular to longer side *l* use table on facing page.

a	*k*										
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.1	1.59	1.76	1.92	2.08	2.73	2.39	2.55	2.71	2.87	3.04	3.20
0.2	1.19	1.38	1.55	1.72	1.87	2.03	2.18	2.33	2.48	2.63	2.78
0.3	.901	1.09	1.26	1.43	1.58	1.73	1.87	2.02	2.16	2.30	2.45
0.4	.714	.881	1.04	1.20	1.35	1.49	1.63	1.77	1.90	2.04	2.17
0.5	.586	.736	.884	1.03	1.17	1.30	1.44	1.57	1.69	1.82	1.95
0.6	.497	.629	.764	.898	1.03	1.16	1.28	1.40	1.52	1.65	1.77
0.7	.430	.548	.671	.795	.916	1.04	1.15	1.27	1.38	1.50	1.61
0.8	.379	.485	.598	.712	.825	.937	1.05	1.16	1.27	1.37	1.48
0.9	.338	.435	.538	.644	.750	.856	.959	1.06	1.17	1.27	1.37
1.0	.305	.394	.489	.588	.687	.786	.884	.982	1.08	1.18	1.27
1.2	.255	.331	.414	.499	.587	.675	.763	.851	.939	1.03	1.12
1.4	.219	.286	.358	.434	.512	.592	.671	.751	.831	.911	.991
1.6	.192	.251	.315	.384	.454	.526	.598	.671	.745	.818	.892
1.8	.171	.224	.282	.344	.408	.473	.540	.607	.674	.742	.810
2.0	.154	.202	.255	.311	.370	.430	.492	.553	.616	.679	.742
2.2	.140	.184	.232	.284	.338	.394	.451	.509	.567	.626	.685
2.4	.129	.169	.213	.261	.312	.364	.417	.471	.525	.580	.636
2.6	.119	.156	.197	.242	.289	.338	.387	.438	.489	.540	.593
2.8	.110	.145	.184	.225	.269	.315	.362	.409	.457	.506	.555
3.0	.103	.135	.172	.211	.252	.295	.339	.384	.430	.476	.522

ECCENTRIC LOADS ON WELD GROUPS

TABLE XIX Coefficients *C*



P = Permissible eccentric load in kips.
l = Length of longer welds in inches.
D = Number of sixteenths of an inch in fillet weld size.
C = Coefficients tabulated below.
C_1 = Coefficient for electrode used (see Table on page 4-67).
= 1.0 for E70XX electrodes.

$$P = CC_1Dl$$

Required Minimum $C = \frac{P}{C_1Dl}$

" " $D = \frac{P}{CC_1l}$

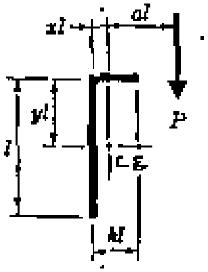
" " $l = \frac{P}{CC_1D}$

Note: When load *P* is parallel to longer side *l* use table on facing page.

a	*k*										
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.1	1.16	1.36	1.57	1.78	1.98	2.19	2.39	7.59	2.80	3.00	3.20
0.2	.844	1.02	1.21	1.40	1.59	1.79	1.99	2.18	2.38	2.58	2.78
0.3	.663	.819	.984	1.15	1.33	1.51	1.69	1.88	2.07	2.25	2.45
0.4	.546	.683	.829	.982	1.14	1.30	1.47	1.64	1.82	1.99	2.17
0.5	.464	.585	.716	.854	.998	1.15	1.30	1.46	1.62	1.78	1.95
0.6	.404	.512	.630	.755	.887	1.02	1.16	1.31	1.46	1.61	1.77
0.7	.357	.455	.562	.677	.798	.924	1.05	1.19	1.33	1.47	1.61
0.8	.320	.410	.508	.613	.725	.841	.962	1.09	1.21	1.35	1.48
0.9	.290	.373	.463	.561	.664	.772	.885	1.00	1.12	1.24	1.37
1.0	.265	.341	.426	.516	.613	.714	.819	.927	1.04	1.15	1.27
1.2	.226	.293	.366	.446	.530	.619	.712	.809	.908	1.01	1.12
1.4	.197	.256	.321	.392	.468	.547	.630	.716	.805	.897	.991
1.6	.175	.228	.286	.350	.418	.490	.565	.643	.724	.807	.892
1.8	.157	.205	.258	.316	.378	.444	.512	.583	.657	.732	.810
2.0	.143	.186	.235	.288	.345	.406	.468	.533	.601	.671	.742
2.2	.131	.171	.216	.265	.317	.373	.431	.491	.554	.618	.685
2.4	.121	.158	.199	.245	.294	.345	.399	.456	.514	.574	.636
2.6	.112	.146	.185	.228	.273	.322	.372	.425	.479	.535	.593
2.8	.104	.137	.173	.213	.256	.301	.348	.398	.449	.501	.555
3.0	.098	.128	.162	.200	.240	.283	.327	.374	.422	.471	.522

ECCENTRIC LOADS ON WELD GROUPS

TABLE XX Coefficients *C*



P = Permissible eccentric load in kips.
l = Length of weld parallel to load *P* in inches.
D = Number of sixteenths of an inch in fillet weld size.
C = Coefficients tabulated below.
C_1 = Coefficient for electrode used (see Table on page 4-67).
= 1.0 for E70XX electrodes.
xl = Distance from vertical weld to center of gravity of weld group.
yl = Distance from horizontal weld to center of gravity of weld group.

$$P = CC_1Dl$$

$$\text{Required Minimum } C = \frac{P}{C_1Dl}$$

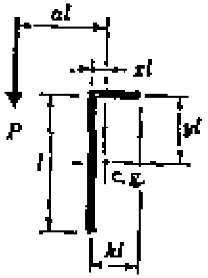
$$\text{" \quad " } D = \frac{P}{CC_1l}$$

$$\text{" \quad " } l = \frac{P}{CC_1D}$$

a	*k*															
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0
0.1	.796	.854	.900	.944	.990	1.04	1.09	1.15	1.22	1.29	1.36	1.52	1.69	1.86	2.04	2.22
0.2	.594	.671	.715	.748	.780	.815	.855	.900	.951	1.01	1.07	1.70	1.35	1.51	1.68	1.85
0.3	.451	.521	.580	.611	.638	.661	.698	.736	.778	.826	.879	.998	1.13	1.27	1.42	1.58
0.4	.357	.415	.466	.513	.537	.562	.589	.621	.658	.700	.746	.851	.970	1.10	1.24	1.38
0.5	.294	.342	.384	.427	.463	.485	.509	.537	.570	.607	.648	.742	.850	.967	1.09	1.23
0.6	.248	.290	.326	.362	.402	.426	.448	.473	.502	.536	.573	.658	.756	.864	.980	1.10
0.7	.215	.251	.282	.313	.348	.380	.400	.423	.449	.479	.513	.591	.680	.780	.888	1.00
0.8	.189	.221	.248	.276	.306	.342	.361	.382	.406	.433	.464	.536	.619	.711	.811	.918
0.9	.169	.198	.222	.246	.273	.305	.329	.348	.370	.396	.424	.490	.567	.653	.747	.847
1.0	.153	.178	.200	.222	.246	.275	.302	.320	.340	.364	.390	.452	.524	.604	.692	.786
1.2	.128	.149	.168	.186	.206	.229	.257	.275	.293	.314	.337	.391	.454	.525	.603	.688
1.4	.110	.128	.144	.160	.177	.197	.221	.241	.257	.275	.296	.344	.401	.464	.535	.611
1.6	.096	.113	.126	.140	.155	.172	.193	.215	.229	.246	.264	.307	.358	.416	.480	.549
1.8	.086	.100	.112	.124	.138	.153	.171	.193	.207	.222	.238	.278	.324	.377	.436	.499
2.0	.077	.090	.101	.112	.124	.138	.154	.174	.188	.202	.217	.253	.296	.345	.399	.458
2.2	.070	.082	.092	.102	.113	.125	.140	.158	.173	.185	.200	.233	.272	.317	.368	.422
2.4	.064	.075	.084	.093	.103	.115	.128	.144	.160	.171	.185	.216	.252	.294	.341	.392
2.6	.059	.070	.078	.086	.095	.106	.118	.133	.148	.159	.172	.201	.235	.274	.318	.366
2.8	.055	.065	.072	.080	.086	.098	.110	.124	.139	.149	.160	.185	.220	.257	.298	.343
3.0	.052	.060	.068	.075	.083	.092	.103	.115	.130	.140	.150	.176	.206	.241	.280	.323
x	.000	.005	.017	.035	.057	.083	.113	.144	.178	.213	.250	.327	.408	.492	.579	.667
y	.500	.455	.417	.385	.357	.333	.313	.294	.278	.264	.250	.227	.208	.192	.179	.167

ECCENTRIC LOADS ON WELD GROUPS

TABLE XXI Coefficients *C*



P = Permissible eccentric load in kips.
l = Length of weld parallel to load *P* in inches.
D = Number of sixteenths of an inch in fillet weld size.
C = Coefficients tabulated below.
C_1 = Coefficient for electrode used (see Table on page 4-67).
= 1.0 for E70XX electrodes.
xl = Distance from vertical weld to center of gravity of weld group.
yl = Distance from horizontal weld to center of gravity of weld group.

$$P = CC_1Dl$$

$$\text{Required Minimum } C = \frac{P}{C_1Dl}$$

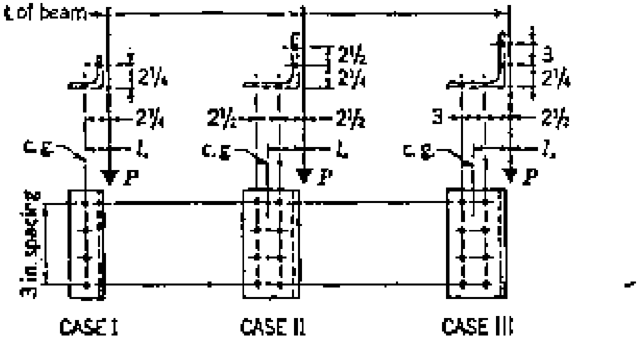
$$\text{" \quad " } D = \frac{P}{CC_1l}$$

$$\text{" \quad " } l = \frac{P}{CC_1D}$$

a	*k*															
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0
0.1	.796	.886	.964	1.04	1.11	1.18	1.26	1.33	1.41	1.49	1.58	1.75	1.92	2.09	2.27	2.45
0.2	.594	.674	.739	.798	.857	.920	.987	1.06	1.14	1.21	1.29	1.46	1.63	1.81	1.98	2.16
0.3	.451	.517	.570	.619	.669	.723	.782	.847	.917	.991	1.07	1.23	1.40	1.57	1.74	1.91
0.4	.357	.412	.456	.497	.539	.585	.638	.695	.759	.827	.899	1.05	1.21	1.38	1.54	1.71
0.5	.294	.340	.377	.412	.448	.489	.535	.586	.643	.705	.771	.913	1.06	1.22	1.38	1.54
0.6	.248	.289	.320	.351	.382	.418	.459	.504	.556	.612	.672	.804	.945	1.09	1.24	1.39
0.7	.215	.250	.278	.305	.333	.364	.401	.442	.488	.539	.595	.716	.848	.987	1.13	1.27
0.8	.189	.221	.245	.269	.294	.323	.356	.393	.435	.482	.533	.645	.769	.899	1.03	1.17
0.9	.169	.197	.219	.241	.264	.289	.319	.353	.392	.435	.482	.587	.702	.825	.953	1.08
1.0	.152	.178	.198	.218	.239	.262	.290	.321	.357	.396	.440	.537	.646	.762	.884	1.01
1.2	.128	.149	.166	.183	.200	.221	.244	.271	.302	.336	.374	.460	.556	.660	.770	.884
1.4	.110	.128	.143	.157	.173	.190	.211	.234	.261	.292	.325	.401	.487	.581	.681	.786
1.6	.096	.112	.125	.138	.152	.167	.185	.206	.230	.257	.257	.356	.434	.519	.611	.707
1.8	.086	.100	.111	.123	.135	.149	.165	.184	.206	.230	.257	.320	.391	.469	.553	.642
2.0	.077	.090	.101	.111	.122	.134	.149	.166	.186	.208	.233	.290	.355	.428	.506	.588
2.2	.070	.082	.092	.101	.111	.122	.136	.152	.170	.190	.213	.265	.326	.393	.465	.542
2.4	.064	.075	.084	.093	.102	.112	.125	.139	.156	.175	.196	.244	.301	.363	.431	.503
2.6	.059	.069	.078	.085	.094	.104	.115	.129	.144	.162	.182	.227	.279	.338	.401	.469
2.8	.055	.065	.072	.079	.087	.097	.107	.120	.134	.151	.169	.211	.260	.319	.375	.440
3.0	.052	.060	.067	.074	.082	.090	1.00	.112	.126	.141	.158	.198	.244	.296	.353	.413
x	.000	.005	.017	.035	.057	.083	.113	.144	.178	.213	.250	.327	.408	.492	.579	.667
y	.500	.455	.417	.385	.357	.333	.313	.294	.278	.263	.250	.227	.208	.192	.179	.167

ONE-SIDED CONNECTIONS

In designing a one-sided connection it is customary to consider vertical shear or bearing in all fasteners and the effect of eccentricity in the outstanding leg fasteners. Shown below is a table of coefficients for one-sided framed beam connections and an example of its use.



n	Coefficient C		
	Case I	Case II	Case III
1	...	0.63	0.67
2	1.41	2.05	1.99
3	2.68	4.10	3.88
4	3.92	6.64	6.31
5	5.00	9.32	8.97
6	6.00	11.83	11.60
7	7.00	14.00	14.00
8	8.00	16.00	16.00
9	9.00	18.00	18.00
10	10.00	20.00	20.00

$P = Cr_v$ or $C = P/r_v$

n = Total number of fasteners in one vertical row

C = Coefficient

P = Permissible load, kips

r_v = Allowable shear or bearing value for one fastener, kips

$l_a = l_{actual}$ = Actual arm between center line of beam and center of gravity of fasteners

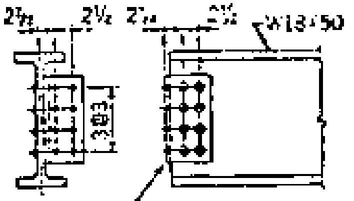
$l_e = l_{eff.}$ = Effective arm between center line of beam and center of gravity of fasteners

In computation of coefficients C the actual moment arm l_a is corrected to l_e using the empirical formulas, $l_e = l_a - \left(\frac{1+2n}{4}\right)$ for single gage and $l_e = l_a - \left(\frac{1+n}{2}\right)$ for double gage.

Do not exceed gages shown for web leg. Pattern of web leg fasteners may vary to suit required number of fasteners. For outstanding leg gages, other than those shown, coefficients may be interpolated from Tables X to XII, Part 4 of the Manual. Select angle thickness to provide sufficient gross shear capacity, or limit connection capacity to permissible shear value of angle used. Use minimum angle thickness of $\frac{3}{8}$" for $\frac{3}{4}$" diam. and $\frac{7}{8}$" diam. fasteners, and $\frac{1}{2}$" for 1" diam. fasteners. It will be permissible to design a connection using combinations of leg widths as well as fastener specification and diameters.

EXAMPLE 1

Given: Select a one-sided connection for a W18×50, F_y = 36 ksi with an end reaction of 50 kips. Use $\frac{7}{8}$" diam. ASTM A502 Gr 1 rivets in the [illegible] web leg and $\frac{7}{8}$" diam. ASTM A325 friction type bolts in the outsi[illegible] leg.



Solution:

1. *Outstanding leg:*
   Single shear value of $\frac{7}{8}$" diam. A325 bolt, from shear allowable load tables = 9.02 kips.

$$C = \frac{50}{9.02} = 5.54$$

The next larger value of C in the table above requires six A325 bolts in Case I or eight A325 bolts in Case II. Since the beam depth will not allow Case I to be used, use 8 bolts as shown.

2. *Web leg:*
   Single shear value of $\frac{7}{8}$" diam. A502 Gr 1 rivets from shear allowable load tables = 9.02 kips.

   Bearing value of $\frac{7}{8}$" diam. rivet in 0.358" thick web, from bearing allowable load tables = 0.358 × 42.5 = 15.2 kips.

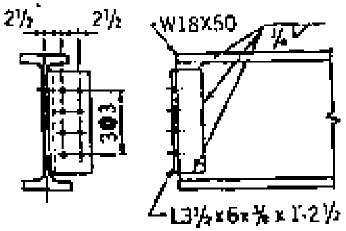
   Single shear at 9.02 kips governs, requiring 50/9.02 = 5.54 rivets.

   Use: 8 rivets arranged in pattern dictated by outstanding leg.

3. *Angle size:* Try 6 × 6 × $\frac{3}{8}$ × 11½" angle. Allowable load = 11.5 × $\frac{3}{8}$ × 14.5 = 62.5 > 50 kips o.k. Use: 6 × 6 × $\frac{3}{8}$ × 11½" angle.

EXAMPLE 2

Given: Same as Example 1 except weld the web leg of the connection.



Solution:

1. *Outstanding leg:* Same as Example 1.
2. *Web leg:* The required weld may be determined from Framed Beam Connections, Welded, E70XX electrodes, Table III, page 4 - 31.

Since the capacities shown in Table III are for two angles, it will be convenient to double the given reaction and select weld sizes directly from the tables, and angle lengths directly or by interpolation.

Since R = 50 kips, the tabular capacity needed is 100 kips.

From Table III, which covers F_y = 36 ksi connections and E70XX electrodes, the capacity of Weld A at ¼ in. on a 1'-2½" angle is 102 kips.

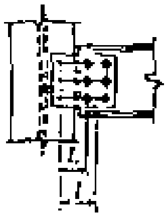
Check beam web thickness: 0.358 > 0.41/2 o.k.

∴ Use: E70XX ¼ in. weld (as shown).

3. *Angle size:* Use 6" for outstanding leg and 3½" for web leg. The required thickness of $\frac{3}{8}$" for the web leg is the same as required for the outstanding leg and will accept the ¼ in. weld.
   Use: 6 × 3½ × $\frac{3}{8}$ × 1'-2½" angle.

ECCENTRIC CONNECTIONS

BEAM TO COLUMN CONNECTION To avoid moment in the column full eccentricity in the fasteners connecting plate to beam should be figured. Lever arm l should be used. A coefficient for this fastener group, for ordinary cases, can be found in the tables on pages 4 - 62 to 4 - 65.



Field fasteners connecting plate to column should be used (least number) if beam can be erected and if there are no interfering details in the web of the column. The plate should figure for a moment with lever arm l_1. See page 4 - 79 for table of Net Section Moduli of Bracket Plates.

SYMMETRICAL BEAM TO COLUMN CONNECTIONS A single plate across the column may be used. If the reactions of the two beams are equal there is no eccentricity to figure on either beams or columns. The case of live load on one beam only must, however, be considered. Where for this or other reason the beam reactions are unequal, figure the fasteners in the column for the sum of the reactions and the difference of the moments, taken to the center of the connection. See page 4 - 60.

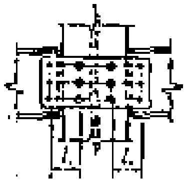
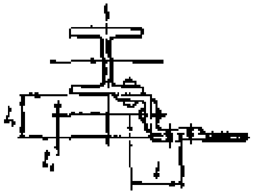


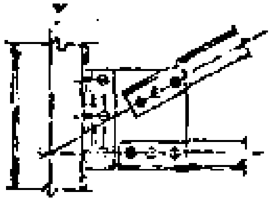
Plate should figure for greater moment with lever arm l_1. See page 4 - 79 for table of Net Section Moduli of Bracket Plates.

ZEE CONNECTIONS In general use for light loads only. Eccentricity in fasteners connecting connection angle to the beam should be figured, using the lever arm l. Eccentricity in fasteners connecting connection angle to column, with a lever arm of l_1, should be figured. The thickness of the angle should be ample to resist the bending moment. See page 4 - 80.



Eccentricity in fasteners connecting the two connection angles should be figured if the lever arm l_1 is 2½″ or more. The connection should be designed so field work is at a minimum. There can be many variations of this type of connection depending on the length of l_1. The eccentricity should be considered in all cases.

TRUSS CONNECTION

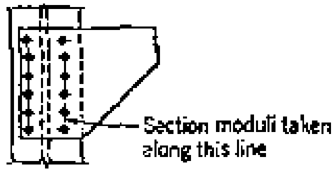


The intersection of the working lines should be located to hold the effect of moment on connection and column to a minimum.

BRACKET PLATES

Net Section Moduli

Diameter of holes assumed ⅛ in. larger than nominal diameter of fastener



Fasteners spaced 3 in. vertically

No. of Fasteners in One Vertical Line	Depth of Plate in Inches	¾ in. Fasteners					⅞ in. Fasteners					1 in. Fasteners				
		Thickness of Plate, In.					Thickness of Plate, In.					Thickness of Plate, In.				
		¼	⅜	½	⅝	¾	⅜	½	⅝	¾	⅞	½	⅝	¾	⅞	1
2	6	1.2	1.8	2.3	2.9	3.5	1.7	2.3	2.9	3.4	4.0	2.2	2.7	3.2	3.8	4.3
3	9	2.5	3.8	5.0	6.3	7.5	3.6	4.8	5.9	7.1	8.3	4.5	5.6	6.8	7.9	9.0
4	12	4.4	6.3	8.7	11	13	6.2	8.2	10	12	14	7.8	9.7	12	14	16
5	15	6.8	10	14	17	20	10	13	16	19	22	12	15	18	21	24
6	18	9.6	15	19	24	29	14	18	23	27	32	17	21	26	30	34
7	21	13	20	26	33	39	19	25	31	37	43	23	29	35	41	47
8	24	17	26	34	43	51	24	32	40	48	56	30	38	45	53	61
9	27	22	32	43	54	65	31	41	51	61	71	38	48	57	67	77
10	30	27	40	53	67	80	38	50	63	75	88	47	59	71	83	94
12	36	38	58	77	96	115	54	72	90	108	126	68	85	102	119	136
14	42	52	78	104	130	157	74	98	123	147	172	92	115	138	161	184
16	48	68	102	136	170	204	96	128	160	192	224	120	150	180	211	241
18	54	86	129	172	215	259	122	162	203	243	284	152	190	228	266	304
20	60	106	160	213	266	319	150	200	250	300	350	188	235	282	329	376
22	66	129	193	257	322	386	182	242	303	363	424	227	284	341	398	454
24	72	153	230	306	383	459	216	288	360	432	504	270	338	406	473	541
26	78	180	270	359	449	539	254	338	423	507	592	317	397	476	555	634
28	84	208	313	417	521	625	294	392	490	588	686	368	460	552	644	736
30	90	240	359	478	596	718	338	450	563	675	788	427	528	633	739	845
32	96	272	408	544	680	816	384	512	640	768	896	480	600	721	841	961
34	102	308	461	614	768	922	434	578	723	867	1012	542	678	813	949	1085
36	108	344	517	689	861	1033	486	648	810	972	1134	608	760	912	1064	1216

Interpolate for intermediate thickness of plates.

General equation for net section modulus of bracket plates:

$$S_{net} = \frac{t_p d^2}{6} - \frac{b^2 n(n^2 - 1)[t_p \times (\text{Bolt Diam.} + 0.125)]}{6d}$$

where

t_p = Plate thickness, inches
d = Plate depth, inches
n = Number of fasteners in one vertical row
b = Fastener spacing vertically, inches

HANGER TYPE CONNECTIONS

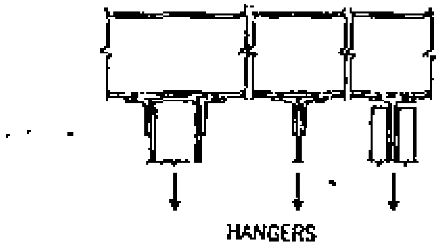
Fasteners loaded in tension

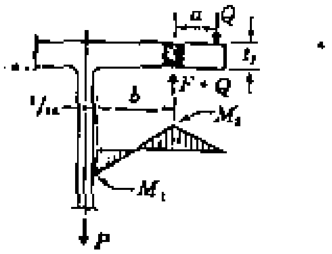
In the design of hanger type connections, prying action must be considered. It will usually increase the tension in the fasteners transmitting tension force through the flange of a tee or the outstanding leg of angles and it will introduce additional bending stresses in the steel fitting.

The following table is useful for making a rapid selection of a trial fitting using $F_y = 36$ ksi. The fitting must then be checked for bending stresses due to prying force Q and possible increase in size.

STRUCTURAL TEE OR DOUBLE ANGLE HANGERS

Loads in kips per linear inch for trial section





b In.	Thickness of angle or flange of tee, t_f, inches															
	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/16	1 1/8	1 3/16	1 1/4
1	1.76	2.53	3.45	4.50	5.70	7.03	8.51	10.13	11.88	13.78	15.82	18.00	20.32	22.78	25.38	28.13
1¼	1.41	2.03	2.76	3.60	4.56	5.63	6.81	8.10	9.51	11.03	12.66	14.40	16.26	18.23	20.31	22.50
1½	1.17	1.69	2.30	3.00	3.80	4.69	5.67	6.75	7.92	9.19	10.55	12.00	13.55	15.19	16.92	18.75
1¾	1.00	1.45	1.97	2.57	3.25	4.02	4.86	5.79	6.79	7.88	9.04	10.29	11.61	13.02	14.50	16.07
2	0.88	1.27	1.72	2.25	2.85	3.52	4.25	5.06	5.94	6.89	7.91	9.00	10.16	11.39	12.69	14.06
2¼	0.78	1.13	1.53	2.00	2.53	3.13	3.78	4.50	5.28	6.13	7.03	8.00	9.03	10.13	11.28	12.50
2½	0.70	1.01	1.38	1.80	2.28	2.81	3.40	4.05	4.75	5.51	6.33	7.20	8.13	9.11	10.15	11.25
2¾	0.64	0.92	1.25	1.64	2.07	2.56	3.09	3.68	4.32	5.01	5.75	6.55	7.39	8.28	9.23	10.23
3	0.59	0.84	1.15	1.50	1.90	2.34	2.84	3.38	3.96	4.59	5.27	6.00	6.77	7.59	8.46	9.38
3¼	0.54	0.78	1.06	1.38	1.75	2.16	2.62	3.12	3.66	4.24	4.87	5.54	6.25	7.01	7.81	8.65

For the above table, the points of critical moment are assumed at the fastener line and at a point one-sixteenth of an inch from the near face of the outstanding leg of the angle or tee.

$$M = \frac{P}{2} \times \frac{b}{2} = \frac{27t_f^2}{6};\quad P = \frac{18t_f^2}{b}$$

where

P = Allowable load on two angles or structural tee, in kips per linear inch, using maximum allowable bending stress of 27.0 ksi

b = Distance from fastener line to near face of outstanding leg of angle or structural tee less 1/16" ($b/2$ is the lever arm used to determine the assumed moment)

t_f = Thickness of angle or flange of tee

The table is based upon the simplifying approximation that the moments M_1 and M_2 are equal in magnitude and opposite in direction; that the geometry of the fittings is such that $a \cong b/2$; and that the prying force, Q, therefore, is equal to F, the applied force per fastener. A tentative selection of required fitting thickness can be made from the values tabulated, and a fastener size assumed. The corresponding prying force, Q, can then be determined for connections assembled with high strength bolts, and any necessary adjustment made in fitting thickness to satisfy the calculated prying force.

In the case of connections assembled with rivets or A307 bolts, for which formulas similar to those for high strength bolts are not available, an assumed value of Q equal to $F/2$ will generally provide a conservative design.

PRYING ACTION

Precise evaluation of the prying effect in a given connection involves complex analysis. Research* on test joints reported to date (1969) has resulted in the following empirical formulas:

For connections using A325 bolts:

$$Q = F\left[\frac{100b(d_b)^2 - 18w(t_f)^2}{70a(d_b)^2 + 21w(t_f)^2}\right]$$

For connections using A490 bolts:

$$Q = F\left[\frac{100b(d_b)^2 - 14w(t_f)^2}{62a(d_b)^2 + 21w(t_f)^2}\right]$$

where

Q = Prying force per fastener, kips
F = Externally applied load per fastener = $wP/2$, kips
w = Length of flange tributary to each bolt, in.
d_b = Nominal bolt diameter, in.
a = Distance from fastener line to edge of flange, not to exceed $2t_f$, in.

The adequacy of the fasteners must be checked against the total tension due to external loading and prying action. The adequacy of the fitting flange must be checked against the bending stress due to the prying action moment, and the adequacy of the tee stem or outstanding angle leg must be checked against the tensile stress due to external loading P.

EXAMPLE

Select a tee-section hanger using A36 steel and fasteners to support 44 kips suspended from bottom flange of a W36 × 160.

Given:

Fasteners to be located on 4" beam gage
Fitting length: 9"
Fasteners: Four A325 bolts

Solution:

1. *Trial section:*

44/9 = 4.9 kips per lin. inch of fitting

---

* *Behavior of Bolts in Tee-Connections Subject to Prying Action* Structural Research Series No. 353, University of Illinois, Sept. 1969.

Distance b is estimated at $1\frac{3}{4}''$ on the basis of a age. From hanger table, on the $b = 1\frac{3}{4}''$ line and in the $\frac{3}{4}''$ t_f n, the next larger P value is 5.79 kips per lin. in. Therefore, try a 9" length of tee cut from W18×70; $t_f = 0.751''$

Note that t_f for supporting member is $1.02 > 0.751''$.

2. *Trial fasteners:*

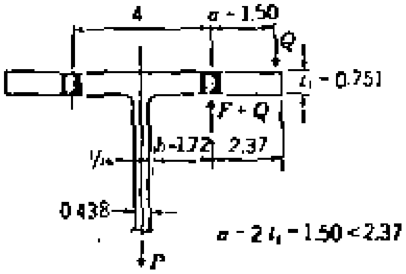
External load per bolt: $F = 44/4 = 11.0$ kips (assuming 4 bolts)

Try prying ratio Q/F of 0.5; then $Q = 5.5$ kips

Total trial load per bolt $= 11.0 + 5.5 = 16.5$ kips

Allowable tensile load per bolt, $\frac{3}{4}''$ diam. A325 $= 17.67$ kips

3. *Compute Q:*



$$Q = F\left[\frac{100b(d_b)^2 - 18w(t_f)^2}{70a(d_b)^2 + 21w(t_f)^2}\right]$$

$$= F\left[\frac{100 \times 1.72 \times (\frac{3}{4})^2 - 18 \times 4.5 \times (0.751)^2}{70 \times 1.50 \times (\frac{3}{4})^2 + 21 \times 4.5(0.751)^2}\right]$$

$$= 0.455\ F$$

Since $F = \dfrac{wP}{2}$,

$$Q = \frac{0.455 \times 4.5 \times 4.9}{2} = 5.0 \text{ kips}$$

4. *Check fastener load:*

Total tension on $\frac{3}{4}''$ diam. A325 $= F + Q = 11.0 + 5.0 = 16.0$ kips

Allowable tensile load $= 17.67$ kips, ∴ bolts are o.k.

Check bending strength of flange:

Moment $M_1 = Qa = 5.0 \times 1.50 = 7.5$ kip-in.

Moment $M_1 = (F + Q)b - Q(a + b)$
$= 16.0 \times 1.72 - 5.0 \times 3.22$
$= 27.5 - 16.1 = 11.4$ kip-in. (governs)

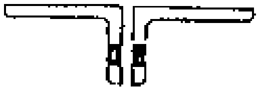
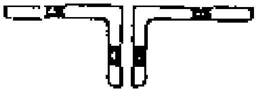
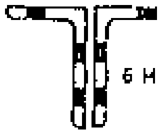
$$f_b = \frac{11.4}{\dfrac{4.5 \times (0.751)^2}{6}} = 27.0 \text{ ksi} = \text{allowable } 27.0 \text{ ksi}$$

tee cut from W18×70, 9" long, is o.k.

Notes

TENSION MEMBERS

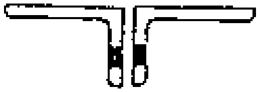
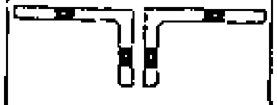
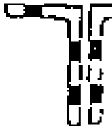
Net Areas

Angle Designation	TWO ANGLES—NET AREA											
	 2 Holes out				 4 Holes out				 6 Holes out			
	Fastener Diam., In.				Fastener Diam., In.				Fastener Diam., In.			
	¾	⅞	1	1⅛	¾	⅞	1	1⅛	¾	⅞	1	1⅛
L 9 × 4 × 1	22.3	22.0	21.8	21.5	20.5	20.0	19.5	19.0	18.8	18.0	17.3	16.5
⅞	19.7	19.5	19.3	19.0	18.2	17.7	17.3	16.8	16.6	16.0	15.3	14.7
¾	17.1	16.9	16.7	16.5	15.8	15.4	15.0	14.6	14.4	13.9	13.3	12.8
⅝	14.4	14.2	14.1	13.9	13.3	13.0	12.7	12.3	12.2	11.7	11.2	10.8
9/16	13.0	12.9	12.7	12.6	12.0	11.8	11.5	11.2	11.1	10.6	10.2	9.78
½	11.6	11.5	11.4	11.3	10.8	10.5	10.3	10.0	9.88	9.50	9.12	8.75
L 8 × 8 × 1⅛	31.5	31.2	30.9	30.7	29.5	29.0	28.4	27.8	27.6	26.7	25.9	25.0
1	28.3	28.0	27.8	27.5	26.5	26.0	25.5	25.0	24.8	24.0	23.3	22.5
⅞	24.9	24.7	24.5	24.3	23.4	23.0	22.5	22.1	21.9	21.2	20.6	19.9
¾	21.6	21.4	21.2	21.0	20.3	19.9	19.5	19.1	18.9	18.4	17.8	17.3
⅝	18.1	18.0	17.8	17.7	17.0	16.7	16.4	16.1	15.9	15.5	15.0	14.5
9/16	16.4	16.2	16.1	16.0	15.4	15.1	14.8	14.6	14.4	14.0	13.6	13.2
½	14.6	14.5	14.4	14.3	13.8	13.5	13.3	13.0	12.9	12.5	12.1	11.8
L 8 × 6 × 1	24.3	24.0	23.8	23.5	22.5	22.0	21.5	21.0	20.8	20.0	19.3	18.5
⅞	21.4	21.2	21.0	20.8	19.9	19.5	19.0	18.6	18.4	17.7	17.1	16.4
¾	18.6	18.4	18.2	18.0	17.3	16.9	16.5	16.1	15.9	15.4	14.8	14.3
⅝	15.6	15.5	15.3	15.2	14.5	14.2	13.9	13.6	13.4	13.0	12.5	12.0
9/16	14.1	14.0	13.9	13.7	13.2	12.9	12.6	12.3	12.2	11.8	11.3	10.9
½	12.6	12.5	12.4	12.3	11.8	11.5	11.3	11.0	10.9	10.5	10.1	9.75
7/16	11.1	11.0	10.9	10.8	10.3	10.1	9.89	9.67	9.56	9.24	8.91	8.58
L 8 × 4 × 1	20.3	20.0	19.8	19.5	18.5	18.0	17.5	17.0	16.8	16.0	15.3	14.5
⅞	17.9	17.7	17.5	17.3	16.4	16.0	15.5	15.1	14.9	14.2	13.6	12.9
¾	15.6	15.4	15.2	15.0	14.3	13.9	13.5	13.1	12.9	12.4	11.8	11.3
⅝	13.1	13.0	12.8	12.7	12.0	11.7	11.4	11.1	10.9	10.5	10.0	9.53
9/16	11.9	11.7	11.6	11.5	10.9	10.6	10.3	10.1	9.90	9.50	9.09	8.64
½	10.6	10.5	10.4	10.3	9.75	9.50	9.25	9.00	8.87	8.50	8.13	7.75
7/16	9.35	9.24	9.14	9.03	8.59	8.37	8.15	7.93	7.83	7.50	7.18	6.84
L 7 × 4 × ⅞	16.2	16.0	15.8	15.5	14.7	14.2	13.8	13.3	13.1	12.5	—	—
¾	14.1	13.9	13.7	13.5	12.8	12.4	12.0	11.6	11.4	10.9	—	—
⅝	11.9	11.7	11.6	11.4	10.8	10.5	10.2	9.84	9.70	9.23	—	—
9/16	10.8	10.6	10.5	10.3	9.77	9.49	9.21	8.93	8.78	8.38	—	—
½	9.62	9.50	9.37	9.25	8.75	8.50	8.25	8.00	7.87	7.50	—	—
7/16	8.47	8.36	8.26	8.15	7.71	7.49	7.27	7.06	6.95	6.62	—	—
⅜	7.32	7.23	7.14	7.04	6.67	6.48	6.27	6.08	6.01	5.73	—	—
L 6 × 6 × 1	20.3	20.0	19.8	19.5	18.5	18.0	17.5	17.0	16.8	16.0	—	—
⅞	17.9	17.7	17.5	17.3	16.4	16.0	15.5	15.1	14.9	14.2	—	—
¾	15.6	15.4	15.2	15.0	14.3	13.9	13.5	13.1	12.9	12.4	—	—
⅝	13.1	13.0	12.8	12.7	12.0	11.7	11.4	11.1	10.9	10.5	—	—
9/16	11.9	11.7	11.6	11.5	10.9	10.6	10.3	10.1	9.91	9.49	—	—
½	10.6	10.5	10.4	10.3	9.75	9.50	9.25	9.00	8.87	8.50	—	—
7/16	9.35	9.24	9.14	9.03	8.59	8.37	8.15	7.93	7.82	7.50	—	—
⅜	8.06	7.97	7.88	7.78	7.41	7.22	7.03	6.84	6.75	6.47	—	—

Net areas are computed in accordance with AISC Specification, Section 1.14.5.

TENSION MEMBERS

Net Areas

Angle Designation	TWO ANGLES—NET AREA											
	 2 Holes out				 4 Holes out				 6 Holes out			
	Fastener Diam., In.				Fastener Diam., In.				Fastener Diam., In.			
	¾	⅞	1	1⅛	¾	⅞	1	1⅛	¾	⅞	1	1⅛
L 6 × 4 × ⅞	14.4	14.2	14.0	13.8	12.9	12.5	12.0	11.6	11.4	—	—	—
¾	12.6	12.4	12.2	12.0	11.3	10.9	10.5	10.1	9.94	—	—	—
⅝	10.6	10.5	10.3	10.2	9.53	9.22	8.91	8.60	8.44	—	—	—
9/16	9.64	9.49	9.35	9.21	8.65	8.37	8.09	7.81	7.67	—	—	—
½	8.62	8.50	8.37	8.25	7.75	7.50	7.25	7.00	6.88	—	—	—
7/16	7.59	7.48	7.38	7.27	6.83	6.61	6.39	6.17	6.06	—	—	—
⅜	6.56	6.47	6.38	6.28	5.91	5.72	5.53	5.34	5.25	—	—	—
L 5 × 5 × ⅞	14.4	14.2	14.0	13.8	12.9	12.5	12.0	11.6	—	—	—	—
¾	12.6	12.4	12.2	12.0	11.3	10.9	10.5	10.1	—	—	—	—
⅝	10.6	10.5	10.3	10.2	9.53	9.22	8.91	8.59	—	—	—	—
½	8.62	8.50	8.37	8.25	7.75	7.50	7.25	7.00	—	—	—	—
7/16	7.59	7.48	7.38	7.27	6.83	6.61	6.39	6.17	—	—	—	—
⅜	6.56	6.47	6.38	6.28	5.91	5.72	5.53	5.34	—	—	—	—
L 6 × 3½ × ½	8.12	8.00	7.87	—	7.25	7.00	—	—	6.38	—	—	—
⅜	6.18	6.09	6.00	—	5.53	5.34	—	—	4.87	—	—	—
5/16	5.19	5.11	5.04	—	4.65	4.49	—	—	4.10	—	—	—
L 5 × 3½ × ¾	10.3	10.1	9.93	—	8.99	8.62	—	—	—	—	—	—
⅝	8.75	8.59	8.43	—	7.65	7.34	—	—	—	—	—	—
½	7.12	7.00	6.87	—	6.25	6.00	—	—	—	—	—	—
7/16	6.29	6.18	6.08	—	5.53	5.31	—	—	—	—	—	—
⅜	5.44	5.35	5.25	—	4.79	4.60	—	—	—	—	—	—
5/16	4.57	4.49	4.42	—	4.03	3.87	—	—	—	—	—	—
L 5 × 3 × ½	6.62	6.50	—	—	5.75	5.50	—	—	—	—	—	—
⅜	5.06	4.97	—	—	4.41	4.22	—	—	—	—	—	—
5/16	4.25	4.17	—	—	3.71	3.55	—	—	—	—	—	—
L 4 × 4 × ¾	9.57	9.38	9.19	9.00	8.26	7.88	—	—	—	—	—	—
⅝	8.13	7.97	7.81	7.66	7.03	6.72	—	—	—	—	—	—
½	6.62	6.50	6.37	6.25	5.75	5.50	—	—	—	—	—	—
7/16	5.85	5.74	5.64	5.53	5.09	4.87	—	—	—	—	—	—
⅜	5.06	4.97	4.88	4.78	4.41	4.22	—	—	—	—	—	—
5/16	4.25	4.17	4.10	4.02	3.71	3.55	—	—	—	—	—	—
L 4 × 3½ × ⅝	7.51	7.35	7.19	—	6.42	6.10	—	—	—	—	—	—
½	6.12	6.00	5.87	—	5.25	5.00	—	—	—	—	—	—
7/16	5.41	5.30	5.20	—	4.65	4.43	—	—	—	—	—	—
⅜	4.68	4.59	4.50	—	4.03	3.84	—	—	—	—	—	—
5/16	3.95	3.87	3.80	—	3.41	3.25	—	—	—	—	—	—
L 4 × 3 × ⅝	6.87	6.71	—	—	5.77	5.46	—	—	—	—	—	—
½	5.62	5.50	—	—	4.75	4.50	—	—	—	—	—	—
7/16	4.97	4.86	—	—	4.21	3.99	—	—	—	—	—	—
⅜	4.30	4.21	—	—	3.65	3.45	—	—	—	—	—	—
5/16	3.63	3.56	—	—	3.09	2.93	—	—	—	—	—	—
¼	2.94	2.88	—	—	2.50	2.38	—	—	—	—	—	—

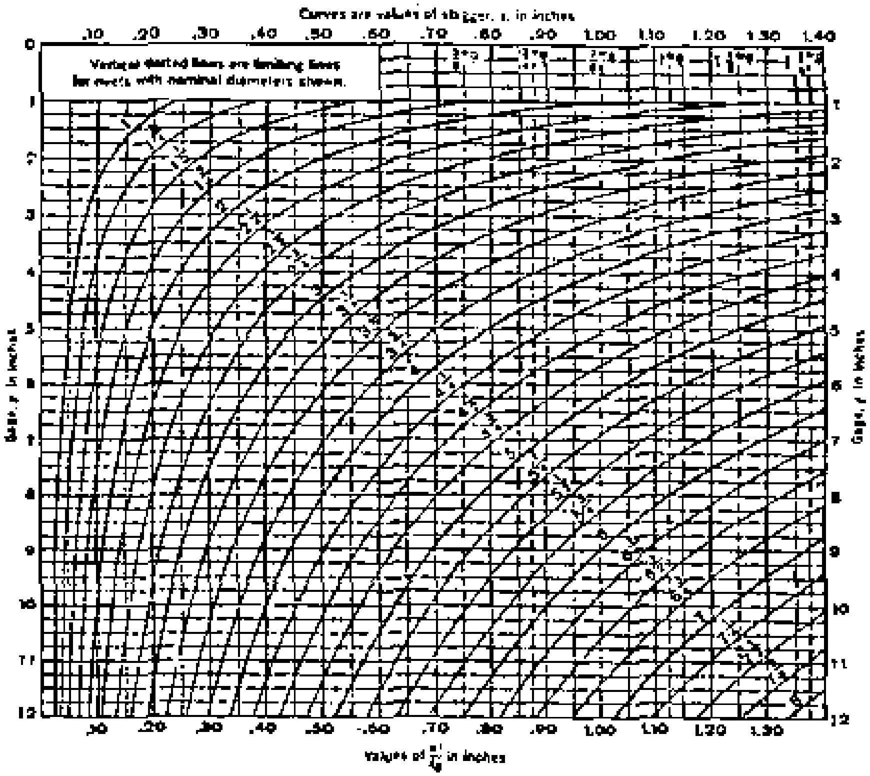
Net areas are computed in accordance with AISC Specification, Section 1.14.5.

REDUCTION OF AREA FOR BOLT AND RIVET HOLES

Area in square inches = assumed diameter of hole by thickness of metal. For computation purposes holes shall be taken as the nominal diameter of fastener plus 1/8 inch

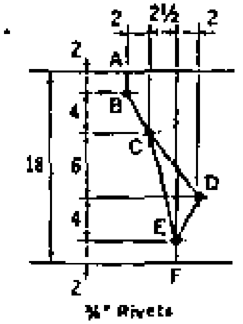
Thickness of Metal Inches	Diameter of Hole, Inches					
	3/4	7/8	1	1 1/8	1 1/4	1 3/8
3/16	.141	.164	.188	.211	.234	.258
1/4	.188	.219	.250	.281	.313	.344
5/16	.234	.273	.313	.352	.391	.430
3/8	.281	.328	.375	.422	.469	.516
7/16	.328	.383	.438	.492	.547	.602
1/2	.375	.438	.500	.563	.625	.688
9/16	.422	.492	.563	.633	.703	.773
5/8	.469	.547	.625	.703	.781	.859
11/16	.516	.602	.688	.773	.859	.945
3/4	.563	.656	.750	.844	.938	1.031
13/16	.609	.711	.813	.914	1.016	1.117
7/8	.656	.766	.875	.984	1.094	1.203
15/16	.703	.820	.938	1.055	1.172	1.289
1	.750	.875	1.000	1.125	1.250	1.375
1/16	.797	.930	1.063	1.195	1.328	1.461
1/8	.844	.984	1.125	1.266	1.406	1.547
3/16	.891	1.039	1.188	1.336	1.484	1.633
1/4	.938	1.094	1.250	1.406	1.563	1.719
5/16	.984	1.148	1.313	1.477	1.641	1.805
3/8	1.031	1.203	1.375	1.547	1.719	1.891
7/16	1.078	1.258	1.438	1.617	1.797	1.977
1/2	1.125	1.313	1.500	1.688	1.875	2.063
9/16	1.172	1.367	1.563	1.758	1.953	2.148
5/8	1.219	1.422	1.625	1.828	2.031	2.234
11/16	1.266	1.477	1.688	1.898	2.109	2.320
3/4	1.313	1.531	1.750	1.969	2.188	2.406
13/16	...	1.586	1.813	2.039	2.266	2.492
7/8	...	1.641	1.875	2.109	2.344	2.578
15/16	...	1.695	1.938	2.180	2.422	2.664
2	...	1.750	2.000	2.250	2.500	2.750
1/16	...	1.805	2.063	2.320	2.578	2.836
1/8	...	1.859	2.125	2.391	2.656	2.922
3/16	...	1.914	2.188	2.461	2.734	3.008
1/4	...	1.969	2.250	2.531	2.813	3.094
5/16	...	2.023	2.313	2.602	2.891	3.180
3/8	...	2.078	2.375	2.672	2.969	3.256
7/16	...	2.133	2.438	2.742	3.047	3.352
1/2	...	2.188	2.500	2.813	3.125	3.438
5/8	...	2.297	2.625	2.953	3.281	3.609
3/4	...	2.406	2.750	3.094	3.438	3.781
7/8	...	2.516	2.875	3.234	3.594	3.953
3	...	2.625	3.000	3.375	3.750	4.125

NET SECTION OF TENSION MEMBERS



The above chart will simplify the application of the rule for net width, Sections 1.14.3 and 1.14 of the AISC Specification. Entering the chart at left or right with the gage g and proceeding horizontally to intersection with the curve for the pitch s, thence vertically to top or bottom, the value of $s^2/4g$ may be read directly.

Step 1 of the example below illustrates the application of the rule and the use of the chart, Step 2 illustrates the application of the 85% of gross area limitation.



3/4" Rivets

Step 1: Chain A B C E F
Deduct for 3 holes @ (3/4 + 1/8) = −2.625
BC, $g = 4$, $s = 2$; add $s^2/4g$ = +0.25
CE, $g = 10$, $s = 2½$; add $s^2/4g$ = +0.16
Total Deduction = −2.215"
Chain A B C D E F
Deduct for 4 holes @ (3/4 + 1/8) = −3.50
BC, as above, add = +0.25
CD, $g = 6$, $s = 4½$; add $s^2/4g$ = +0.85
DE, $g = 4$, $s = 2$; add $s^2/4g$ = +0.25
Total Deduction = −2.15"
Net Width = 18.0 − 2.215 = 15.785".

Step 2: Net width = 18.0 × 0.85 = 15.3"
(Governs in this example)

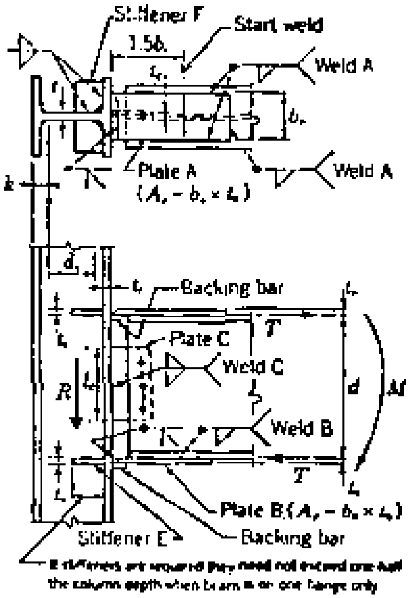
In comparing the path CDE with the path CE, it is seen that if the sum of the two values of $s^2/4g$ for CD and DE exceed the single value of $s^2/4g$ for CE, by more than the deduction for one hole, then the path CDE is not critical as compared with CE.

Evidently if the value of $s^2/4g$ for one leg CD of the path CDE is greater than the deduction for one hole, the path CDE cannot be critical as compared with CE. The vertical dotted lines in the chart serve to indicate, for the respective rivet diameters noted at the top thereof, that any value of $s^2/4g$ to the right of such line is derived from a non-critical chain which need not be further considered.

MOMENT CONNECTIONS

Welded

Many connections in Type 3 "semi-rigid framing" must be designed to develop specified resisting moments. The following method is recommended for design of such a connection subjected to gravity loading.



M = Connection moment, kip-ft.
R = End reaction of beam, kips
r_v = Allowable shear or bearing value for one fastener, kips
F_{vp} = Allowable shear in plate, ksi
F_{vw} = Allowable shear in welds, ksi
F_t = Allowable tension stress in plates and groove weld, ksi
D = Number of $\frac{1}{16}$ inches in weld size
$0.928D$ = Value of E70XX weld per lineal inch of filet weld, kips
T = Horizontal force top and bottom of beam, kips
A_p = Area of plate, top or bottom
A_{st} = Area of stiffeners
A_{wc} = Planar area of web at beam-to-column connection
C_1 = Ratio of beam flange yield stress to column yield stress
C_2 = Ratio of column yield stress to stiffener yield stress.

The moment is assumed to be resisted by plates "A" and "B" welded to the top and bottom of beam and to the column. The shear is assumed to be transferred to the column by a vertical side plate, using fasteners in the beam web and shop welds on the column. A length of the top plate, equal to 1.5 times the width b_A, is kept free of weld to allow the elongation under load that is necessary to obtain the desired semi-rigid connection action.

AISC Specification Reference

1. Determine horizontal force $T = \frac{M \times 12}{d}$
2. Design top plate A: determine length and size of weld A.

$$A_p = \frac{T}{F_t}$$

Length of weld $= \frac{T}{0.928D}$ (for E70XX electrodes)

3. Select bottom plate B and determine length and size of weld B. Area plate B should be ≥ area plate A.
4. Determine number of fasteners in vertical plate C and weld between plate and column.

AISC Specification Reference

No. of fasteners $= \frac{R}{r_v}$; select l_c and assume weld full length.

Min. $t_c = \frac{R}{F_{vp} \times l_c}$

Min. $D = \frac{R}{2 \times 0.928 \times l_c}$ (E70XX electrodes, welded full length both sides)

If intermittent or less than full length welds are used, min. t_c and min. D must be adjusted to satisfy Specification Sects. 1.5.3 and 1.17.6

5. Investigate column web shear. 1.5.1.2

Column web reinforcement required if

$$t_w < \frac{32M}{A_{wc}F_y}$$

Commentary 1.5.1.2

6. Check column for web crippling. Column web stiffeners are required: 1.15.5

At compression flange if $t < \frac{C_1 A_f}{t_b + 5k}$ or when $t \leqslant \frac{d_c\sqrt{F_y}}{180}$ Formulas (1.15-1) and (1.15-2)

At tension flange if $t_f < 0.4\sqrt{C_1 A_f}$ Formula (1.15-3)

If required, bearing area of stiffeners

$$A_{st} \geqslant [C_1 A_f - t(t_b + 5k)]C_2$$ Formula (1.15-4)

Check stiffener width-thickness ratio. 1.9.1.2

Fillet weld stiffener full length to column web.

Min. $D = \frac{(t \text{ or } t_s)F_{vs}}{2 \times 0.928}$ (E70XX electrodes)

Total length of weld against column tension flange.

$$l = \frac{A_{st}F_y}{0.928D \times 1.65}$$

EXAMPLE

Given: Design a semi-rigid connection for a W18×50 (t = 0.358) framed to one side of a W10×49 column (t = 0.340; k = 1.12). The end moment is 100 kip-ft. and end reaction is 26 kips. Beam and connection material are F_y = 36 ksi steel with F_t = 22.0 ksi. The column is F_y = 50 ksi steel. Use ASTM A325 bolts in a bearing type connection and E70XX electrodes, with 0.928D value per lineal inch of weld. Stiffeners, if required, be F_y = 36 ksi steel.

AISC Specification Reference

1. $T = \dfrac{100 \times 12}{18} = 66.7$ kips

2. $A_p = \dfrac{66.7}{22.0} = 3.03$ in.^{2}

   Use: ½ × 6" for top Plate A with 5⁄16 in. Weld A.

   $l = \dfrac{66.7}{5 \times 0.928} = 14.4"$

   Use: 6" across end and 4½" each side.

3. Use: ⅜ × 9" for bottom Plate B.

   $A_p = 3.38 > 3.03$ in.^{2}

   Use: 5⁄16 in. Weld B; 7½" each side.

4. Try ¾" diam. A325 bolts in a bearing type connection, with threads excluded from shear planes.

   Bearing on web $r_p = 0.358 \times 0.75 \times 48.6 = 13.1$ kips
   Single shear $r_v = 9.72$ kips (governs). See pg. 4-4.

   1.5.2 and Appendix A (1.5.2)

   No. of bolts $= \dfrac{26}{9.72} = 2.67$

   Use: Three bolts and 8½" long vertical Plate C.

   Min. $t_c = \dfrac{26}{14.5 \times 8.5} = 0.21"$; try ¼ × 4 × 8½" plate.

   Bearing on plate $= \dfrac{26}{3 \times 0.25 \times 0.75}$
   $= 46.3 < 48.6$ ksi o.k.

   $t_f = 0.558"$ for W10 × 49; min. weld size is ¼ in.

   1.17.5

   Minimum length of weld to avoid overstressing base metal of plate:

   $l = \dfrac{26}{0.25 \times 14.5} = 7.2 < 8.5"$ o.k.

   Min. $D = \dfrac{26}{2 \times 0.928 \times 8.5} = 1.65 < 4$ o.k.

   Use: ¼ × 4 × 8½" plate with ¼ in. Weld C for full length each side.

5. Investigate column web shear.

   1.5.1.2 and Commentary 1.5.1.2

   $A_{bc} = (18.00 + \tfrac{1}{2} + \tfrac{3}{8})(10.00) = 189$ in.^{2}

   $\dfrac{32M}{A_{bc}F_y} = \dfrac{32 \times 100}{189 \times 50} = 0.339 < t_w = 0.34$

   ∴ Column web need not be reinforced.

Specification Reference

6. Stiffener E (compression flange):

   1.15.5

   $C_1 = \dfrac{36}{50} = 0.72$

   $\dfrac{0.72 \times 3.03}{0.375 + (5 \times 1.12)} = 0.365 > t = 0.34"$

   Formula (1.15-1)

   ∴ Stiffeners required.

   Stiffener F (tension flange):

   Formula (1.15-3)

   $0.4\sqrt{0.72 \times 3.03} = 0.59 > t_f = 0.558"$

   ∴ Stiffeners required.

   $C_2 = \dfrac{50}{36} = 1.39$

   $A_{st} = [0.72\,(3.03) - 0.34\,(0.375 + 5 \times 1.12)]\,1.39$
   $= 0.21$ in.^{2} or 0.105 in.^{2} per stiffener

   Formula (1.15-4)

As a practical solution stiffeners requiring such small area may be omitted. However, if stiffeners are demanded:

Assume total stiffener width $b = 6"$.

Try: 3" wide stiffeners, with clipped corners and 2½" bearing width.

Min. $t_s = \dfrac{3.0}{15.8} = 0.19"$; use ¼ in.

Min. $D = \dfrac{\frac{1}{4} \times 14.5}{2 \times 0.928} = 1.95$

1.9.1.2 and Appendix A (1.9.1)

3⁄16 in. weld permissible at web of column; ¼ in. weld at column flange.

1.17.5

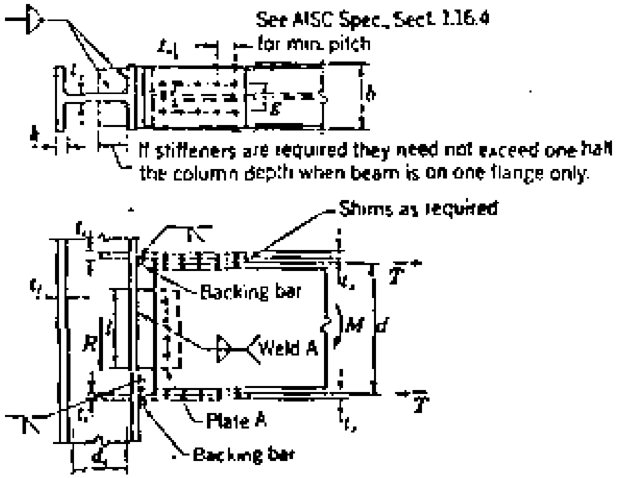
$l = \dfrac{0.21 \times 36}{0.928 \times 3 \times 1.65} = 1.64"$ total $= 0.82"$ per stiffener

(for ¼ in. weld, min. $l = 1.23"$)

Use: Two plates ¼ × 3 × 4½" at both tension and compression flanges with two 3⁄16 × 4" welds against column web and two ¼ × 2½" welds against column flange opposite beam tension flange.

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. 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. 1.10.1

2. Determine horizontal force $T = \frac{M \times 12}{d}$

3. Design flange plates: $A_p = \frac{T}{F_t}$;

$$b = \frac{A_p}{t_p} + \text{Diam. of fastener holes deducted}$$

4. Determine the number of fasteners required to develop the horizontal force in the flanges.

$$\text{No. of fasteners} = \frac{T}{r_v}$$

AISC Specification Reference

5. Determine number of fasteners in vertical plate A, size of weld, and size of plate.

$$\text{No. of fasteners} = \frac{R}{r_v}; \qquad \text{select } l$$

$$\text{Min. } t_A = \frac{R}{F_{vp} \times l}$$

Welds to be full length of plate and on both sides.

$$\text{Min. weld } D = \frac{R}{2 \times 0.928 \times l} \text{ (E70XX electrodes)}$$

6. Check column web shear. Commentary 1.5.1.2

Column web reinforcement required where

$$t_w < \frac{32M}{A_{bc}F_y}$$

7. Check column for web crippling. 1.16.5

Column web stiffeners are required:

At compression flange, if $t < \frac{C_1 A_p}{t_p + 5k}$ or $t \leqslant \frac{d_c\sqrt{F_y}}{180}$ Formulas (1.15-1 & -2)

At tension flange, if $t_f < 0.4\sqrt{C_1 A_p}$ Formula (1.15-3)

Determine area of stiffeners, if required: Formula (1.15-4)

$$A_{st} \geqslant [C_1 A_p - t(t_p + 5k)]C_1$$

Check width-thickness ratio. 1.9.1.2

For stiffener welds see Step 6 of example for "Moment Connections, Welded."

EXAMPLE

Given: Design a moment connection for a W18 × 55 beam framed to a W12 × 99 column. The design moment is 163 kip-ft. and the end reaction is 35 kips. All material is ASTM A36 steel with F_t = 22.0 ksi (for beam, F_b = 24.0 ksi). Use ASTM A325 bolts in a bearing type connection and E70XX electrodes.

1. $M = 163$ kip-ft.; $S_{req} = \frac{163 \times 12}{24.0} = 81.5 \text{ in.}^3$

Assuming ⅞" diam. A325 bolts in a bearing type connection, threads excluded from shear plane (2 rows):

A_f (gross) $= 7.532 \times 0.630 = 4.75 \text{ in.}^2$

$\therefore A_f$ (net) $= 4.75 - 2(0.875 + 0.125)(0.63) = 3.49 \text{ in.}^2$ 1.14.5

$$\frac{4.75 - 3.49}{4.75}(100) = 26.5\%$$ 1.10.1

$$\frac{-\ 15.0\%}{11.5\% \text{ excess}}$$

AISC Specification Reference

$$I\text{ (net)} = 891 - \left[2 \times 0.115 \times 4.75 \left(\frac{18.12 - 0.63}{2}\right)^2\right]$$ 1.10.1

$$= 807.5\text{ in.}^4$$

$$S\text{ (net)} = \frac{807.5}{9.06} = 89 > 81.5\text{ in.}^3\text{ o.k.}$$

2. $T = \dfrac{163(12)}{18.12} = 108$ kips

3. $F_t = 22$ ksi; $A_p = 108/22 = 4.9$ in.^{2} (net)

Try ⅞" plate thickness: $t_p = 0.875$ in.

$$b\text{ (gross)} = \frac{4.9}{0.875} + 2(0.875 + 0.125) = 7.6''$$ 1.14.5

Use: ⅞ × 8" flange plates.

4. Flange connection:

Bearing on beam flange $r_b = 0.63 \times 0.875 \times 48.6$
$= 26.8$ kips. See pg. 4-7.

Single shear $r_v = 13.23$ kips (governs). See pg. 4-6.

No. of bolts $= \dfrac{108}{13.23} = 8.2$ Use 10 bolts

5. Web connection:

Assume ⅞" diam. A325 bolts in a bearing type connection with threads in shear plane.

Try ¼" plate:

Bearing on ¼" plate $r_b = 10.6$ kips. See pg. 4-7.
Single shear $r_v = 9.02$ kips (governs). See pg. 4-6.

No. of bolts $= \dfrac{35}{9.02} = 3.88$ Use 4 bolts

At 3" pitch and 1½ in. edge distance, the plate length is 12 in.

Min. t_h for shear $= \dfrac{35}{14.5 \times 12} = 0.20 < 0.25''$ o.k.

Use: ¼ × 4 × 1′-0″ plate for web connection.

Weld A connecting web plate to column flange:

$t_f = 0.921''$ for W12 × 99; minimum weld size is $\frac{5}{16}$ in. 1.17.5

Weld plate full length on each side.

Min. $D = \dfrac{35}{2 \times 0.928 \times 12} = 1.57 < 5$ o.k.

Use: $\frac{5}{16}$ in. weld, full length, each side.

AISC Specification Reference

6. Column web shear:

$A_{bc} = [18.12 + (2 \times 0.875)] \times 12.75 = 253$ in.^{2} Commentary 1.5.1.2

$$\frac{32M}{A_{bc}F_y} = \frac{32 \times 163}{253 \times 36} = 0.573 < t = 0.582\text{ in.}$$

∴ Column web need not be reinforced.

7. Column web stiffeners: 1.15.5

Req'd. A_p(net) $= 4.9$ in.^{2} (See Step 3.)

At compression flange: $t = 0.582$ in.

$$\frac{C_1A_f}{t_b + 5k} = \frac{4.9}{0.875 + (5 \times 1.625)} = 0.544 < 0.582\text{ in. o.k.}$$ Formula (1.15-1)

$$\frac{d_c\sqrt{F_y}}{180} = \frac{9.5\sqrt{36}}{180} = 0.317 < 0.582\text{ in. o.k.}$$ Formula (1.15-2)

∴ Stiffeners not required at compression flange.

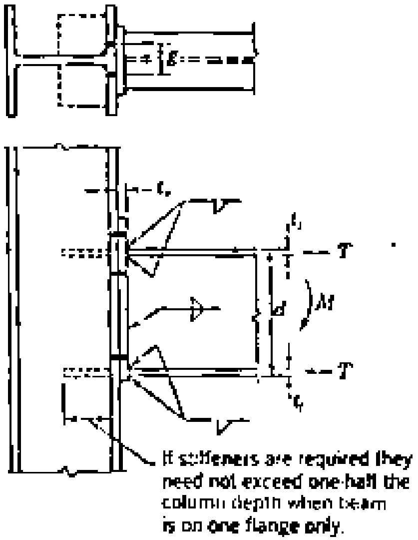
At tension flange: $t_f = 0.921$ in.

$$0.4\sqrt{C_1A_f} = 0.4\sqrt{4.9} = 0.885 < 0.921\text{ in. o.k.}$$ Formula (1.15-3)

∴ Stiffeners not required at tension flange

MOMENT CONNECTIONS
End plate

DESIGN EXAMPLE



If stiffeners are required they need not exceed one-half the column depth when beam is on one flange only.

Given: A beam having an end reaction of 30 kips and a fixed-end negative moment of 120 kip-ft. framed 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 all members. 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: Select the beam and assume its flanges are stressed to the full allowable stress. Based on the beam and column dimensions and normal gage lines, an end plate size with bolts is then selected. Use fillet welds between the beam flanges and end plate capable of developing the necessary flange force. The beam web will be attached with fillet welds as necessary to resist the end shear and moment equivalent to the web. The fillet welds must also satisfy Sect. 1.17.5 of the AISC Specification. Alternatively, if beam ends are milled or saw-cut to bear, welds are not required between the end plate and the compression flange.

AISC Specification or Manual Reference

A. Beam selection:

1. Required section modulus: $S = \frac{120 \times 12}{24} = 60$ in.^{3}

Use: W16 × 40 ($S = 64.6 > 60$ in.^{3}) — pg. 2-10

Dimensions: — Properties tables (Part 1)

Depth d = 16.0″
Flange width b_f = 7.00″
Flange t_f = 0.503″
w = 0.307″

T = [illegible] × 7.00 × 0.503 = 84.5 kips

AISC Specification or Manual Reference

B. Trial end plate size:

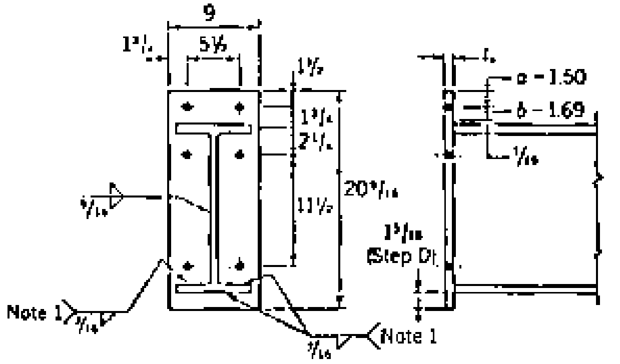
1. Assume four 1″ diam. bolts at top flange of beam.
2. Determine size of weld required to develop top flange between flange and end plate:

$l = 2b_f - t = (2 \times 7.00) - 0.307 = 13.69''$

$D = \frac{84.5}{0.928 \times 13.69} = 6.65$; Use: $\frac{7}{16}$ in. fillet weld. — Specification Table 1.5.3

3. Trial width for end plate (W):

Column b_f = 15.66″; column g = 5½″
Try W = 9″ (see sketch below).



Note 1: Typ top and bottom flange — 1.16.5

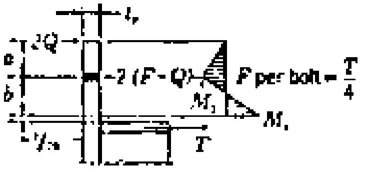
4. Determine thickness of end plate, including effect of prying action:

Determine b-distance; where b is distance from center line of bolts to top flange of beam minus $\frac{1}{16}$″. (See "Hanger Type Connections", Part 4.) — Commentary 1.5.2.1

Minimum clearance for installing a 1″ diam. bolt = $1\frac{5}{16}$″. (See "Threaded Fasteners, Erection Clearances", Part 4.)

$b = 1\frac{5}{16} + \frac{7}{16} - \frac{1}{16} = 1\frac{11}{16}$″; Use: b = 1.69″

Trial thickness of end plate, t_p: F_b = 27 ksi — 1.5.1.4.[illegible]



AISC Specification or Manual Reference

3. Check shear and tension on bolts:

Assume six 1" diam. bolts.

$$f_v = \frac{30}{6(0.7854)} = 6.37 \text{ ksi} < F_v = 15 \text{ ksi o.k.}$$

Specification Table 1.5.2.1

If considered as a friction type connection, the interaction equation in Sect. 1.6.3 need not be checked (see Fig. 2a and discussion of that figure in Sect. C4, *Specification for Structural Joints Using ASTM A325 or A490 Bolts*.

Assume bolts to be in a bearing type connection:
Allowable tensile stress $F_t = 50 - 1.6(6.37)$
$= 39.8$ ksi > 23.4 ksi (Step C1) o.k.

1.6.3

Use: Six 1" diam. A325 bolts.

4. Welding:

As bottom flange is not considered in bearing, flange welds have been determined to be 5/16 in. fillet welds (Step B2).

Min. size fillet weld is 5/16 in. for web.

1.17.5

Min. length to avoid overstressing base metal of web

$$\text{in shear} = \frac{30}{0.307 \times 14.5} = 6.73''$$

Since allowable bending stress of 0.66 F_y was used for the compact beam, the web must be capable of bending to this stress throughout its entire depth. Therefore, weld web both sides entire depth.

Required weld to develop web to $0.66F_y$:

$$D = \frac{(0.307)(0.66F_y)}{2(0.928)} = 3.9 < 5 \therefore 5/16'' \text{ weld o.k.}$$

D. *Column web stiffeners and reinforcement.*

Commentary 1.5.1.2 and 1.15.5

Check column web as in previous moment connection examples. Note that by extending the end plate 1 5/16" below the beam flange and assuming a stress flow through the end plate on a 1:1 slope, $(t_b + 5k + 2t_p)$ may be conservatively used in lieu of $(t_b + 5k)$ in Formula (1.15-1). In this example stiffeners were not required opposite the beam compression flange; due to the spacing of bolts at the tension flange, stiffeners were also not required at the tension flange.

Use: 1 5/16 × 9 × 1'-8 9/16" end plate without column web stiffeners.

AISC Specification or Manual Reference

For trial assume $Q = 0$ and $M_2 = 0$.
Let $M_1 = 2F \times b = Tb/2 = S \times$ allowable F_b,
where

$S = \dfrac{t_p^2 W}{6}$

W = width of end plate

$$\therefore \text{Req'd } t_p = \sqrt{\frac{3Tb}{WF_b}} = \sqrt{\frac{3(84.5)(1.69)}{9(27)}} = 1.33''$$

Try 1 5/16" plate.

C. *Check trial end plate:*

1. Compute prying force assuming 1" diam. bolts. See "Hanger Type Connections", Part 4.

$$\frac{Q}{F} = \frac{100b(d_b)^2 - 18w(t_p)^2}{70a(d_b)^2 + 21w(t_p)^2} \text{ (for A325 bolts),}$$

where

Q = Prying force per bolt, kips
F = Externally applied load per bolt, kips
d_b = Nominal diameter of bolt, in.
a = Distance from bolt line to edge of plate, but not more than $2t_p$
w = Width of plate tributary to each bolt, in.
= $W/2$ for this example

$$\frac{Q}{F} = \frac{100(1.69)(1)^2 - 18(4.5)(1.313)^2}{70(1.5)(1)^2 + 21(4.5)(1.313)^2} = 0.11$$

$$F = \frac{84.5}{4} = 21.1 \text{ kips;} \quad Q = 21.1 \times 0.11 = 2.32 \text{ kips}$$

Total load per bolt $= 21.1 + 2.3 = 23.4$ kips (tension)

Allowable load for 1" diam. bolt = 31.4 kips. See pg. 4-3.

2. Check bending stress in plate:

$M_2 = 2(2.32)1.5 = 6.96$ kip-in.

$M_1 = 2(21.1 + 2.32)(1.69) - 2(2.32)(1.5 + 1.69)$
$= 64.3$ kip-in.

$$\text{Section modulus of plate} = \frac{(9)(1.313)^2}{6} = 2.59 \text{ in.}^3$$

$$\text{Max. bending stress } f_b = \frac{64.3}{2.59} = 24.8 < 27 \text{ ksi o.k.}$$

1.5.1.4.3

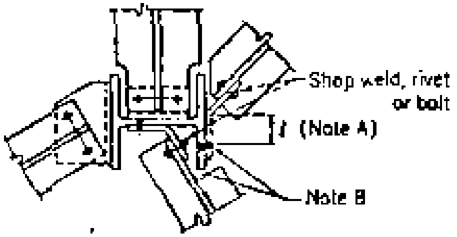
Notes

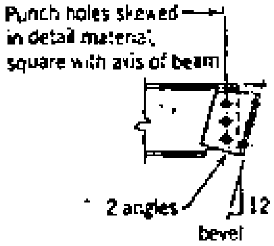
SUGGESTED DETAILS

Beam framing

Details on this and succeeding pages are suggested treatments only, and are not intended to limit the use of other similar connections not illustrated.

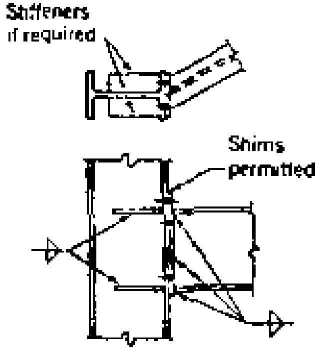
SKEWED AND SLOPED CONNECTIONS

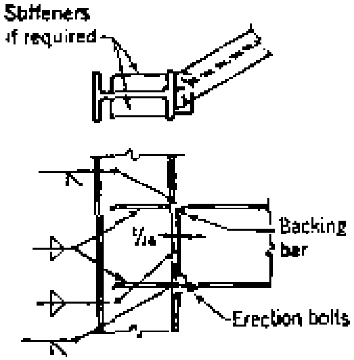


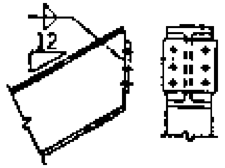


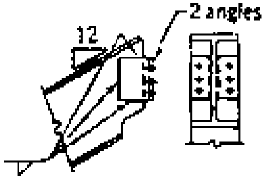
Note A: For bent plate connection, size of plate should be checked using arm l, and eccentricity in fasteners checked using tables of Eccentric Loads on Fastener Groups.

Note B: If a combination of several connections occur at one level, provide field and driving clearance.







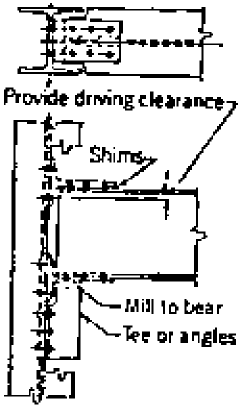


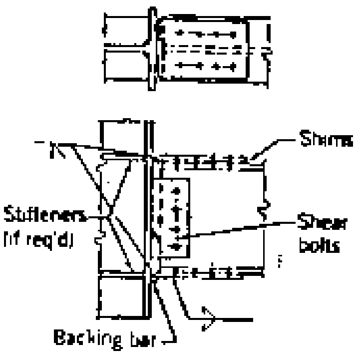
SUGGESTED DETAILS

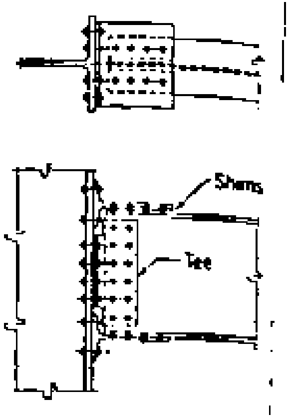
Beam framing

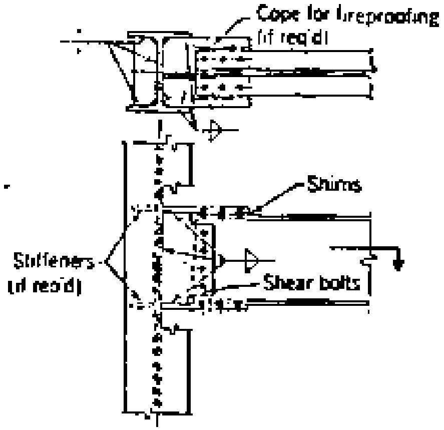
MOMENT CONNECTIONS

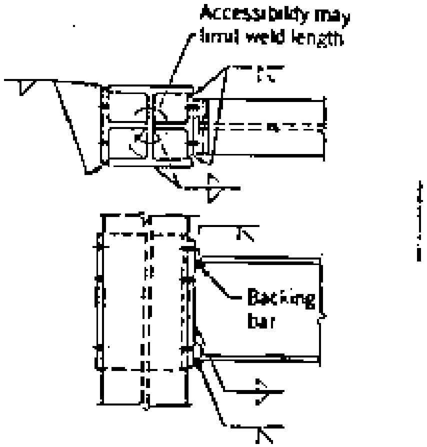
Wind bracing connections, or connections designed to resist bending moments, are usually made with angles, structural tees or plates.

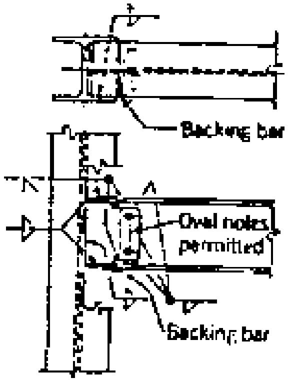


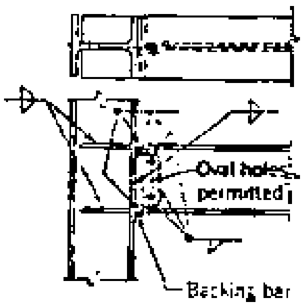


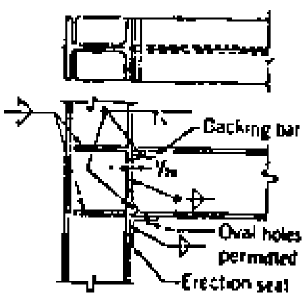








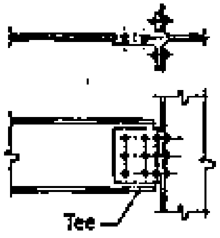


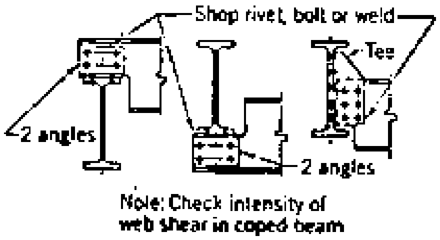


SUGGESTED DETAILS

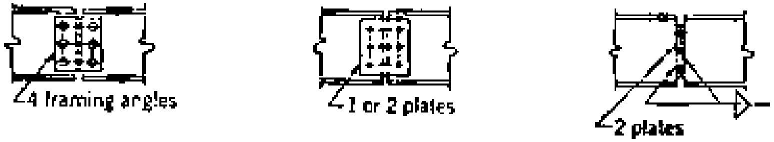
Beam framing

SHEAR CONNECTIONS



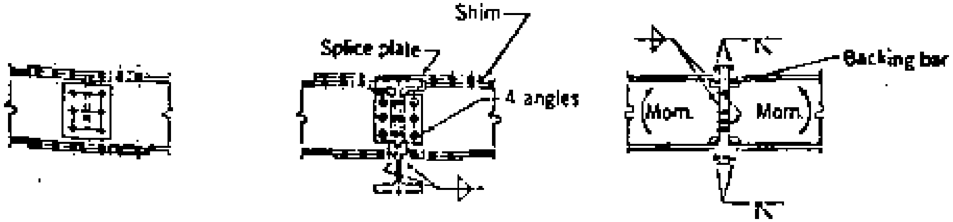


SHEAR SPLICES



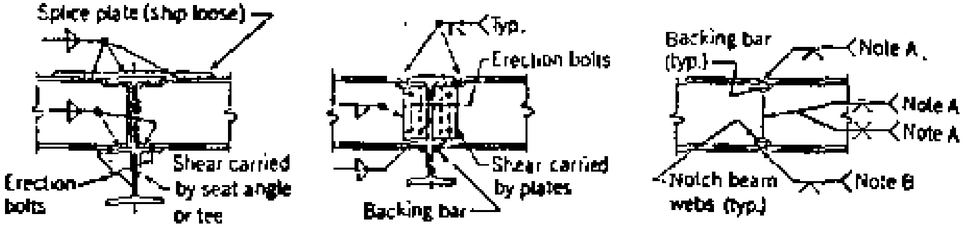
Note: Of the above types, 4 framing angles is most flexible.

BOLTED MOMENT SPLICES



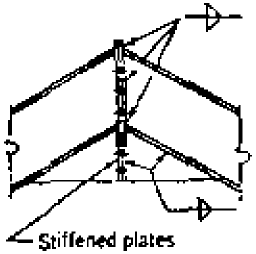
SUGGESTED DETAILS
Beam Framing

WELDED MOMENT SPLICES

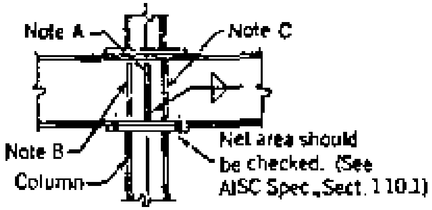


Note A: Joint preparation depends on thickness of material, and welding process.
Note B: Invert this joint preparation if beam cannot be turned over.

MOMENT SPLICE AT RIDGE (FIELD BOLTED)



*BEAM OVER COLUMN (WITH CONTINUITY)



Note A: Two stiffeners, effective only if deck or slab prevents rotation of top flange.
Note B: Optional location of 2 stiffeners over supporting column flanges.
Note C: If column above, use 4 fitted stiffeners.

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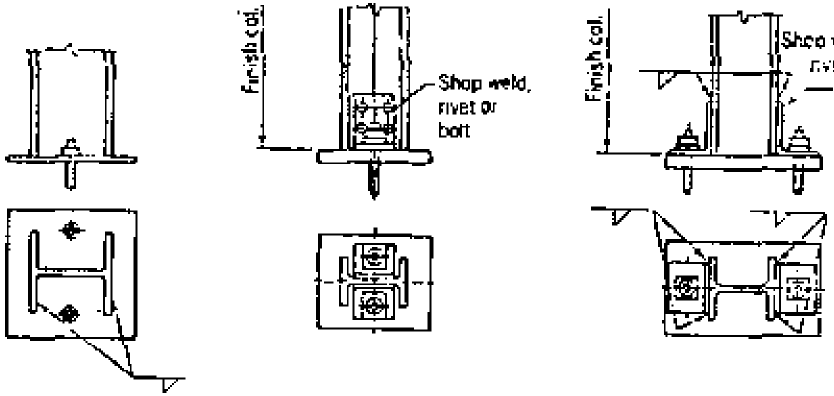
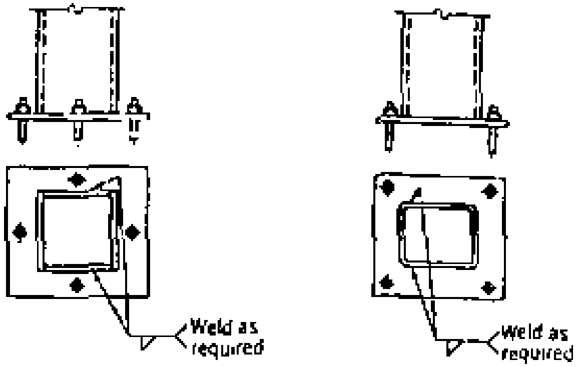
* For Plastic Design see Spec. Sects. 1.15.1 and 2.6.

SUGGESTED DETAILS
Column base plates



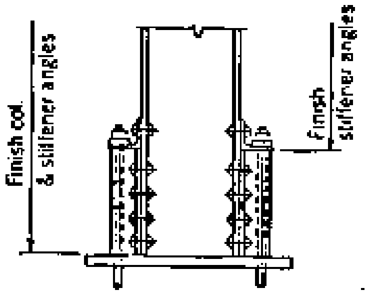
Base plate detailed and shipped separately when required.

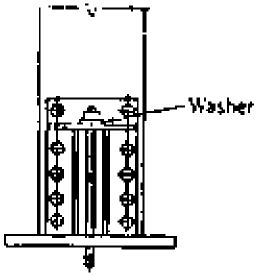


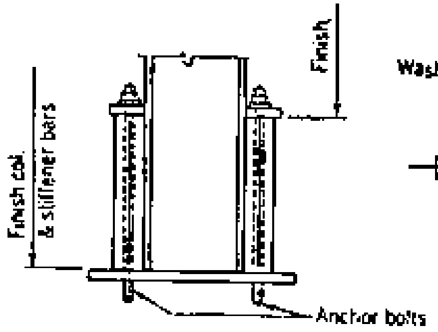
Note: Anchor bolts should be spread as far as practical for safety during erection.

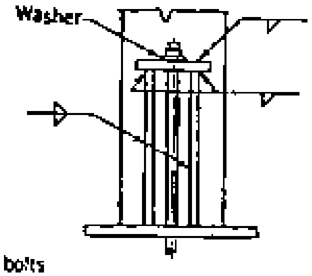
SUGGESTED DETAILS

Column base plates







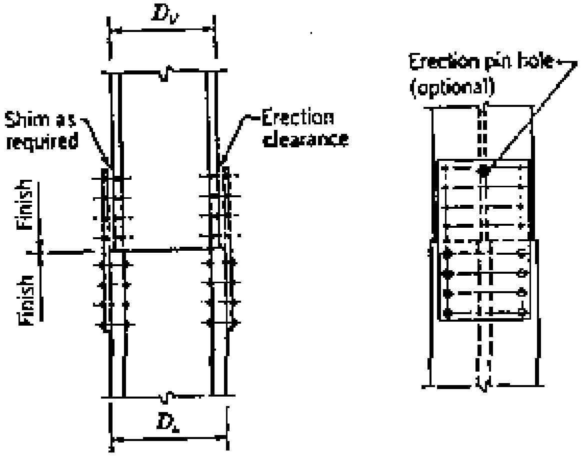


Note: Anchor bolts should be spread as far as practical for safety during erection. Base plate detailed and shipped separately when required.

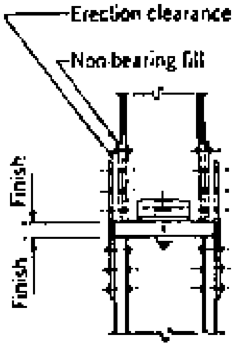
SUGGESTED DETAILS

Column splices

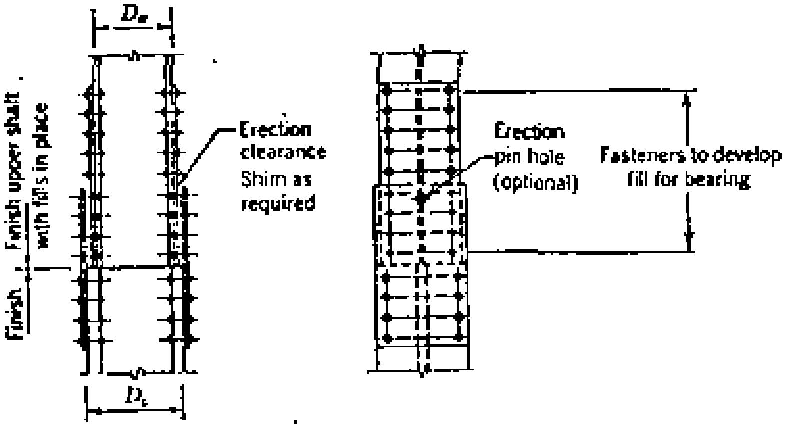
Riveted and bolted



DEPTH OF D_U AND D_L
NOMINALLY THE SAME



BUTT PLATE



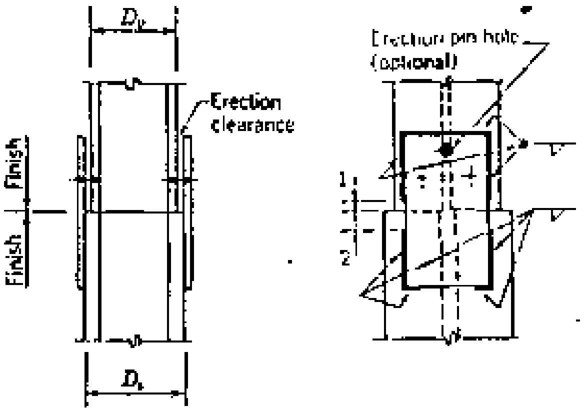
DEPTH D_U NOMINALLY
2 IN. LESS THAN D_L

Note: Erection clearance = ⅛ in.

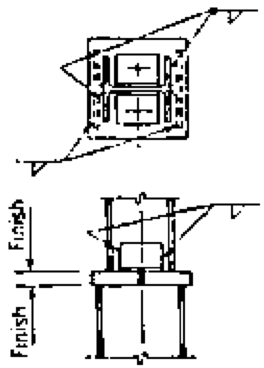
SUGGESTED DETAILS

Column splices

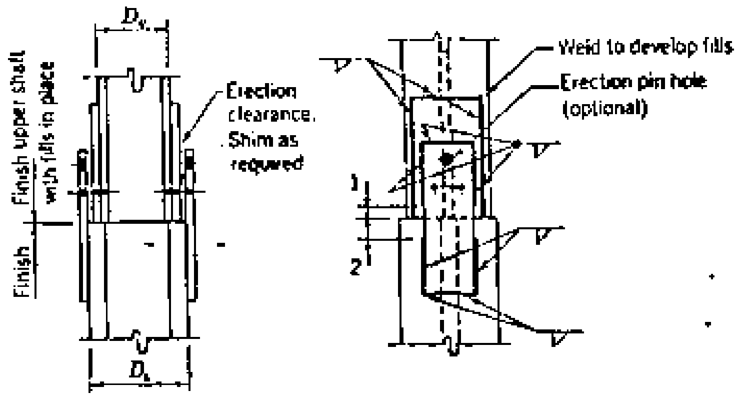
Welded



DEPTH OF D_U AND D_L
NOMINALLY THE SAME



BUTT PLATE



DEPTH D_U NOMINALLY
2 IN. LESS THAN D_L

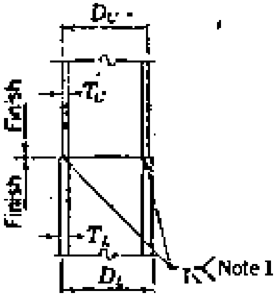
Note 1: Erection clearance = $\frac{1}{16}$ in.

Note 2: When D_U and D_L are nominally the same and thin fills are required, shop may attach splice plate to upper section and provide field clearance over lower section.

SUGGESTED DETAILS

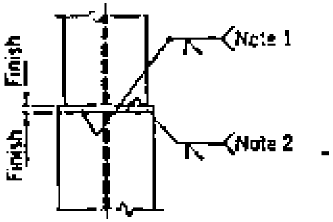
Column splices

Welded



$T_U \leq T_L$

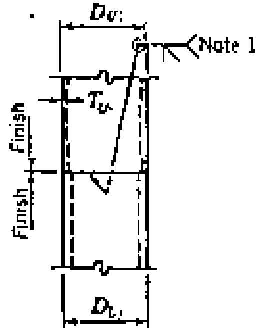
DEPTH OF D_U AND D_L
NOMINALLY THE SAME

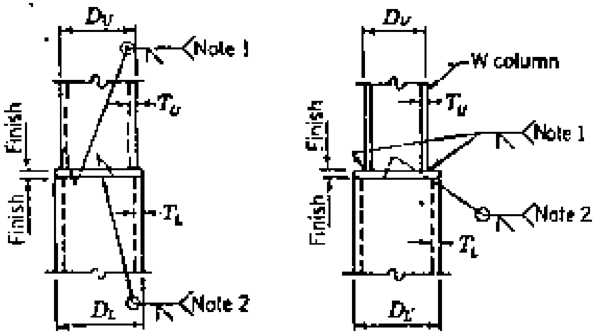


BUTT PLATE

DEPTH D_U NOMINALLY
2 IN. LESS THAN D_L

Box columns





BUTT PLATE

DEPTH OF D_U AND D_L
NOMINALLY THE SAME

DEPTH D_U NOMINALLY
2 IN. LESS THAN D_L

SPEC.

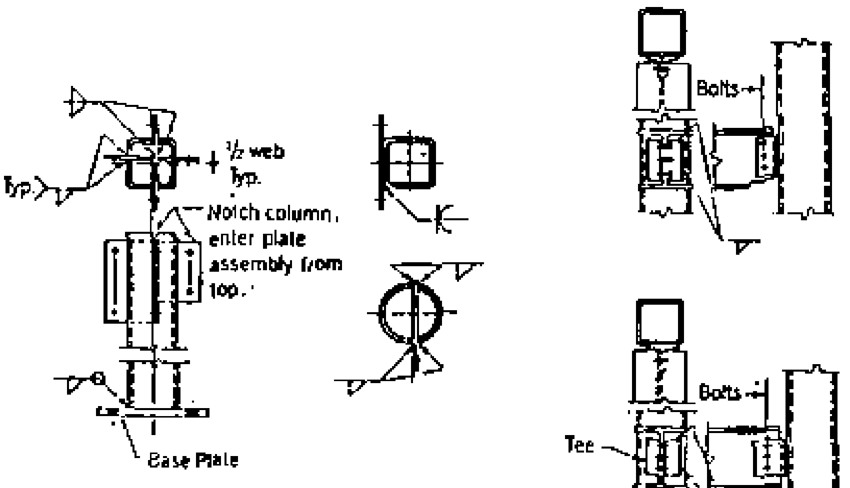
Note 1: Weld size based on T_U.

Note 2: Weld size based on T_L.

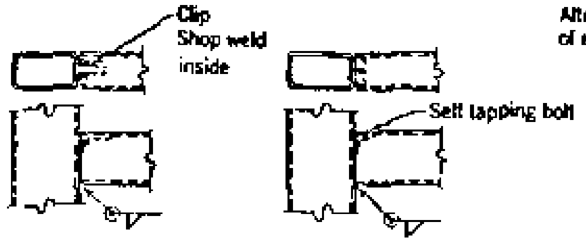
SUGGESTED DETAILS

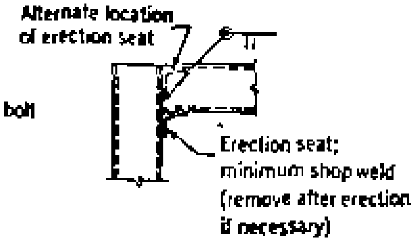
Miscellaneous

STRUCTURAL TUBING AND PIPE BEAM-TO-COLUMN CONNECTIONS

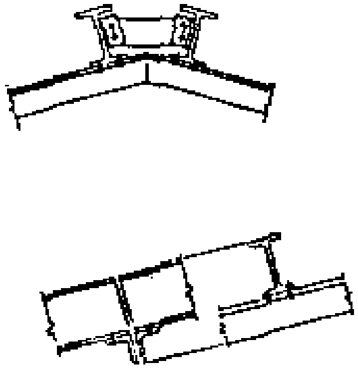


Note: Details similar for pipe and tubing.

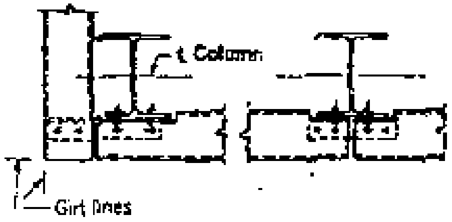




PURLIN CONNECTIONS



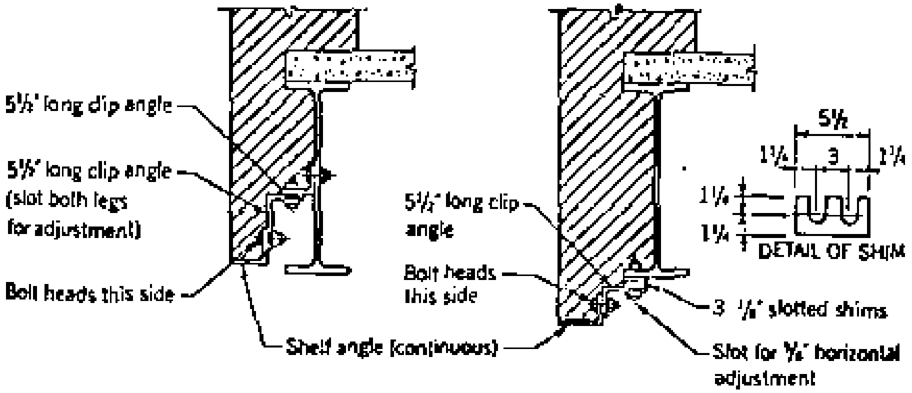
GIRT CONNECTIONS



SUGGESTED DETAILS

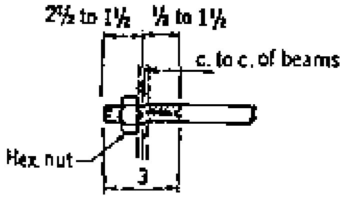
Miscellaneous

SHELF ANGLES WITH ADJUSTMENT



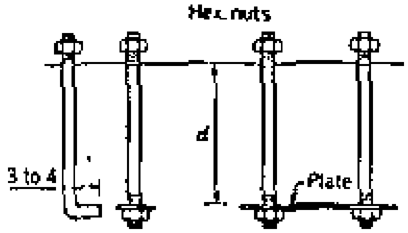
Note: Horizontal adjustment is made by slotted holes; vertical adjustment may be made by slotted holes or by shims.
For tolerance allowance in alignment, see AISC Code of Standard Practice.

TIE RODS AND ANCHORS



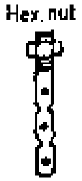
Length of rod o. to o. should be specified in multiples of 3 in.

Tie Rods

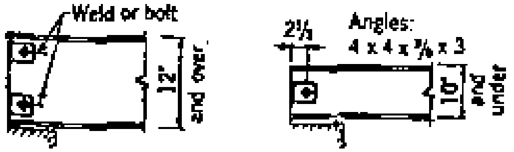


Note: Dimension *d* should be based on design req't for uplift

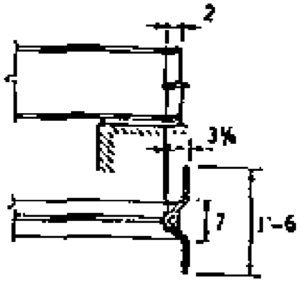
Anchor Bolts



Swedge Bolts



Angle Wall Anchors



Government Anchor

DETAILING PRACTICE

Bolted and riveted connections

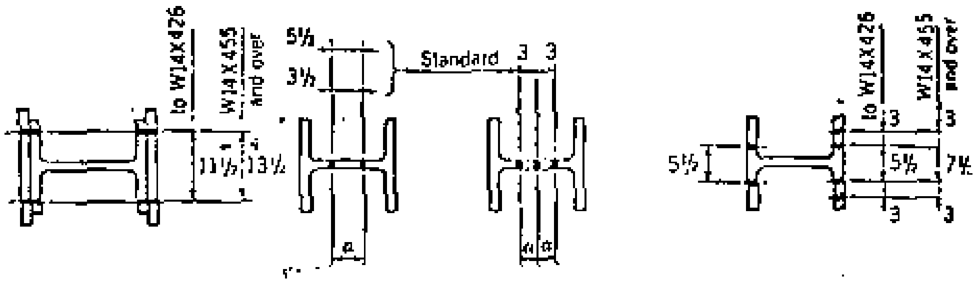
Maximum efficiency in the fabrication of structural steel by modern shops is entirely dependent upon close cooperation between designing office, drafting room and shop. Designs should be favorable to, the drafting room should recognize and call for, and the shop should adapt its equipment to, the use of recurrent details which have been standardized.

Consideration should be given to duplication of details and multiple punching or drilling. Utilization of standard jigs and machine set-ups eliminates unnecessary handling of material and aids drilling or punching holes in groups.

Column gage lines should conform to the standard machine set-ups illustrated below. Once determined they should be duplicated as far as possible throughout any one job. Gages on an individual member if possible should not be varied throughout the length of that member.

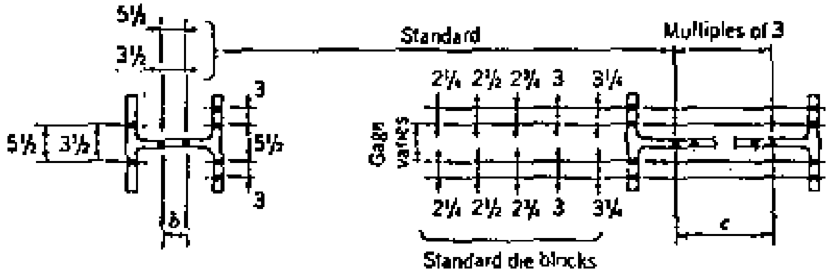
DRILL GAGES

Keep gages and longitudinal spacing alike, if possible, as drilling can be done simultaneously in both flanges.



Minimum a = 3 in.; maximum a controlled by size of member. Gages other than standard should be multiples of 3 in.

PUNCH GAGES



Minimum b = 2¼ in.; maximum b controlled by size of member. Gages other than standard should be multiples of 3 in. Maximum c controlled by size of member.

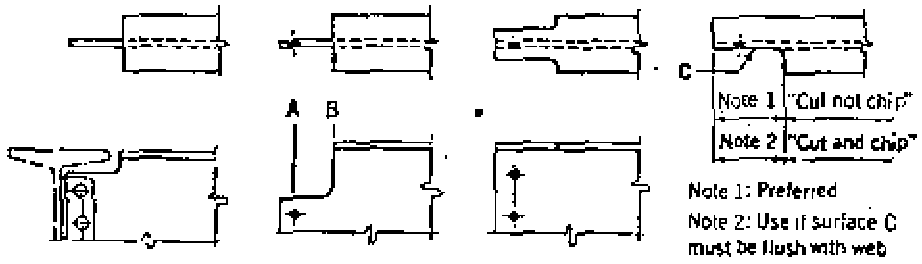
Longitudinal spacing of holes for both punched and drilled work should be 3 in. or multiples of 3 in. The adoption of such spacing facilitates the use of multiple drills and punches and makes possible the use of the Framed Beam Connections given on page 17 to 4 - 26.

In general the principles governing the selection of gages and longitudinal spacing of holes in beam webs and flanges are identical with those for columns. Sketches and notes for "Punch Gages" apply to all sections. Minimum gages are tabulated under "Dimensions for Detailing" in Part 1. See page 4 - 115 for information and dimensions pertaining to clearance requirements.

Beams are connected to columns or other beams by framed, heavy framed or seated connections. The need of providing for wind or bending requires a specially designed moment connection. Typical examples of seated and wind bracing connections are illustrated on page 4 - 102.

Heavy Framed Beam Connections, page 4 - 22, should be used only when the capacities of Framed Beam Connections are exceeded. Stiffened beam seats, page 4 - 47, should be used only when the capacities of unstiffened beam seats are exceeded.

Copes, blocks and cuts



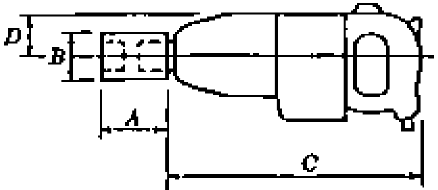
All re-entrant corners shall be shaped, notch free, to a radius of at least ½ in.

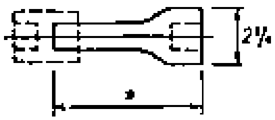
These sketches indicate standard methods of providing clearance for beams connecting to beams or columns. Where possible, a minimum clearance of ½ in. is to be provided. Fabricators may vary in designation and dimensions of copes and blocks. Some fabricators designate all of the operations pictured above by the term "cuts."

For economy, coping or blocking of beams should be avoided if possible. When construction will permit, the elevation of the top of filler beams should be established a sufficient distance below the top of girders to clear the girder fillet. Unusually long or deep copes and blocks, or blocks in beams with thin webs, may materially affect the capacity of the beam. Such beams must be investigated for both shear and moment at lines A and B and, when necessary, adequate reinforcement provided.

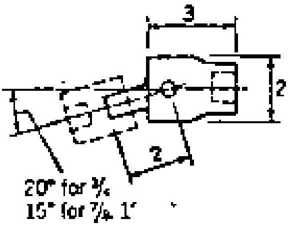
Erection clearances

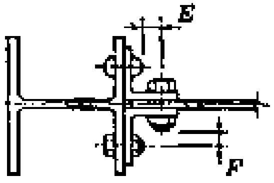
BOLT IMPACT WRENCHES





*Available in lengths 6½" to 1-3



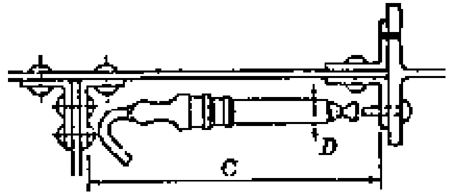


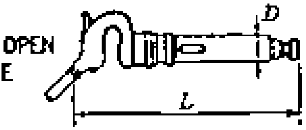
MINIMUM CLEARANCES

	Size	C	D
Light Wrenches	⅝ to 1	1-1¼ to 1-2	2⅛
Heavy Wrenches	1 to 1½	1-2¾ to 1-5¼	2½

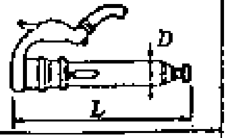
Sockets			Min. Clear.	
Bolt Size	A	B	E	F
⅝	2⅝	1¾		
¾	3	2¼	1⅛	1¼
⅞	3¼	2½	1¼	1⅜
1	3½	2⅝	1⁵⁄₁₆	1⁷⁄₁₆
1⅛	3¾	2⅞	1⁷⁄₁₆	1⁹⁄₁₆
1¼	4	3⅛	1⁹⁄₁₆	1¹¹⁄₁₆
1⅜	4¼	3¼	1⅝	1¾
1½	4⅝	4¼	2⅛	2¼

RIVET GUNS





STANDARD OPEN HANDLE

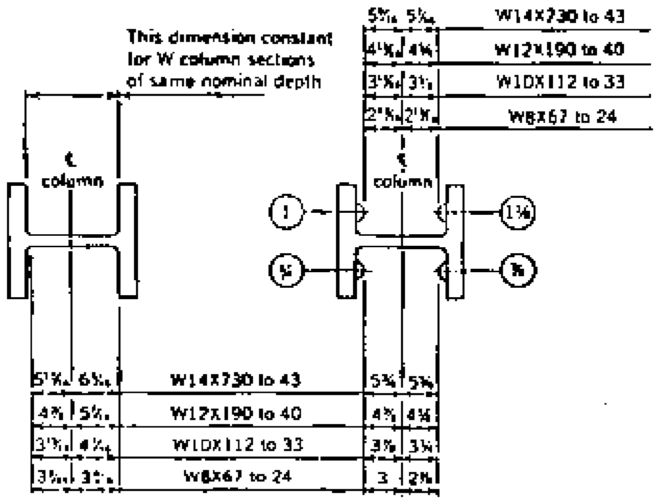


INVERTED HANDLE

	Rivet Size	D	Standard		Inverted	
			L	C	L	C
Light Hammer	⅝, ¾, ⅞	2½	1-5½ to 1-9½	1-9 to 2-2	1-2 to 1-3¾	1-5 to 1-7
Medium Hammer	¾ to 1⅜	2½	1-10¾ to 1-11½	2-2 to 2-4	1-5½ to 1-8¼	1-9 to 1-10½
Heavy Hammer	1½	2½	2½	2-7	...	...

Field erection clearances

RIVET CLEARANCE—W COLUMNS

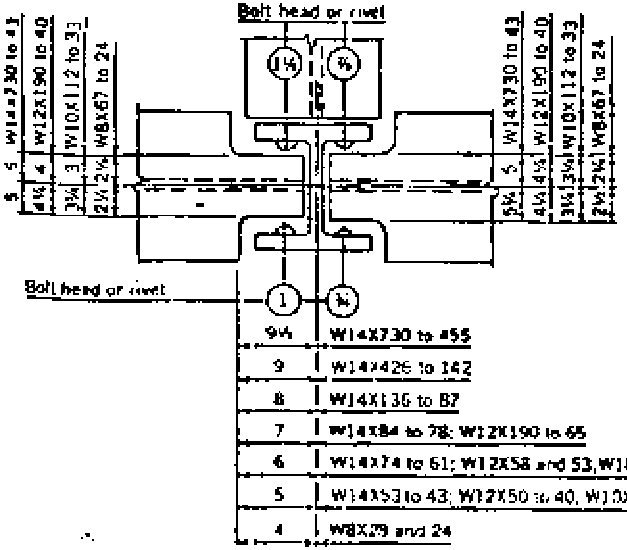


Based on Dimensions of Structural Rivets, page 4-116.

BOLT CLEARANCE—W COLUMNS

Values shown above for clearances over rivet heads are conservative when applied to bolts. See "Specification for Structural Joints using ASTM A325 or A490 Bolts" to compute overall lengths for various grips.

FLANGE CUTS FOR COLUMN WEB CONNECTIONS



When beams framing to the flanges of columns interfere with beams framing to the web of the column, the latter must be cut as shown.

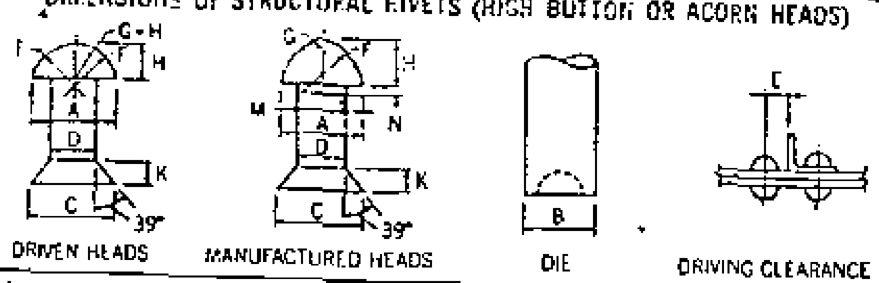
Dimensions are for bolts and rivets.

In all cases where members must be erected by dropping down, allow at least ½" clearance.

Based on Dimensions of Structural Rivets, page 4-116, and Bolts, pages 4-120, 4-121.

RIVETS AND THREADED FASTENERS

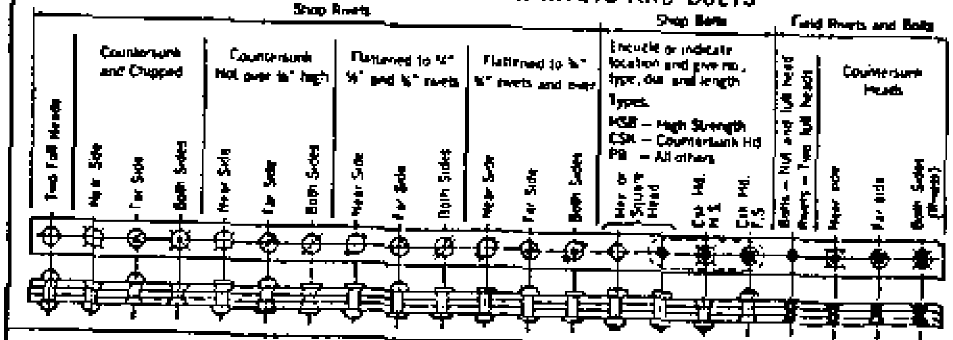
DIMENSIONS OF STRUCTURAL RIVETS (HIGH BUTTON OR ACORN HEADS)



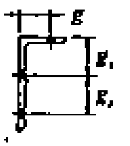
DRIVEN HEADS MANUFACTURED HEADS DIE DRIVING CLEARANCE

Diam. of Rivet, Inches				½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½
Driven Head Inches	Full	A	1.5 D + ⅛	⅞	1 1/16	1¼	1 7/16	1⅝	1 13/16	2	2 3/16	2⅜
		H	.425 A	⅜	7/16	17/32	⅝	11/16	¾	27/32	15/16	1
		F	1.5 H	9/16	11/16	13/16	15/16	1 1/32	1 5/32	1 9/32	1 13/32	1½
	Clsk.	C	1.81 D	29/32	1⅛	1 11/32	1 19/32	1 13/16	2 1/32	2¼	2½	2 23/32
		K	.5 D	¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾
Manufactured Head Inches	Full	A	1.5 D + 1/32	25/32	31/32	1 5/32	1 11/32	1 17/32	1 23/32	1 29/32	2 3/32	2 9/32
		H	.75 D + ⅛	½	19/32	11/16	25/32	⅞	31/32	1 1/16	1 5/32	1¼
		F	.75 D + 9/32	21/32	¾	27/32	15/16	1 1/32	1⅛	1 7/32	1 5/16	1 13/32
		M	.50	½	½	½	½	½	½	½	½	½
		N	.094	3/32	3/32	3/32	3/32	3/32	3/32	3/32	3/32	3/32
		G	.75 D − 9/32	3/32	3/16	9/32	⅜	15/32	9/16	21/32	¾	27/32
	Clsk.	C	1.81 D	29/32	1⅛	1 11/32	1 19/32	1 13/16	2 1/32	2¼	2½	2 23/32
		K	.5 D	¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾
Die, In.		B		1¾	2	2¼	2½	2¾	3	3¼	3½	3¾
Driving Clearance Inches			E (min.)	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾
			E (pref.)	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2

CONVENTIONAL SIGNS FOR RIVETS AND BOLTS



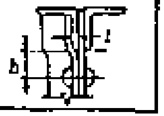
USUAL GAGES FOR ANGLES, INCHES



Leg	8	7	6	5	4	3½	3	2½	2	1¾	1½	1⅜	1¼	1
g	4½	4	3½	3	2½	2	1¾	1⅜	1⅛	1	⅞	⅞	¾	⅝
g₁	3	2½	2¼	2										
g₂	3	3	2½	1¾										

CRIMPS

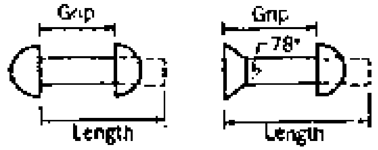
b = t + 1½
Min. = 2



RIVETS

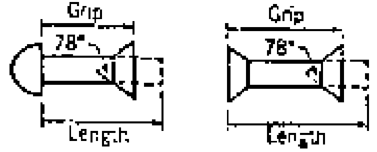
Lengths of undriven rivets

In inches, for various grips



FULL HEAD

Grip Inches	½	⅝	¾	⅞	1	1⅛	1¼
	Diameter of Rivet, Inches						
½	1⅝	1⅞	1⅞	2	2⅛		
⅝	1¾	2	2	2⅛	2¼		
¾	1⅞	2⅛	2⅛	2¼	2⅜		
⅞	2	2¼	2¼	2⅜	2½		
1	2¼	2⅜	2⅜	2½	2⅝	2¾	2⅞
⅛	2⅜	2½	2½	2⅝	2¾	2⅞	3
¼	2½	2⅝	2⅝	2¾	2⅞	3	3⅛
⅜	2⅝	2¾	2¾	2⅞	3	3⅛	3¼
½	2⅞	3	3	3⅛	3¼	3⅜	3½
⅝	3	3⅛	3⅛	3¼	3⅜	3½	3⅝
¾	3⅛	3¼	3¼	3½	3⅝	3¾	3¾
⅞	3¼	3⅜	3⅜	3⅝	3¾	3⅞	3⅞
2	3½	3½	3⅝	3¾	3⅞	4	4
⅛	3⅝	3⅝	3¾	3⅞	4	4⅛	4⅛
¼	3¾	3⅞	3⅞	4	4⅛	4¼	4¼
⅜	4	4	4	4⅛	4¼	4⅜	4⅜
½	4⅛	4⅛	4⅛	4¼	4⅜	4½	4½
⅝	4¼	4¼	4¼	4⅜	4½	4⅝	4⅝
¾	4⅜	4⅜	4⅜	4½	4⅝	4¾	4¾
⅞	4⅝	4⅝	4⅝	4⅝	4¾	4⅞	5
3	...	4¾	4¾	4⅞	5	5	5⅛
⅛	...	4⅞	4⅞	5	5⅛	5¼	5¼
¼	...	5	5	5⅛	5¼	5⅜	5⅜
⅜	...	5⅛	5⅛	5¼	5⅜	5½	5½
½	...	5⅜	5⅜	5⅜	5½	5⅝	5⅝
⅝	...	5½	5½	5½	5⅝	5¾	5¾
¾	...	5⅝	5⅝	5⅝	5¾	5⅞	5⅞
⅞	...	5¾	5¾	5¾	5⅞	6	6
4	...	...	5⅞	6	6	6⅛	6⅛
⅛	...	...	6	6⅛	6¼	6¼	6⅜
¼	...	...	6⅛	6¼	6⅜	6½	6½
⅜	...	...	6⅜	6½	6½	6⅝	6⅝
½	...	...	6½	6⅝	6⅝	6¾	6¾
⅝	...	...	6⅝	6¾	6¾	6¾	6⅞
¾	...	...	6¾	6⅞	6⅞	7	7
⅞	...	...	6⅞	7	7	7⅛	7⅛
5	...	...	...	7⅛	7⅛	7¼	7¼
⅛	...	...	...	7¼	7¼	7⅜	7⅜
¼	...	...	...	7⅜	7⅜	7½	7½
⅜	...	...	...	7⅝	7⅝	7¾	7⅝
½	...	...	...	7¾	7¾	7⅞	7⅞
⅝	...	...	...	7⅞	7⅞	8	8
¾	...	...	...	8	8	8⅛	8⅛
⅞	...	...	...	8⅛	8⅛	8¼	8¼



COUNTERSUNK HEAD

Grip Inches	½	⅝	¾	⅞	1	1⅛	1¼
	Diameter of Rivet, Inches						
½	1	1	1⅛	1¼	1¼		
⅝	1⅛	1¼	1¼	1⅜	1⅜		
¾	1⅜	1⅜	1⅜	1½	1½		
⅞	1½	1½	1½	1⅝	1⅝		
1	1⅝	1⅝	1⅝	1¾	1¾	1⅞	1⅞
⅛	1¾	1¾	1⅞	1⅞	1⅞	2	2
¼	2	2	2	2	2	2⅛	2⅛
⅜	2⅛	2⅛	2⅛	2¼	2¼	2⅜	2⅜
½	2¼	2¼	2¼	2⅜	2⅜	2½	2½
⅝	2⅜	2⅜	2⅜	2½	2½	2⅝	2⅝
¾	2⅝	2⅝	2⅝	2⅝	2⅝	2¾	2¾
⅞	2¾	2¾	2¾	2¾	2¾	2⅞	2⅞
2	2⅞	2⅞	2⅞	2⅞	2⅞	3	3
⅛	3⅛	3	3	3	3	3⅛	3⅛
¼	3¼	3⅛	3⅛	3⅛	3⅛	3¼	3¼
⅜	3⅜	3⅜	3⅜	3⅜	3⅜	3⅜	3⅜
½	3½	3½	3½	3½	3½	3⅝	3⅝
⅝	3¾	3⅝	3⅝	3⅝	3⅝	3¾	3¾
¾	3⅞	3¾	3¾	3¾	3¾	3⅞	3⅞
⅞	4	3⅞	3⅞	3⅞	3⅞	4	4
3	...	4⅛	4⅛	4⅛	4⅛	4⅛	4⅛
⅛	...	4¼	4¼	4¼	4¼	4¼	4¼
¼	...	4⅜	4⅜	4⅜	4⅜	4⅜	4⅜
⅜	...	4½	4½	4½	4½	4½	4½
½	...	4⅝	4⅝	4⅝	4⅝	4⅝	4⅝
⅝	...	4¾	4¾	4¾	4¾	4¾	4¾
¾	...	5	5	5	5	5	5
⅞	...	5⅛	5⅛	5⅛	5⅛	5⅛	5⅛
4	...	...	5¼	5¼	5¼	5¼	5¼
⅛	...	...	5⅜	5⅜	5⅜	5⅜	5⅜
¼	...	...	5½	5½	5½	5½	5½
⅜	...	...	5⅝	5⅝	5⅝	5⅝	5⅝
½	...	...	5¾	5¾	5¾	5¾	5¾
⅝	...	...	6	6	6	6	6
¾	...	...	6⅛	6⅛	6⅛	6⅛	6⅛
⅞	...	...	6¼	6¼	6¼	6¼	6¼
5	...	...	...	6⅜	6⅜	6⅜	6⅜
⅛	...	...	...	6½	6½	6½	6½
¼	...	...	...	6⅝	6⅝	6⅝	6⅝
⅜	...	...	...	6¾	6¾	6¾	6¾
½	...	...	...	6⅞	6⅞	6⅞	6⅞
⅝	...	...	...	7	7	7	7
¾	...	...	...	7¼	7¼	7¼	7¼
⅞	...	...	...	7⅜	7⅜	7⅜	7⅜

Above table may vary from standard practice of individual fabricators and should be checked against such standards by user.

RIVETS

Weights

WEIGHT WITH ONE HIGH BUTTON (ACORN) MANUFACTURED HEAD IN POUNDS PER 100

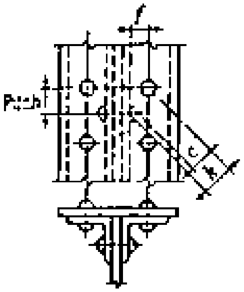
Length Inches	Diameter of Rivet, Inches						
	½	⅝	¾	⅞	1	1⅛	1¼
1¼	11						
⅜	12						
½	12	20	31	45	60	81	104
⅝	13	21	32	47	63	85	108
¾	14	22	33	49	66	88	113
⅞	14	23	35	51	69	92	117
2	15	24	37	53	72	95	122
⅛	16	25	39	55	74	99	126
¼	17	26	40	57	77	102	130
⅜	17	27	42	59	80	106	135
½	18	28	43	62	83	109	139
⅝	19	29	45	64	85	113	143
¾	19	31	46	66	88	116	148
⅞	20	32	48	68	91	120	152
3	21	33	50	70	94	123	156
⅛	21	34	51	72	97	127	161
¼	22	35	53	74	99	131	165
⅜	23	36	54	76	102	134	169
½	23	37	56	79	105	138	174
⅝	24	38	57	81	108	141	178
¾	25	39	59	83	110	145	182
⅞	26	40	60	85	113	148	187
4	26	41	62	87	116	152	191
⅛	27	42	64	89	119	155	195
¼	28	44	65	91	122	159	200
⅜	78	45	67	93	124	162	204
½	29	45	68	96	127	166	208
⅝	30	47	70	98	130	169	213
¾	30	48	71	100	133	173	217
⅞	31	49	73	102	135	176	221
5	...	50	74	104	138	180	226
⅛	...	51	76	106	141	183	230
¼	...	52	78	108	144	187	234
⅜	...	53	79	110	147	190	239
½	...	54	81	113	149	194	243
⅝	...	55	82	115	152	197	247
¾	...	57	84	117	155	201	252
⅞	...	58	85	119	158	204	256
6	...	...	87	121	161	208	261
⅛	...	...	89	123	163	212	265
¼	...	...	90	125	166	215	269
⅜	...	...	92	127	169	219	274
½	...	...	93	130	172	222	278
⅝	...	...	95	132	174	226	282
¾	...	...	96	134	177	229	287
⅞	...	...	98	136	180	233	291
7	...	...	100	138	183	236	295
⅛	...	...	101	140	186	240	300
¼	...	...	103	142	188	243	304
⅜	...	...	104	144	191	247	308
½	...	...	106	147	194	250	313
⅝	...	...	107	149	197	254	317
¾	...	...	109	151	199	257	321
⅞	...	...	110	153	202	261	326
8	...	...	...	155	205	264	330
⅛	...	...	...	157	208	268	334
¼	...	...	...	159	211	271	339
⅜	...	...	...	161	213	275	343
½	...	...	...	164	216	278	347
⅝	...	...	...	166	219	282	352
¾	...	...	...	168	222	285	356
⅞	...	...	...	170	224	289	360

WEIGHT WITH ONE COUNTERSUNK HEAD IN POUNDS PER 100

For Countersunk Rivets, use weight given above with following deductions.	Diameter of Rivet, Inches						
	½	⅝	¾	⅞	1	1⅛	1¼
Deduction, Lb.	3	4	7	12	18	26	36

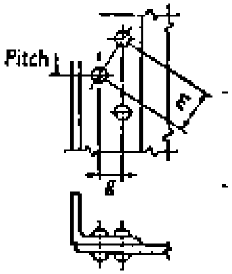
WEIGHT OF HIGH BUTTON (ACORN) HEADS AFTER DRIVING

Diameter of Rivet, Inches	½	⅝	¾	⅞	1	1⅛	1¼
Weight per 100 Heads, Lb.	4	7	12	18	26	36	49



RIVETS

Spacing



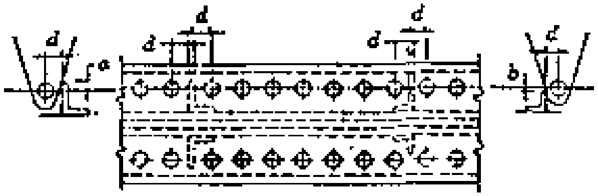
MINIMUM PITCH FOR MACHINE RIVETING

Diam. of Rivet	c	k	Distance, f, inches													
			1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜	2½	2¾	3
⅜	⅞	1³⁄₁₆	¼	0												
½	1	1⅜	¾	½	0											
⅝	1⅛	1⁹⁄₁₆	1⅛	1	¾	⅝	0									
¾	1¼	1¾	...	1¼	1⅛	1	¾	0								
⅞	1⅜	2	...	...	1½	1⅜	1⅛	⅞	⅝	0						
1	1½	2³⁄₁₆	...	...	...	1⅝	1½	1⅜	1⅛	⅞	½	0				
1⅛	1⅝	2⅜	...	...	...	...	1¾	1⅝	1½	1⅜	1⅛	⅞	0			
1¼	1¾	2⅝	...	...	...	...	...	2	1⅞	1¾	1½	1¼	1	⅝	0	
1⅜	1⅞	2¹³⁄₁₆	...	...	...	...	...	...	2⅛	2	1⅞	1¾	1½	1¼	½	0
1½	2	3	...	...	...	...	...	...	...	2¼	2⅛	2	1⅞	1⅝	1⅛	0

MINIMUM PITCH TO MAINTAIN 3 DIAMETERS C. TO C.

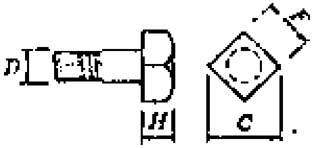
Diam. of Rivet	m	Distance, g, Inches														
		1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½
⅜	1⅛	½	0													
½	1½	1⅛	⅞	0												
⅝	1⅞	1⅝	1⅜	1⅛	⅝	0										
¾	2¼	2	1⅞	1⅝	1⅜	1	0									
⅞	2⅝	2½	2⅜	2⅛	2	1¾	1⅜	¾	0							
1	3	2⅞	2¾	2⅝	2½	2¼	2	1⅝	1¼	0						
1⅛	3⅜	3¼	3⅛	3	2⅞	2¾	2½	2¼	2	1½	⅞	0				
1¼	3¾	3⅝	3½	3⅜	3⅜	3¼	3	2¾	2½	2¼	1⅞	1⅜	0			
1⅜	4⅛	4	4	3⅞	3¾	3⅝	3½	3¼	3⅛	2⅞	2⅝	2⅛	1¾	1	0	
1½	4½	4⅜	4⅜	4¼	4⅛	4	3⅞	3¾	3½	3⅜	3⅛	2⅞	2½	2	1½	0

COVER PLATE RIVETING

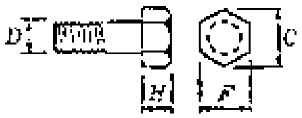


a In.	d In.	b In.	d In.
½	2½		2½
1	2⅝	½	2⅜
1½	2¾	¾	2¼
2	2¾	1	2¼
2½	2⅞	1¼	2⅛
3	2⅞	1½	2
3½	3	1¾	1¾
4	3⅛	2	1½
5	3¼	2¼	1
6	3⅜	2½	...

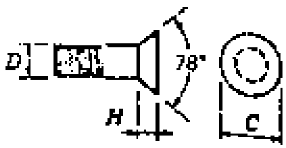
Bolt heads



Square



Hex



Countersunk

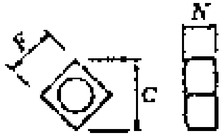
Bolt head dimensions, rounded to nearest 1/16 inch, are in accordance with ANSI B18.2.1—1965 (Square and Hex) and ANSI 16.5—1959 (Countersunk)

Standard Dimensions for Bolt Heads

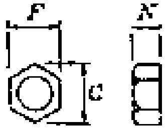
Diam. of Bolt D	Square Width F	Square Width C	Square Height H	Hex Width F	Hex Width C	Hex Height H	Heavy Hex Width F	Heavy Hex Width C	Heavy Hex Height H	Countersunk Diam. C	Countersunk Height H
In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
¼	⅜	½	3/16	7/16	½	3/16	...	...	...	½	⅛
⅜	9/16	13/16	¼	9/16	⅝	¼	...	...	...	11/16	3/16
½	¾	1 1/16	5/16	¾	⅞	5/16	⅞	1	5/16	⅞	¼
⅝	15/16	1 5/16	7/16	15/16	1 1/16	7/16	1 1/16	1¼	7/16	1⅛	5/16
¾	1⅛	1 9/16	½	1⅛	1 5/16	½	1¼	1 7/16	½	1⅜	⅜
⅞	1 5/16	1⅞	⅝	1 5/16	1½	⅝	1 7/16	1 11/16	⅝	1 9/16	7/16
1	1½	2⅛	11/16	1½	1¾	11/16	1⅝	1⅞	11/16	1 13/16	½
1⅛	1 11/16	2⅜	¾	1 11/16	1 15/16	¾	1 13/16	2 1/16	¾	2 1/16	9/16
1¼	1⅞	2⅝	⅞	1⅞	2 3/16	⅞	2	2 5/16	⅞	2¼	⅝
1⅜	2 1/16	2 15/16	15/16	2 1/16	2⅜	15/16	2 3/16	2½	15/16	2½	11/16
1½	2¼	3 3/16	1 1/16	2¼	2⅝	1 1/16	2⅜	2¾	1 1/16	2 11/16	¾
1¾	...	...	...	2⅝	3	1 3/16	2¾	3 3/16	1 3/16	...	...
2	...	...	...	3	3 7/16	1⅜	3⅛	3⅝	1⅜	...	...
2¼	...	...	...	3⅜	3⅞	1 9/16	3½	4 1/16	1 9/16	...	...
2½	...	...	...	3¾	4 5/16	1 11/16	3⅞	4½	1 11/16	...	...
2¾	...	...	...	4⅛	4¾	1⅞	4¼	4 15/16	1⅞	...	...
3	...	...	...	4½	5 3/16	2 1/16	4⅝	5 5/16	2⅛	...	...
3¼	...	...	...	4⅞	5⅝	2¼	...	...	...	...	...
3½	...	...	...	5¼	6 1/16	2⅜	...	...	...	...	...
3¾	...	...	...	5⅝	6½	2 9/16	...	...	...	...	...
4	...	...	...	6	6 15/16	2¾	...	...	...	...	...

For dimensions for high strength bolts, refer to "Specifications for Structural Joints Using ASTM A325 or A490 Bolts" in Part 5 of this manual.

Nuts



Square



Hex

Nut dimensions, rounded to nearest 1/16 inch, are in accordance with ANSI B18.2.2—1965.

Dimensions for Nuts

Nut Size	Square Width F	Square Width C	Square Height N	Hex Width F	Hex Width C	Hex Height N	Heavy Square Width F	Heavy Square Width C	Heavy Square Height N	Heavy Hex Width F	Heavy Hex Width C	Heavy Hex Height N
In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
¼	7/16	⅝	¼	7/16	½	¼	½	11/16	¼	½	9/16	¼
⅜	⅝	⅞	⅜	9/16	⅝	5/16	11/16	1	⅜	11/16	13/16	⅜
½	13/16	1⅛	7/16	¾	⅞	7/16	⅞	1¼	½	⅞	1	½
⅝	1	1 7/16	9/16	15/16	1 1/16	9/16	1 1/16	1½	⅝	1 1/16	1¼	⅝
¾	1⅛	1 9/16	11/16	1⅛	1 5/16	11/16	1¼	1¾	¾	1¼	1 7/16	¾
⅞	1 5/16	1⅞	13/16	1 5/16	1½	¾	1 7/16	2 1/16	⅞	1 7/16	1 11/16	⅞
1	1½	2⅛	⅞	1½	1¾	⅞	1⅝	2 5/16	1	1⅝	1⅞	1
1⅛	1 11/16	2⅜	1	1 11/16	1 15/16	1	1 13/16	2 9/16	1⅛	1 13/16	2 1/16	1⅛
1¼	1⅞	2⅝	1⅛	1⅞	2 3/16	1⅛	2	2 13/16	1 3/16	2	2 5/16	1¼
1⅜	2 1/16	2 15/16	1¼	2 1/16	2⅜	1 3/16	2 3/16	3⅛	1 5/16	2 3/16	2½	1⅜
1½	2¼	3 3/16	1⅜	2¼	2⅝	1 5/16	2⅜	3⅜	1 7/16	2⅜	2¾	1½
1¾	...	...	...	...	...	...	...	...	...	2¾	3 3/16	1¾
2	...	...	...	...	...	...	...	...	...	3⅛	3⅝	2
2¼	...	...	...	...	...	...	...	...	...	3½	4 1/16	2¼
2½	...	...	...	...	...	...	...	...	...	3⅞	4½	2½
2¾	...	...	...	...	...	...	...	...	...	4¼	4 15/16	2¾
3	...	...	...	...	...	...	...	...	...	4⅝	5 5/16	3
3¼	...	...	...	...	...	...	...	...	...	5	5¾	3¼
3½	...	...	...	...	...	...	...	...	...	5⅜	6 3/16	3½
3¾	...	...	...	...	...	...	...	...	...	5¾	6⅝	3¾
4	...	...	...	...	...	...	...	...	...	6⅛	7 1/16	4

For dimensions for high strength bolts, refer to "Specifications for Structural Joints Using ASTM A325 or A490 Bolts" in Part 5 of this manual.

THREADED FASTENERS

Weight of bolts

With square heads and hexagon nuts in pounds per 100

Length Under Head Inches	Diameter of Bolt in Inches								
	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼
1	2.38	6.11	13.0	24.1	38.9	...	...	...	...
1¼	2.71	6.71	14.0	25.8	41.5	...	...	...	...
1½	3.05	7.47	15.1	27.6	44.0	67.3	95.1	...	...
1¾	3.39	8.23	16.5	29.3	46.5	70.8	99.7	...	...
2	3.73	8.99	17.8	31.4	49.1	74.4	104	143	...
2¼	4.06	9.75	19.1	33.5	52.1	77.9	109	149	...
2½	4.40	10.5	20.5	35.6	55.1	82.0	114	155	206
2¾	4.74	11.3	21.8	37.7	58.2	86.1	119	161	213
3	5.07	12.0	23.2	39.8	61.2	90.2	124	168	221
3¼	5.41	12.8	24.5	41.9	64.2	94.4	129	174	229
3½	5.75	13.5	25.9	44.0	67.2	98.5	135	181	237
3¾	6.09	14.3	27.2	46.1	70.2	103	140	188	246
4	6.42	15.1	28.6	48.2	73.3	107	145	195	254
4¼	6.76	15.8	29.9	50.3	76.3	111	151	202	262
4½	7.10	16.6	31.3	52.3	79.3	115	156	208	271
4¾	7.43	17.3	32.6	54.4	82.3	119	162	215	279
5	7.77	18.1	33.9	56.5	85.3	123	167	222	288
5¼	8.11	18.9	35.3	58.6	88.4	127	172	229	296
5½	8.44	19.6	36.6	60.7	91.4	131	178	236	304
5¾	8.78	20.4	38.0	62.8	94.4	136	183	242	313
6	9.12	21.1	39.3	64.9	97.4	140	188	249	321
6¼	9.37	21.7	40.4	66.7	100	143	193	255	329
6½	9.71	22.5	41.8	68.7	103	147	198	262	337
6¾	10.1	23.3	43.1	70.8	106	151	204	269	345
7	10.4	24.0	44.4	72.9	109	156	209	275	354
7¼	10.7	24.8	45.8	75.0	112	160	214	282	362
7½	11.0	25.5	47.1	77.1	115	164	220	289	371
7¾	11.4	26.3	48.5	79.2	118	168	225	296	379
8	11.7	27.0	49.8	81.3	121	172	231	303	387
8½	...	28.6	52.5	85.5	127	180	241	316	404
9	...	30.1	55.2	89.7	133	189	252	330	421
9½	...	31.6	57.9	53.9	139	197	263	343	438
10	...	33.1	60.6	98.1	145	205	274	357	454
10½	...	34.6	63.3	102	151	213	284	371	471
11	...	36.2	66.0	106	157	221	295	384	488
11½	...	37.7	68.7	110	163	230	306	398	505
12	...	39.2	71.3	115	170	238	316	411	522
12½	...	...	74.0	119	176	246	327	425	538
13	...	...	76.7	123	182	254	338	439	556
13½	...	...	79.4	127	188	263	349	452	572
14	...	...	82.1	131	194	271	359	466	589
14½	...	...	84.8	135	200	279	370	479	605
15	...	...	87.5	140	206	287	381	493	622
15½	...	...	90.2	144	212	296	392	507	639
16	...	...	92.9	148	218	304	402	520	656
Per Inch Additional	1.3	3.0	5.4	8.4	12.1	16.5	21.4	27.2	33.6

Note: Bolt is Square Bolt, ANSI B18.2.1—65 and nut is Hex Nut, ANSI B18.2.2—65. This table conforms to weight standards adopted by the Industrial Fasteners Institute.

THREADED FASTENERS

Weight of bolts

Special cases in pounds per 100

VARIATIONS IN BOLT AND NUT TYPES

Weights for combinations of bolt heads and nuts, other than square heads and hex nuts, may be determined by making the appropriate additions and deductions tabulated below from the weight per 100 shown on the previous page.

Combination	Add or Subtract	Diameter of Bolt in Inches								
		¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼
Square bolt with square nut	+	0.1	1.0	2.0	3.4	3.5	5.5	8.0	12.2	16.3
Square bolt with heavy square nut	+	0.6	2.1	4.1	7.0	11.6	17.2	23.2	32.1	41.2
Square bolt with heavy hex nut	+	0.4	1.5	2.8	4.6	7.6	10.7	14.2	18.9	24.3
Hex bolt with square nut	+	0.1	0.6	1.1	1.4	0.2	0.5	−0.2	−0.1	−1.7
Hex bolt with hex nut	−	0.0	0.4	0.9	2.0	3.3	5.0	8.2	12.3	18.0
Hex bolt with heavy square nut	+	0.6	1.7	3.2	5.0	8.3	12.2	15.0	19.8	23.2
Hex bolt with heavy hex nut	+	0.4	1.1	1.9	2.6	4.3	5.7	6.0	6.6	6.3
Heavy hex bolt with heavy square nut	+	...	...	4.7	7.3	11.3	16.5	20.7	27.0	33.6
Heavy hex bolt with heavy hex nut	+	...	...	3.4	4.9	7.3	10.0	11.7	13.8	16.7

LARGE DIAMETER BOLTS

Weights of bolts over 1¼ inches in diameter may be calculated from the following data. Standard practice is hex head bolts with heavy hex nut. Square head bolts and square nuts are not standard in sizes over 1½ inches.

Weight of 100 Each	Diameter of Bolt in Inches											
	1⅜	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4
Square heads	105	130	...	...	...	...	...	...	...	...	...	...
Hex heads	84	112	178	259	369	508	680	900	1120	1390	1730	2130
Heavy hex heads	95	124	195	280	397	541	720	950	...	...	...	...
Square nuts	94.5	172	...	...	...	...	...	...	...	...	...	...
Heavy square nuts	125	161	...	...	...	...	...	...	...	...	...	...
Heavy hex nuts	102	131	204	299	419	564	738	950	1190	1530	1810	2190
Linear inch of threaded shank	35.0	42.5	57.4	75.5	97.4	120	147	178	210	246	284	325
Linear inch of unthreaded shank	42.0	50.0	68.2	89.0	113	139	168	200	235	272	313	356

Weight of ASTM A325 or A490 high strength bolts

Heavy hex structural bolts with heavy hex nuts in pounds per 100

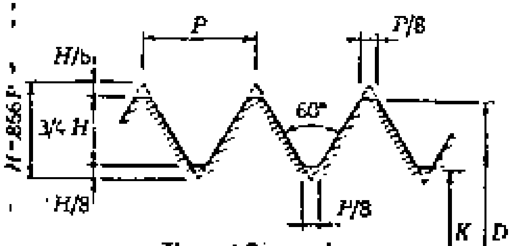
Length Under Head Inches	Diameter of Bolt in Inches								
	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½
1	16.5	29.4	47.0	...	...	...	...	...	...
1¼	17.8	31.1	49.6	74.4	104	...	...	...	...
1½	19.2	33.1	52.2	78.0	109	148	197	...	...
1¾	20.5	35.3	55.3	81.9	114	154	205	261	333
2	21.9	37.4	58.4	86.1	119	160	212	270	344
2¼	23.3	39.8	61.6	90.3	124	167	220	279	355
2½	24.7	41.7	64.7	94.6	130	174	229	290	366
2¾	26.1	43.9	67.8	98.8	135	181	237	300	379
3	27.4	46.1	70.9	103	141	188	246	310	391
3¼	28.8	48.2	74.0	107	146	195	255	321	403
3½	30.2	50.4	77.1	111	151	202	263	332	416
3¾	31.6	52.5	80.2	116	157	209	272	342	428
4	33.0	54.7	83.3	120	162	216	280	353	441
4¼	34.3	56.9	86.4	124	168	223	289	363	453
4½	35.7	59.0	89.5	128	173	230	298	374	465
4¾	37.1	61.2	92.7	133	179	237	306	384	478
5	38.5	63.3	95.8	137	184	244	315	395	490
5¼	39.9	65.5	98.9	141	190	251	324	405	503
5½	41.2	67.7	102	146	196	258	332	416	515
5¾	42.6	69.8	105	150	201	265	341	426	527
6	44.0	71.9	108	154	207	272	349	437	540
6¼	...	74.1	111	158	212	279	358	447	552
6½	...	76.3	114	163	218	286	367	458	565
6¾	...	78.5	118	167	223	293	375	468	577
7	...	80.6	121	171	229	300	384	479	589
7¼	...	82.8	124	175	234	307	392	489	602
7½	...	84.9	127	179	240	314	401	500	614
7¾	...	87.1	130	183	246	321	410	510	626
8	...	89.2	133	187	251	328	418	521	639
8¼	...	...	...	192	257	335	427	531	651
8½	...	...	...	196	262	342	435	542	664
8¾	...	...	...	...	...	...	444	552	676
9	...	...	...	...	...	...	453	563	689
Per inch additional add	5.5	8.6	12.4	16.9	22.1	28.0	34.4	42.5	49.7
For each 100 plain round washers add	2.1	3.6	4.8	7.0	9.4	11.3	13.8	16.8	20.0
For each 100 beveled square washers add	23.1	22.4	21.0	20.2	19.2	34.0	31.6	...	...

Note: This conforms to weight standards adopted by the Industrial Fasteners Institute, 1965, updated for washer weights.

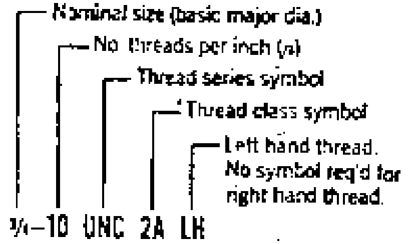
SCREW THREADS

Unified Standard Series—UNC and 4 UN

ANSI B1.1—1960



Thread Dimensions



Standard Designations

Diameter		Area			ᵇThr'ds per Inch	Diameter		Area			ᵇThr'ds per Inch
Basic Major D	Root K	Gross A_D	Root A_K	ªTensile Stress	n	Basic Major D	Root K	Gross A_D	Root A_K	ªTensile Stress	n
In.	In.	In.²	In.²	In.²		In.	In.	In.²	In.²	In.²	
¼	.185	.049	.027	.032	20	2¾	2.425	5.940	4.62	4.93	4
⅜	.794	.110	.068	.078	16	3	2.675	7.069	5.62	5.97	4
½	.400	.196	.126	.142	13	3¼	2.925	8.296	6.72	7.10	4
⅝	.507	.307	.202	.226	11	3½	3.175	9.621	7.92	8.33	4
¾	.620	.442	.302	.334	10	3¾	3.425	11.045	9.21	9.66	4
⅞	.731	.601	.419	.462	9	4	3.675	12.566	10.6	11.1	4
1	.838	.785	.551	.606	8	4¼	3.925	14.186	12.1	12.6	4
1⅛	.939	.994	.693	.763	7	4½	4.175	15.904	13.7	14.2	4
1¼	1.064	1.227	.890	.969	7	4¾	4.425	17.721	15.4	16.0	4
1⅜	1.158	1.485	1.05	1.16	6	5	4.675	19.635	17.2	17.8	4
1½	1.283	1.767	1.29	1.41	6	5¼	4.925	21.648	19.1	19.7	4
1¾	1.490	2.405	1.74	1.90	5	5½	5.175	23.758	21.0	21.7	4
2	1.711	3.142	2.30	2.50	4½	5¾	5.425	25.967	23.1	23.8	4
2¼	1.961	3.976	3.02	3.25	4½	6	5.675	28.274	25.3	26.0	4
2½	2.175	4.909	3.72	4.00	4						

ª Tensile stress area = $0.7854\left(D - \frac{.9743}{n}\right)^2$

ᵇ For basic major diameters of ¼ to 4 in. incl., thread series is UNC (coarse); for 4¼ in. diameter and larger, thread series is 4UN.

ᶜ 2A denotes Class 2A fit applicable to external threads. 2B denotes corresponding Class 2B fit for internal threads.

MINIMUM LENGTH OF THREAD ON BOLTS

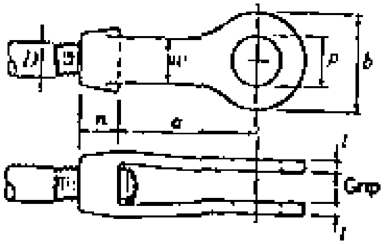
ANSI B18.2.1—1965

Length of Bolt	Diameter of Bolt, D, Inches																
	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1¾	2	2¼	2½	2¾	3
To 6 in. Incl.	¾	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3¾	4¼	4¾	5¼	5¾	6
Over 6 in.	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	4	4½	5	5½	6	6½

Note 1. Thread length for bolts up to 6 in. long is $2D + \frac{1}{4}$. For bolts over 6 in. long, thread length is $2D + \frac{1}{2}$. These proportions may be used to compute thread length for diameters not shown in the table. Bolts which are too short for listed or computed thread lengths are threaded as close to the head as possible.

Note 2. For thread lengths for high strength bolts, refer to "Specifications for Structural Joints Using ASTM A325 or A490 Bolts," in Part 5 of this manual.

CLEVISES



Grip = thickness plate + ¼"

Thread: UNC Class 2B

Clevis Number	Dimensions, Inches							Weight Pounds	Safe Working Load, Kips*
	Max. D	Max. p	b	n	a	w	t		
2	⅝	¾	1 7/16	⅝	3⅜	1 1/16	5/16(+ 1/32 − 0)	1.0	7.0
2½	⅞	1½	2½	1⅛	4	1¼	7/16(+ 1/32 − 0)	2.0	7.5
3	1⅜	1¾	3	1 9/16	5	1½	½(+ 1/32 − 0)	4.0	15
3½	1½	2	3½	1⅝	6	1¾	½(+ 1/32 − 0)	6.0	18
4	1¾	2¼	4	1¾	6	2	½(+ 1/32 − 0)	8.0	21
5	2	2½	5	2¼	7	2½	⅝(+ 1/16 − 0)	16.0	37.5
6	2½	3	6	2¾	8	3	¾(+ 1/32 − 0)	26.0	54
7	3	3¾	7	3	9	3½	⅞(+ ⅛ − 0)	36.0	68.5
8	4	4	8	4	10	4	1½(+ ⅛ − 0)	80.0	135

* Safe working load based on 5:1 safety factor using maximum pin diameter.

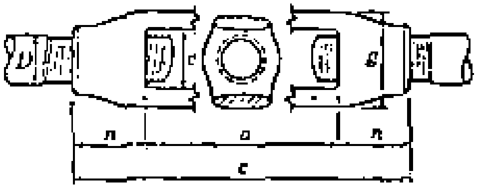
CLEVIS NUMBERS FOR VARIOUS RODS AND PINS

Diameter of Tap Inches	Diameter of Pin, Inches															
	⅝	¾	⅞	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4
⅝	2	2	2½	2½	2½	2½										
¾	...	2½	2½	2½	2½	2½										
⅞	...	...	2½	2½	2½	2½										
1	...	...	...	3	3	3	3									
1¼	...	...	...	3	3	3	3	3½								
1⅜	...	...	...	3	3	3	3½	3½	4							
1½	...	...	...	3½	3½	3½	4	4	5							
1¾	...	...	...	...	4	4	5	5	5	6						
2	...	...	...	...	...	5	5	5	5	5	6	6				
2¼	...	...	...	...	...	...	...	6	6	6	6	6	7	7		
2½	...	...	...	...	...	...	...	6	6	6	7	7	7	7	7	
2¾	...	...	...	...	...	...	...	...	...	7	7	7	7	8	8	
3	...	...	...	...	...	...	...	...	...	7	8	8	8	8	8	8
3¼	...	...	...	...	...	...	...	...	...	...	8	8	8	8	8	8
3½	...	...	...	...	...	...	...	...	...	...	8	8	8	8	8	8
3¾	...	...	...	...	...	...	...	...	...	...	8	8	8	8	8	8
4	...	...	...	...	...	...	...	...	...	...	8	8	8	8	8	8

Above Table of Clevis Sizes is based on the Net Area of Clevis through Pin Hole being equal to or greater than 125 per cent of Net Area of Rod. Table applies to round rods without upset ends. Pins are sufficient for shear but must be investigated for bending. For other combinations of pin and rod or net area ratios, required clevis size can be calculated by reference to the tabulated dimensions.

Weights and dimensions of clevises are typical. Products of all suppliers are similar and essentially the same.

TURNBUCKLES



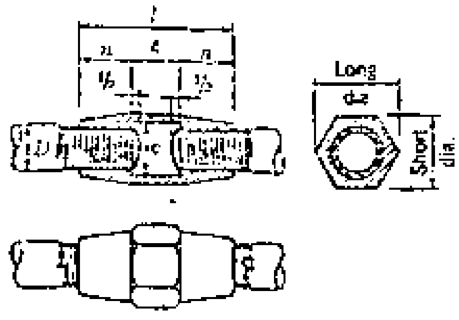
Thread: UNC and 4 UN Class 2B

Diam. D In.	Standard Turnbuckles					Weight of Turnbuckles, Pounds						Turnbuckle Safe Working Load, Kips*
	Dimensions, Inches					Length, a, Inches						
	a	n	c	e	g	6	9	12	18	24	36	
⅜	6	9/16	7⅛	9/16	1 5/32	.41						1.2
½	6	¾	7½	11/16	1 5/16	.75	.80	1.00				2.2
⅝	6	29/32	7 13/16	13/16	1½	1.00	1.38	1.50	2.43			3.5
¾	6	1 1/16	8⅛	15/16	1 25/32	1.45	1.63	2.13	3.06	4.25		5.2
⅞	6	1 7/32	8 7/16	1 1/32	1⅞	1.85		2.83	4.20	5.43		7.2
1	6	1⅜	8¾	1 5/32	2 1/32	2.60		3.20	4.40	6.85	10.0	9.3
1⅛	6	1 9/16	9⅛	1 11/32	2 9/32	2.72		4.70	6.10			11.6
1¼	6	1¾	9½	1 7/16	2 17/32	3.58		4.70	7.13	11.30	13.1	15.2
1⅜	6	1 15/16	9⅞	1 11/16	2¾	4.50						17.4
1½	6	2⅛	10¼	1 23/32	3 1/32	5.50		8.00	9.13	16.80	19.4	21.0
1⅝	6	2¼	10½	1 29/32	3 9/32	7.50						24.5
1¾	6	2½	11	2⅛	3 9/16	9.50		15.25	16.00	19 50		28.3
1⅞	6	2¾	11½	2⅜	4	11.50						37.2
2	6	2¾	11½	2⅜	4	11.50		15.25		27.50		37.2
2¼	6	3⅛	12¼	2 11/16	4⅝	18.00		35.25		43.50		48.0
2½	6	3¾	13½	3	5	23.25		33.60		42.38		60.0
2¾	6	4⅛	14¼	3¼	5⅝	31.50				54.00		75.0
3	6	4½	15	3⅝	6⅛	39.50						96.7
3¼	6	5¼	16½	3⅞	6⅝	60.50						122.2
3½	6	5¼	16½	3⅞	6⅝	60.50						122.2
3¾	6	6	18	4⅜	8½	95.00						167.8
4	6	6	18	4⅜	8½	95.00						167.8
4¼	9	6¾	22½	5¼	9¾		152.0					233.8
4½	9	6¾	22½	5¼	9¾		152.0					233.8
4¾	9	6¾	22½	5¼	9¾		152 0					233.8
5	9	7½	24	6	10		200.0					294.7

* Safe working load based on 5:1 safety factor.

Weights and dimensions of turnbuckles are typical. Products of all suppliers are similar and essentially the same.

SLEEVE NUTS



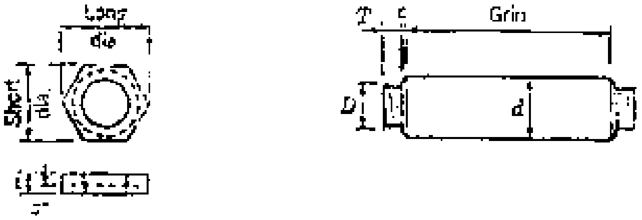
Thread: UNC and 4 UN Class 2B

Diameter of Screw D Inches	Dimensions, Inches					
	Short Diameter	Long Diameter	Length l	Nut n	Clear c	Weight Pounds
⅜	11/16	25/32	4	...	...	.27
7/16	25/32	⅞	4	...	...	.34
½	⅞	1	4	...	...	.43
9/16	15/16	1 1/16	5	...	...	.64
⅝	1 1/16	1 7/32	5	...	...	.93
¾	1¼	1 7/16	5	...	...	1.12
⅞	1 7/16	1⅝	7	1 3/16	1	1.75
1	1⅝	1 13/16	7	1 7/16	1⅛	2.46
1⅛	1 13/16	2 1/16	7½	1⅝	1¼	3.10
1¼	2	2¼	7½	1⅝	1⅜	4.04
1⅜	2 3/16	2½	8	1¾	1½	4.97
1½	2⅜	2 11/16	8	1⅞	1⅝	6.16
1⅝	2 9/16	2 15/16	8½	2 1/16	1¾	7.36
1¾	2¾	3⅛	8½	2 3/16	1⅞	8.87
1⅞	2 15/16	3 5/16	9	2 5/16	2	10.42
2	3⅛	3½	9	2 7/16	2⅛	12.24
2¼	3½	3 13/16	9½	2½	2⅜	16.23
2½	3⅞	4⅜	10	2¾	2⅝	21.12
2¾	4¼	4 13/16	10½	2 15/16	2⅞	26.71
3	4⅝	5¼	11	3 3/16	3⅛	33.22
3¼	5	5⅝	11½	3⅜	3⅜	40.62
3½	5⅜	6	12	3⅝	3⅝	49.07
3¾	5¾	6⅜	12½	3 15/16	3⅞	58.57
4	6⅛	6⅞	13	4 1/16	4⅛	69.22
4¼	6½	7½	13½	4¼	4⅜	75.00
4½	6⅞	7 15/16	14	5	4¾	90.00
4¾	7¼	8⅜	14½	5¼	5	98.00
5	7⅝	8⅞	15	5½	5¼	110.0
5¼	8	9¼	15½	5¾	5½	122.0
5½	8⅜	9¾	16	6	5¾	142.0
5¾	8¾	10⅛	16½	6¼	6	157.0
6	9⅛	10⅝	17	6½	6¼	176.0

Strengths are greater than the corresponding connecting rod when same material is used.

Weights and dimensions are typical. Products of all suppliers are similar and essentially the same.

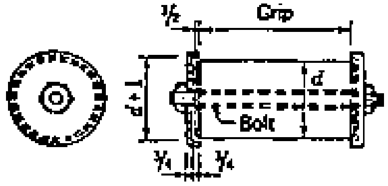
RECESSED PIN NUTS AND COTTER PINS



Material: Steel

Thread: 6 UN Class 2A/2B

Diameter of Pin d			PIN			NUT (Suggested Dimensions)					
			Thread		c	Thickness t	Diameter		Recess		Weight Pounds
			D	T			Short Diam.	Long Diam.	Rough Diam.	s	
	2	2¼	1½	1	⅛	¾	3	3½	2⅝	¼	1
	2½	2¾	2	1⅛	⅛	1	3⅝	4⅛	3⅛	¼	2
3	3¼	3½	2½	1¼	¼	1⅛	4⅛	5	3⅞	⅜	3
	3¾	4	3	1⅜	¼	1¼	4⅝	5⅜	4⅜	⅜	4
4¼	4½	4¾	3½	1½	¼	1⅜	5¼	6⅜	5¼	½	5
	5	5¼	4	1⅝	¼	1½	6¼	7¼	5¾	½	6
5½	5¾	6	4½	1¾	¼	1⅝	7	8⅛	6½	⅝	8
	6¼	6½	5	1⅞	⅜	1¾	7⅝	8⅞	7	⅝	10
	6¾	7	5½	2	⅜	1⅞	8⅛	9⅜	7½	¾	12
	7¼	7½	5½	2	⅜	1⅞	8⅝	10	8	¾	14
7¾	8	8¼	6	2¼	⅜	2⅛	9⅝	10⅞	8¾	¾	19
8½	8¾	9	6	2¼	⅜	2⅛	10¼	11⅜	9⅝	¾	24
	9¼	9½	6	2⅜	⅜	2¼	11¼	13	10⅝	¾	32
	9¾	10	6	2⅜	⅜	2¼	11¼	13	10⅝	¾	32

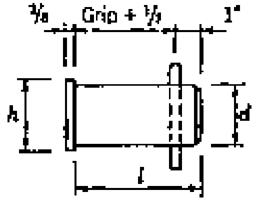


Typical Pin Cap Detail for Pins over 10 Inches in Diameter

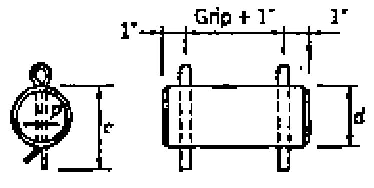
Dimensions shown are approximate

Although nuts may be used on all sizes of pins as shown above, for pins over 10" in diameter the preferred practice is a detail similar to that shown at the left, in which the pin is held in place by a recessed cap at each end and secured by a bolt passing completely through the caps and pin. Suitable provision must be made for attaching pilots and driving nuts.

HORIZONTAL OR VERTICAL PIN



HORIZONTAL PIN



l = Length of pin, in Inches.

Pin Diam. d	Pins With Heads		Cotter			Pin Diam. d	Pins With Heads		Cotter		
	Head Diam. h	Weight of One (Lb.)	Length c	Diam. p	Wt. per 100 (Lb.)		Head Diam. h	Weight of One (Lb.)	Length c	Diam. p	Wt. per 100 (Lb.)
1¼	1½	.19+ .35l	2	¼	2.64	2¾	3⅛	.82+1.68l	4	⅜	11.4
1½	1¾	.26+ .50l	2½	¼	3.10	3	3½	1.02+2.00l	5	½	28.5
1¾	2	.33+ .68l	2¾	¼	3.50	3¼	3¾	1.17+2.35l	5	½	28.5
2	2⅜	.47+ .89l	3	⅜	9.00	3½	4	1.34+2.73l	6	½	33.8
2¼	2⅝	.58+1.13l	3¼	⅜	9.40	3¾	4⅛	1.51+3.13l	6	½	33.8
2½	2⅞	.70+1.39l	3¾	⅜	10.9						

BENT PLATES

Minimum radius for cold bending

The following table gives the generally accepted minimum inside radii of bends in terms of thickness, *t*, for various steels listed. Values are for bend lines transverse to the direction of final rolling. When bend lines are parallel to the direction of final rolling, the values may have to be approximately doubled. When bend lines are longer than 36 inches, all radii may have to be increased if problems in bending are encountered.

Before bending, special attention should be paid to the condition of plate edges transverse to the bend lines. Flame cut edges of hardenable steels should be machined or softened by heat treatment. Nicks should be ground out. Sharp corners should be rounded.

ASTM Designation		Thickness, inches				
		Up to ¼	Over ¼ to ½	Over ½ to 1	Over 1 to 1½	Over 1½ to 2
A36		1½*t*	1½*t*	2*t*	3*t*	4*t*
A242		2*t*	3*t*	5*t*	[a]...	[a]...
A440		2½*t*	3½*t*	6*t*	[a]...	[a]...
A441		2*t*	3*t*	5*t*	[a]...	[a]...
A529		2*t*	2*t*	...	...	...
A572	Gr. 42	2*t*	2*t*	3*t*	4*t*	5*t*
	Gr. 45	2*t*	2*t*	3*t*	4*t*	...
	Gr. 50	2½*t*	2½*t*	4*t*	[a]...	...
	Gr. 55	3*t*	3*t*	5*t*	[a]...	...
	Gr. 60	3½*t*	3½*t*	6*t*	...	...
	Gr. 65	4*t*	4*t*	...	...	...
A588		2*t*	3*t*	5*t*	[a]...	[a]...
A514[b]		2*t*	2*t*	2*t*	3*t*	3*t*

[a] It is recommended that steel in this thickness range be bent hot. Hot bending, however, may result in a slight decrease in the as rolled mechanical properties.

[b] The mechanical properties of ASTM A514 steel results from a quench-and temper operation. Hot bending may adversely affect these mechanical properties. If necessary to hot-bend, fabricator should discuss procedure with the steel supplier.

WELDED JOINTS

Requirements

The AISC Specification and the *Structural Welding Code* of the American Welding Society exempt from tests and qualification most of the common welded joints applicable to steel structures. When the joints detailed on the following pages are welded in accordance with these standards they are designated as *prequalified* for building construction.

AWS prequalification of a weld joint is based upon experience that sound weld metal with appropriate mechanical properties can be deposited. However, use of prequalified joints does not necessarily assure satisfactory performance in heavy highly restrained connections. For additional information refer to *Design, Fabrication and Erection of Highly Restrained Joints to Minimize Lamellar Tearing*, AISC, 1973.

In general, all fillet welds are deemed prequalified, whether illustrated or not, provided they conform to requirements of the AWS Code and the AISC Specification.

These prequalified joints are limited to those made by the manual shielded metal-arc, submerged arc, gas metal-arc and flux cored arc welding processes. Small deviations from dimensions, angles of grooves, and variation in the depth of groove joints are permissible; consult the AWS Code for allowable variation of dimensions and for workmanship tolerances. Other joint forms and welding procedures may be employed provided they are tested and qualified in accordance with AWS D1.1-72.

Most prequalified joints illustrated are also applicable for bridge construction. (See footnotes to joint illustrations in Section 2 and to prohibited types in Section 9 of D1.1-72.)

The designations such as B-L1a, B-L2, B-U2, B-P3 which are given on the following pages are those used in the AWS standards. Groove welds are classified using the following convention:

1. *Symbols for Joint Types*
   - B—butt joint
   - C—corner joint
   - T—tee joint
   - BC—butt or corner joint
   - TC—tee or corner joint
   - BTC—butt, tee or corner joint
2. *Symbols for Base Metal Thickness and Penetration*
   - L—limited thickness, complete joint penetration
   - U—unlimited thickness, complete joint penetration
   - P—partial joint penetration
3. *Symbols for Weld Types*
   - 1—square groove
   - 2—single-vee groove
   - 3—double-vee groove
   - 4—single-bevel groove
   - 5—double-bevel groove
   - 6—single-U groove
   - 7—double-U groove
   - 8—single-J groove
   - 9—double-J groove
4. *Symbols for Welding Processes*

   If not manual shielded metal arc:
   - S—submerged arc
   - G—gas metal arc
   - F—flux cored arc

Standard symbols

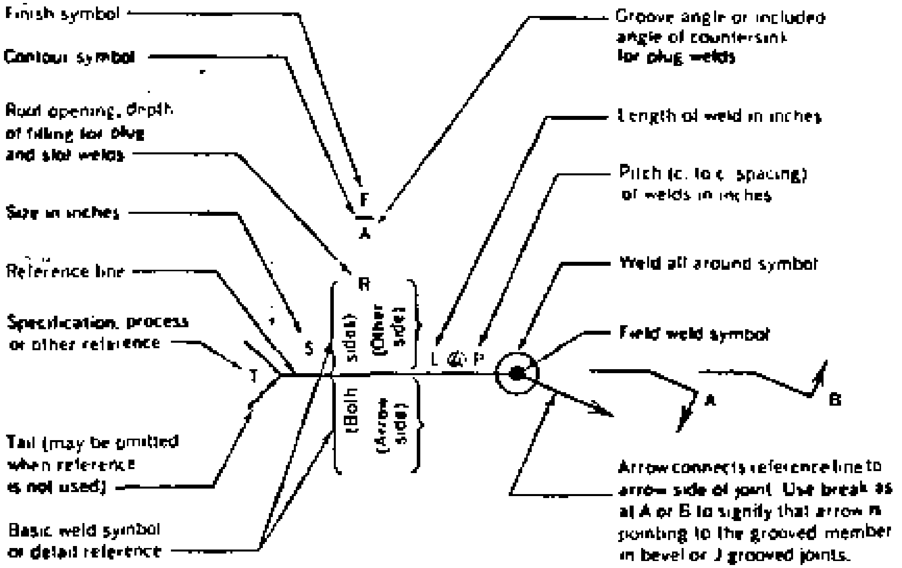
BASIC WELD SYMBOLS

BACK	FILLET	PLUG OR SLOT	GROOVE OR BUTT						
			SQUARE	V	BEVEL	U	J	FLARE V	FLARE BEVEL
⌓	◺	▭	‖	∨	|/	⋃	|)	)(	|(

SUPPLEMENTARY WELD SYMBOLS

	WELD ALL AROUND	FIELD WELD	CONTOUR		For other basic and supplementary weld symbols, see AWS A2.0-68
			FLUSH	CONVEX	
	○	●	—	⌒	

STANDARD LOCATION OF ELEMENTS OF A WELDING SYMBOL



Arrow connects reference line to arrow side of joint. Use break as at A or B to signify that arrow is pointing to the grooved member in bevel or J grooved joints.

Note

Size, weld symbol, length of weld and spacing must read in that order from left to right along the reference line. Neither orientation of reference line nor location of the arrow alter this rule.

The perpendicular leg of ◺, |/, |), |(weld symbols must be at left.

Arrow and Other Side welds are of the same size unless otherwise shown.

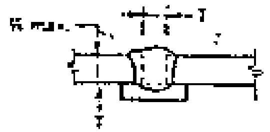
Symbols apply between abrupt changes in direction of welding unless governed by the "all around" symbol or otherwise dimensioned.

These symbols do not explicitly provide for the case that frequently occurs in structural work, where duplicate material (such as stiffeners) occurs on the far side of a web or gusset plate. The fabricating industry has adopted this convention: that when the billing of the detail material discloses the identity of far side with near side, the welding shown for the near side shall also be duplicated on the far side.

Complete penetration

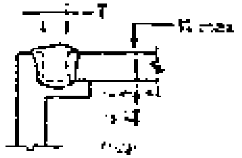
Manual Shielded Metal-Arc Welded Joints of LIMITED Thickness

B-L1a



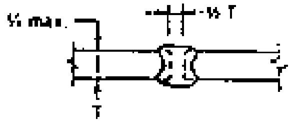
SQUARE GROOVE

C-L1a



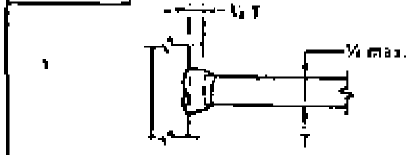
SQUARE GROOVE

B-L1b



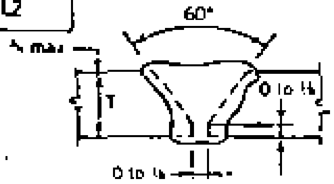
* SQUARE GROOVE

TC-L1b



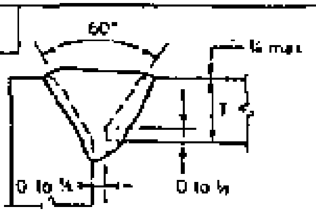
** SQUARE GROOVE

B-L2



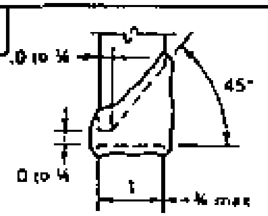
* SINGLE-VEE GROOVE

C-L2



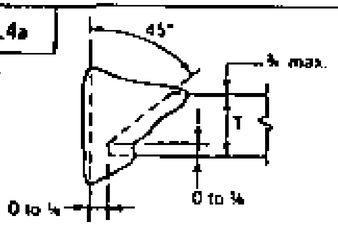
** SINGLE-VEE GROOVE

B-L4



* SINGLE-BEVEL GROOVE

TC-L4a

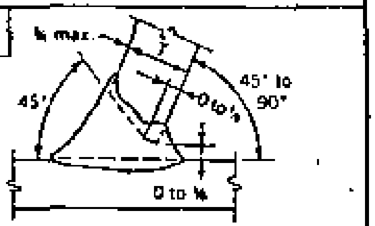


** SINGLE-BEVEL GROOVE

* Gouge root before welding second side

** If used, size of fillet welds reinforcing groove welds in tee and corner joints shall equal T/4 with a ⅜" maximum.

TC-L4b



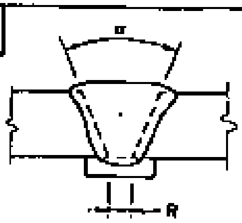
** SINGLE-BEVEL GROOVE

WELDED JOINTS

Complete penetration

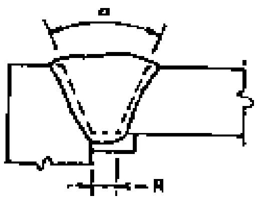
Manual Shielded Metal-Arc Welded Joints of UNLIMITED Thickness

***B-U2**



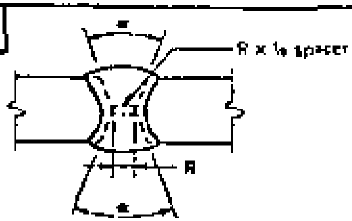
SINGLE-VEE GROOVE

***C-U2**



SINGLE-VEE GROOVE

***B-U3a**

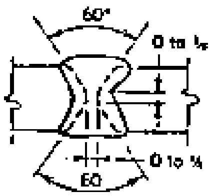


** DOUBLE-VEE GROOVE

* LIMITATIONS FOR JOINTS B-U2, B-U3a AND C-U2

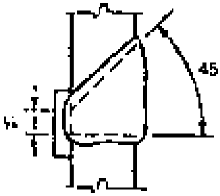
α	R	Permitted welding positions
45°	¼	All positions
30°	⅜	Flat and overhead only
20°	½	Flat and overhead only

B-U3b



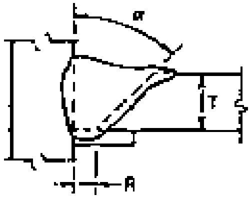
** DOUBLE-VEE GROOVE

B-U4



SINGLE-BEVEL GROOVE

****TC-U4a**

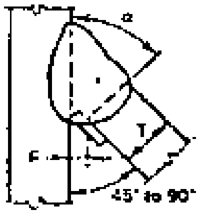


' SINGLE-BEVEL GROOVE

** LIMITATIONS FOR JOINTS TC-U4a AND TC-U4b

α	R	Permitted welding positions
45°	¼	All positions
30°	⅜	Flat and overhead only

****TC-U4b**



' SINGLE-BEVEL GROOVE

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[a] Gouge root before welding second side

[b] This joint should preferably be limited to base material thicknesses of ⅝" or larger

[c] If used, size of fillet welds reinforcing groove welds in tee and corner joints shall equal T/4 with a ⅜" maximum

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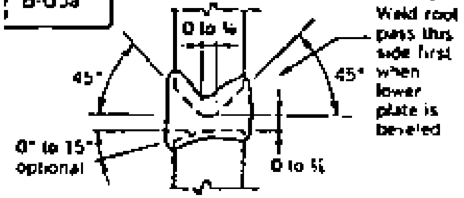
WELDED JOINTS

Complete penetration

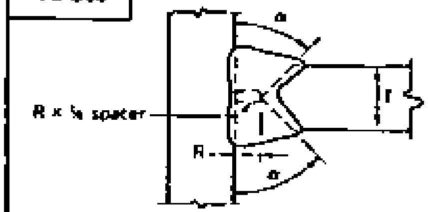
Manual Shielded Metal-Arc Welded Joints of UNLIMITED Thickness

B-U5a



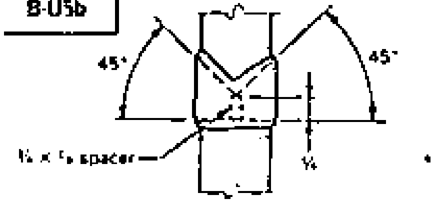
**DOUBLE-BEVEL GROOVE

***TC-U5a**



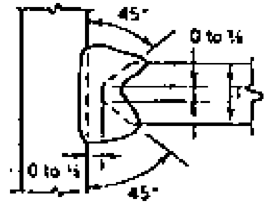
**'DOUBLE-BEVEL GROOVE

B-U5b



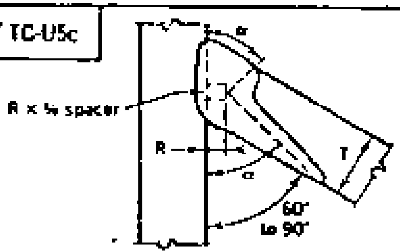
**DOUBLE-BEVEL GROOVE

TC-U5b



**'DOUBLE-BEVEL GROOVE

***TC-U5c**

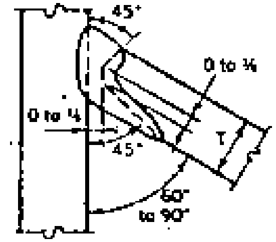


**'DOUBLE-BEVEL GROOVE

* LIMITATIONS FOR JOINTS TC-U5a AND TC-U5c

α	R	Permitted welding positions
45°	¼	All positions
30°	⅜	Flat and overhead only

TC-U5d



**' DOUBLE-BEVEL GROOVE

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[a] Gouge root before welding second side.

[b] This joint should preferably be limited to base material thicknesses of ⅝" or larger

[c] If used, size of fillet welds reinforcing groove welds in tee and corner joints shall equal T/4 with a ⅜" maximum.

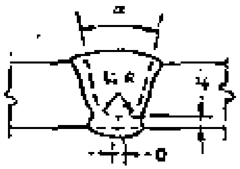
Revised 8/75

WELDED JOINTS

Complete penetration

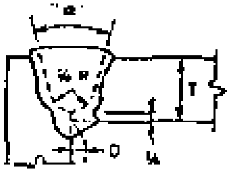
Manual Shielded Metal-Arc Welded Joints of UNLIMITED Thickness

***B-U6**



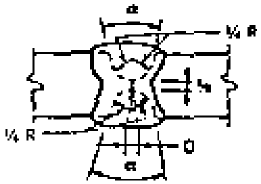
* SINGLE-U GROOVE

***C-U6**



*‡ SINGLE-U GROOVE

***B-U7**



*‡ DOUBLE-U GROOVE

*LIMITATIONS FOR JOINTS
B-U6, B-U7 AND C-U6

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

* Gouge root before welding second side

‡ This joint should preferably be limited to base material thicknesses of ⅝" or larger.

ᶠ If used, size of fillet welds reinforcing groove welds in tee and corner joints shall equal T/4 with a ⅜" maximum

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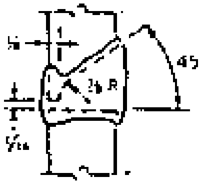
WELDED JOINTS

Complete penetration

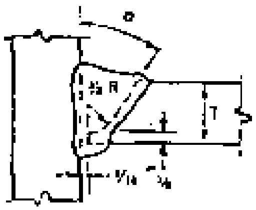
Manual Shielded Metal-Arc Welded Joints of UNLIMITED Thickness

B-U8



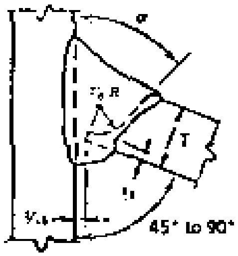
*SINGLE-J GROOVE

***TC-U8a**



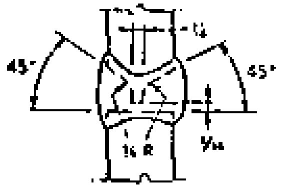
*ᶠ SINGLE-J GROOVE

***TC-U8b**



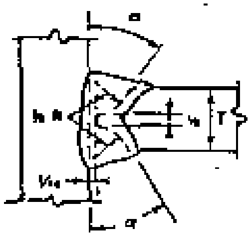
*ᶠ SINGLE-J GROOVE

B-U9



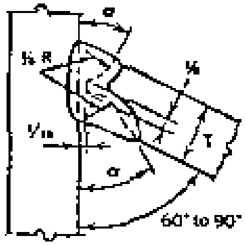
*‡DOUBLE-J GROOVE

***TC-U9a**



*‡ᶠ DOUBLE-J GROOVE

***TC-U9b**



*‡ᶠ DOUBLE-J GROOVE

*LIMITATIONS FOR JOINTS
TC-U8a, TC-U8b, TC-U9a AND TC-U9b

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

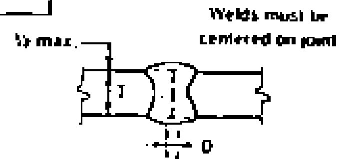
* Gouge root before welding second side

‡ This joint should preferably be limited to base material thicknesses of ⅝" or larger

ᶠ If used, size of fillet welds reinforcing groove welds in tee and corner joints shall equal T/4 with a ⅜" maximum

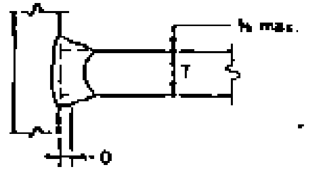
WELDED JOINTS
Complete penetration
Submerged Arc Welded Joints of LIMITED and UNLIMITED Thickness

B-L1-S



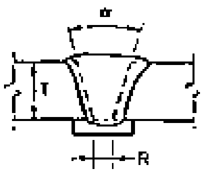
SQUARE GROOVE

TC-L1-S



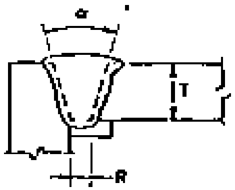
*SQUARE GROOVE

***B-L2a-S**
***B-U2-S**



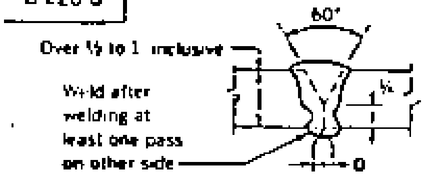
SINGLE-VEE GROOVE

***C-L2a-S**
***C-U2-S**



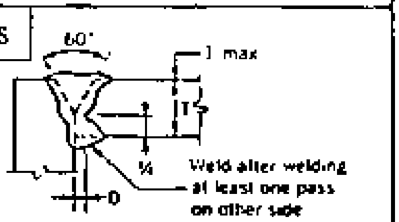
SINGLE-VEE GROOVE

B-L2b-S



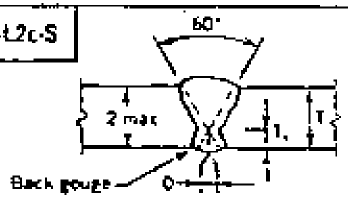
SINGLE-VEE GROOVE

C-L2b-S



*SINGLE-VEE GROOVE

****B-L2c-S**



SINGLE-VEE GROOVE

***LIMITATIONS FOR JOINTS**
B-L2a-S AND C-L2a-S
B-U2-S AND C-U2-S

Designation	α	R	Max. thickness (T)
B-L2a-S C-L2a-S	30°	¼	½
B-U2-S C-U2-S	20°	⅝	Unlimited

****LIMITATIONS FOR JOINT**
B-L2c-S

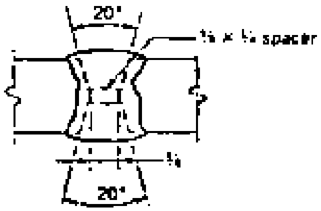
T	T_1
Over ½ to 1	¼
Over 1 to 1½	5/16
Over 1½ to 2	⅜

---

* If used, size of fillet welds reinforcing groove welds in tee and corner joints shall equal T/4 with a ⅜" maximum.

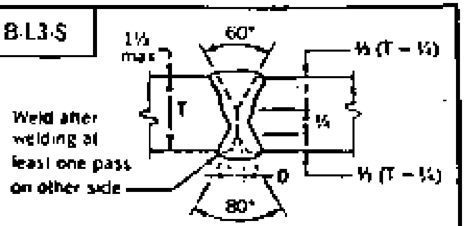
WELDED JOINTS
Complete penetration
Submerged Arc Welded Joints of LIMITED and UNLIMITED Thickness

B-U3a-S



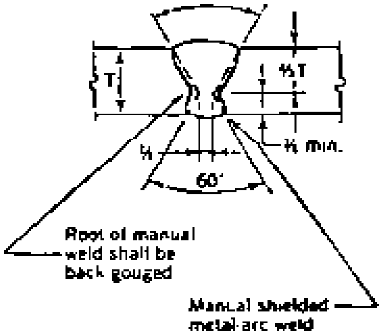
DOUBLE-VEE GROOVE

B-L3-S



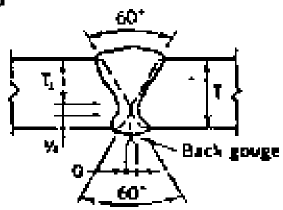
DOUBLE-VEE GROOVE

B-U3b-S



** DOUBLE-VEE GROOVE

***B-U3c-S**



DOUBLE-VEE GROOVE

***LIMITATIONS FOR JOINT**
B-U3c-S

T	T_1
Over 2 to 2½	1⅜
Over 2½ to 3	1¾
Over 3 to 3⅝	2⅛
Over 3⅝ to 4	2⅜
Over 4 to 4¾	2¾
Over 4¾ to 5½	3¼
Over 5½ to 6¼	3¾
For T > 6¼, $T_1 = \frac{1}{2}(T - \frac{1}{4})$	

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* Manual shielded metal arc weld made first with low hydrogen electrodes.

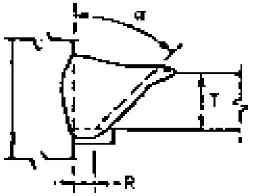
** Single or multiple pass submerged arc weld in flat position after manual welding is completed on other side.

WELDED JOINTS

Complete penetration

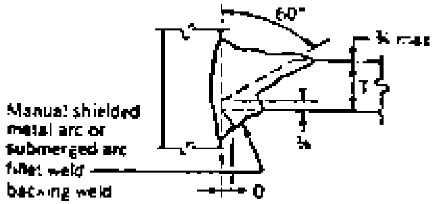
Submerged Arc Welded Joints of LIMITED and UNLIMITED Thickness

TC-U4a-S



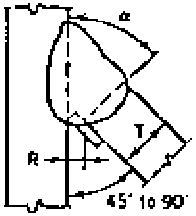
*SINGLE-BEVEL GROOVE

TC-L4a-S



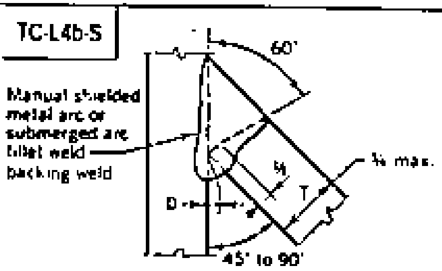
*SINGLE-BEVEL GROOVE

TC-U4b-S



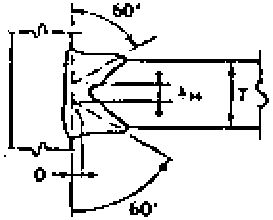
*SINGLE-BEVEL GROOVE

TC-L4b-S



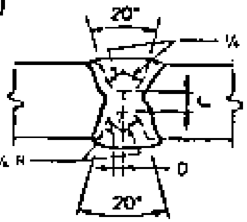
*SINGLE-BEVEL GROOVE

TC-U5-S



*DOUBLE-BEVEL GROOVE

B-U7-S



DOUBLE-U GROOVE

*LIMITATIONS FOR JOINTS
TC-U4a-S AND TC-U4b-S

α	R
45°	¼
30°	⅜

---

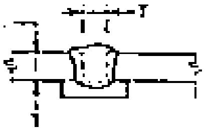
‡ If used, size of fillet welds reinforcing groove welds at tee and corner joints shall equal T/4 with a ⅜" maximum.

WELDED JOINTS

Complete penetration

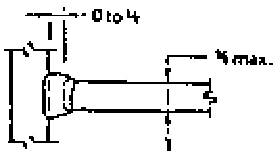
Gas Metal and Flux Cored Arc Welded Joints of LIMITED Thickness

B-L1a-GF



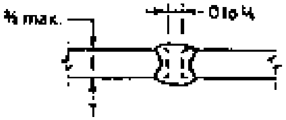
*SQUARE GROOVE

TC-L1-GF



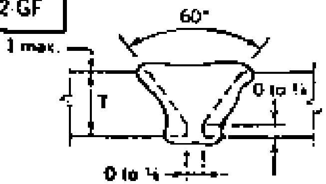
**SQUARE GROOVE

B-L1b-GF



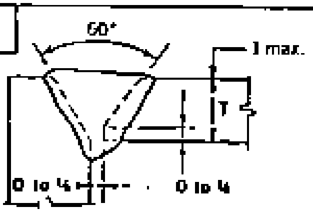
**SQUARE GROOVE

B-L2-GF



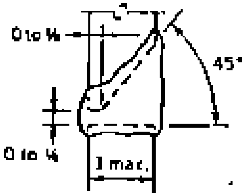
*SINGLE-VEE GROOVE

C-L2-GF



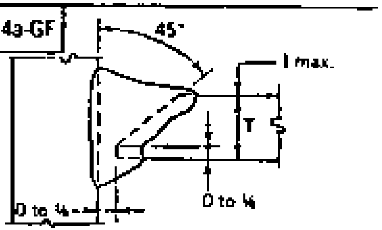
**SINGLE-VEE GROOVE

B-L4-GF



*SINGLE-BEVEL GROOVE

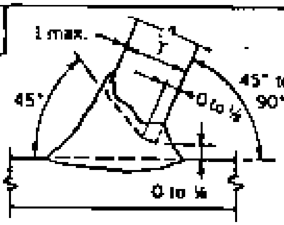
TC-L4a-GF



**SINGLE-BEVEL GROOVE

- * Gouge root before welding second side
- ‡ If used, size of fillet welds reinforcing groove welds in tee and corner joints shall equal T/4 with a ⅜" maximum
- † Not prequalified for gas metal arc welding using short circuiting transfer.

TC-L4b-GF



**SINGLE-BEVEL GRC

SPECIFICATION FOR

Structural Joints Using ASTM A325 or A490 Bolts

Approved by the Research Council on Riveted and Bolted Structural Joints
of the Engineering Foundation, April 18, 1972
Endorsed by American Institute of Steel Construction
Endorsed by Industrial Fasteners Institute

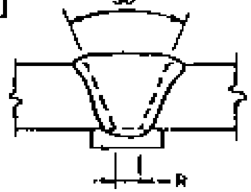
AMERICAN INSTITUTE OF STEEL CONSTRUCTION
101 Park Avenue, New York, N. Y. 10017

WELDED JOINTS

Complete penetration

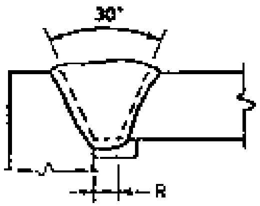
Gas Metal and Flux Cored Arc Welded Joints of UNLIMITED Thickness

*B-U2-GF



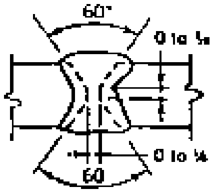
SINGLE-VEE GROOVE

*C-U2-GF



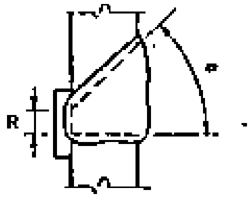
SINGLE-VEE GROOVE

B-U3-GF



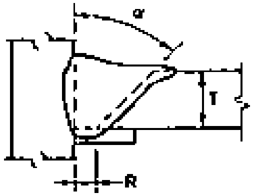
**DOUBLE-VEE GROOVE

**B-U4-GF



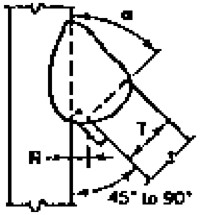
SINGLE-BEVEL GROOVE

**TC-U4a-GF



‡ SINGLE-BEVEL GROOVE

**TC-U4b-GF



‡ SINGLE-BEVEL GROOVE

* LIMITATIONS FOR JOINTS B-U2-GF AND C-U2-GF

Shielding	Permitted welding positions	R
Gas shielded	Flat, vertical and overhead	3/16
No gas shielding	Flat only	¼
	Vertical and overhead	⅜

** LIMITATIONS FOR JOINTS BU4-GF, TC-U4a-GF AND TC-U4b-GF

Shielding	Permitted welding positions	α	R
Gas shielded	All	30°	3/16
		45°	¼
No gas shielding	Flat only	30°	¼
	All	45°	¼

- † Gouge root before welding second side.
- ‡ If used, size of fillet welds reinforcing groove welds in tee and corner joints shall equal T/4 with a ⅜" maximum.
- ᶠ This joint should preferably be limited to base material thicknesses of ⅝" or larger.

SPECIFICATION FOR

Structural Joints Using ASTM A325 or A490 Bolts

Approved by Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation, April 18, 1972
Endorsed by American Institute of Steel Construction, Inc.
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1 Scope

(a) This specification covers the design and assembly of structural joints using ASTM A325 high-strength carbon steel bolts, ASTM A490 high-strength alloy steel bolts, or equivalent fasteners, tightened to a specified tension.

(b) Construction shall conform to an applicable existing code or specification for structures of wrought iron, carbon structural steel or high-strength steel, except as otherwise provided herein.

(c) Joints required to resist shear between their connected parts are designated as either *friction-type* or *bearing-type* connections. Shear connections subjected to stress reversal, severe stress fluctuation, or where slippage would be undesirable, shall be *friction-type*.

(d) The attached Commentary provides guidance in the application of the specification.

2 Bolts, Nuts and Washers

(a) Except as provided in paragraph (d) of this section, bolts, nuts and circular washers if required, shall conform to requirements of the current edition of the specifications of the American Society for Testing and Materials for High-Strength Bolts for Structural Steel Joints, Including Suitable Nuts and Plain Hardened Washers, ASTM A325, or for Quenched and Tempered Alloy Steel Bolts for Structural Steel Joints, ASTM A490. The designer shall specify the grade of bolts to be used.

(b) Except as provided in paragraph (d) of this section, bolt dimensions shall conform to the current requirements of the American National Standards Institute for heavy hex structural bolts, ANSI Standard B18.2.1.

(c) Except as provided in paragraph (d) of this section, nut dimensions shall conform to current requirements of the American National Standards Institute for heavy hex nuts, ANSI Standard B18.2.2.

(d) Other fasteners which meet the materials, manufacturing, and chemical composition requirements of ASTM specification A325 or A490 and which meet the mechanical property requirements of the same specification in full-size tests and which have bo diameter and bearing areas under the head and nut, or their equiv lent, not less than those provided by a bolt and nut of the same nominal dimensions prescribed by paragraphs 2(b) and 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.

Table 1 Washer Dimensions[a]

Bolt Size C	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
½	1 1/16	17/32	0.097	0.177	1¾	5/16	1:6
⅝	1 5/16	21/32	0.122	0.177	1¾	5/16	1:6
¾	1 15/32	13/16	0.122	0.177	1¾	5/16	1:6
⅞	1¾	15/16	0.136	0.177	1¾	5/16	1:6
1	2	1 1/16	0.136	0.177	1¾	5/16	1:6
1⅛	2¼	1¼	0.136	0.177	2¼	5/16	1:6
1¼	2½	1⅜	0.136	0.177	2¼	5/16	1:6
1⅜	2¾	1½	0.136	0.177	2¼	5/16	1:6
1½	3	1⅝	0.136	0.177	2¼	5/16	1:6
1¾	3⅜	1⅞	0.178[b]	0.28[b]	—	—	—
2	3¾	2⅛	0.178[b]	0.28[b]			
Over 2 to 4 incl.	2D − ½	D + ⅛	0.24[c]	0.34[c]	—	—	—

[a] Dimensions in inches. (Tolerances as noted in Table 1-A.)
[b] 3/16 in. nominal.
[c] ¼ in. nominal.

(e) Circular washers and square or rectangular beveled washers shall conform to the dimensions in Table 1 within tolerances given in Table 1-A. 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 ⅞ of the bolt diameter from the center of the washer.

Table 1-A Washer Dimension Tolerances (inches)

Dimension	Washer Size	
	To 1¾ in. Nominal Bolt Size, incl.	Over 1¾ in. Nominal Bolt Size
Nominal diameter of hole	−0; +1/32	−0; +1/16
Nominal outside dimensions	−1/32; +¼	−1/32; +¼
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	.015

Table 2 Allowable Working Stresses for Fasteners[a]

Specification Paragraph	Loading Conditions	ASTM A325 Bolts		ASTM A490 Bolts	
		Bridges	Buildings	Bridges	Buildings
4(b)	Applied tension, psi	36,000	40,000	48,000[b]	54,000[b]
4(c)	Shear, psi				
	1. Friction-type connection	13,500	15,000	18,000	20,000
	2. Bearing-type connection, shear plane through threads	13,500	15,000	20,000	22,500
	3. Bearing-type connection, threads excluded	20,000	22,000	29,000	32,000
4(d)	Bearing, psi[c]	$1.22 F_y$	$1.35 F_y$	$1.22 F_y$	$1.35 F_y$

[a] The tabulated stresses, except for bearing stress, apply to bolts used in any grade of steel.
[b] Static loading only.
[c] F_y = Specified minimum yield point of the lowest strength connected part.

3 Bolted Parts

(a) The slope of surfaces of bolted parts in contact with the bolt head and nut shall not exceed 1:20 with respect to a plane normal to the bolt axis. Bolted parts shall fit solidly together when assembled and shall not be separated by gaskets or any other interposed compressible material. Holes may be punched, subpunched and reamed, or drilled, as required by the applicable code or specification and, except as hereinafter provided, shall be a nominal diameter not more than $\frac{1}{16}$-in. in excess of the nominal bolt diameter.

Where shown in the design drawings and at other locations approved by the designer, oversize, short-slotted, and long-slotted holes[d] may be used with high strength bolts $\frac{5}{8}$-in. in diameter and larger proportioned to meet the allowable working stresses given in Table 2 except as hereinafter restricted:

1. *Oversize holes* are $\frac{3}{16}$-in. larger than bolts $\frac{7}{8}$-in. and less in diameter, $\frac{1}{4}$-in. larger than bolts 1-in. in diameter, and $\frac{5}{16}$-in. larger than bolts $1\frac{1}{8}$-in. and greater in diameter. They may be used in any or all plies of *friction-type* connections. Hardened washers shall be installed over exposed oversize holes.

2. *Short slotted holes* are $\frac{1}{16}$-in. wider than the bolt diameter and have a length which does not exceed the oversize diameter provisions of paragraph 3(a)1 by more than $\frac{1}{16}$-in. They may be used in any or all plies of *friction-type* or *bearing-type* connections. The slots may be used without regard to direction of loading in *friction-type* connections but shall be normal to the direction of the load in *bearing-type* connections. Hardened washers shall be installed over exposed short slotted holes.

3. *Long slotted holes* are $\frac{1}{16}$-in. wider than the bolt diameter and have a length more than allowed in sub-paragraph 2 but not more than $2\frac{1}{2}$ times the bolt diameter.

In *friction-type* connections, they may be used without regard to direction of loading if one-third more bolts are provided than needed to satisfy the allowable working stress given in Table 2.

In *bearing-type* connections, the long diameter of the slot shall be normal to the direction of loading. No increase in the number of bolts over those necessary for the allowable stress given in Table 2 is required.

Long slotted holes may be used in only one of the connected parts of either a friction-type or bearing-type connection at an individual faying surface.

Structural plate washers or a continuous bar not less than $\frac{5}{16}$-in. in thickness are required to cover long slots that are in the outer plies of joints. These washers or bars shall have a size sufficient to completely cover the slot after installation.

(b) When assembled, all joint surfaces, including those adjacent to the bolt heads, nuts or washers, shall be free of scale, except tight mill scale, and shall also be free of burrs, dirt and other foreign material that would prevent solid seating of the parts.

(c) Contact surfaces within *friction-type* joints shall be free of oil, paint, lacquer or other coatings, except as listed below:

1. Hot-dip galvanizing, if contact surfaces are scored by wire brushing or blasting after galvanizing and prior to assembly.

2. Inorganic zinc rich paints as defined in those sections of the Steel Structures Painting Council Systems, SSPC PS 12.00, covering zinc rich paints with inorganic vehicles.

3. Metallized zinc or aluminum applied in accordance with AWS C2.2 Recommended Practice for Metallizing with Aluminum and Zinc for Protection of Iron and Steel, except that subsequent sealing treatments, described in Section IV therein, shall not be used.

Allowable Working Stresses

(a) *Design Stresses.* The allowable working stresses for A325 and A490 bolts specified in the following paragraphs are given, respectively, for bridges and buildings in Table 2. As used in paragraphs (b) and (c), nominal bolt area is defined as the area corresponding to the nominal diameter of the bolt.

(b) *Applied Tension.* Bolts required to support applied load by means of direct tension shall be so proportioned that their average tensile stress, computed on the basis of nominal bolt area and independent of any initial tightening force, will not exceed the appropriate stress given in Table 2. The applied load shall be the sum of the external load and any tension resulting from prying action produced by deformation of the connected parts.

(c) *Shear*

1. Bolts in *friction-type* connections assembled in accordance with the requirements of paragraph 3(c) shall be proportioned on the basis of the appropriate stress given in Table 2. These shear stresses may be used to proportion high-strength bolts used in combination with rivets or welds designed in accordance with the provisions of the applicable code or specification. In *friction-type* connections there need be no consideration of bearing, and fillers need not be "developed." However, eccentricity of forces at short thick fillers must be considered

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[d] See Table 7 in Commentary.

2. Bolts in *bearing-type* connections having thread in a plane of contact surfaces of the connected parts shall be proportioned on the basis of the appropriate stress given in Table 2.

3. Bolts in *bearing-type* connections, where bolt threads are excluded from the shear planes of the contact surfaces between the connected parts, shall be proportioned on the basis of the appropriate stress given in Table 2.

(d) *Bearing.* In *bearing-type* connections the computed bearing pressure, assumed to be distributed over an area equal to the nominal bolt diameter times the thickness of the connected part, shall not exceed the appropriate stress given in Table 2.

In *bearing-type* connections having no more than two bolts in a line parallel to the direction of stress, the distance between the center of the nearest bolt and that end of the connected member towards which the pressure from the bolt is directed shall be not less than AC/t for single shear or $2AC/t$ for double shear, where A is the nominal cross-sectional area of the fastener, t is the thickness of the connected part and C is the ratio of specified minimum tensile strength of the fastener to the specified minimum tensile strength of the connected part. This end distance may be proportionately less where the shear stress per bolt is less than that permitted in this section, but not less than 1½ times the bolt diameter. It need not exceed 1½ times the transverse spacing of the fasteners.

(e) *Increase in Working Stress.* Increase in working stress allowed in the applicable code or specification may be applied to the stresses given in this section (see Commentary for *Shear; Friction-Type Connections*).

6 Installation

(a) *Fastener Tension.* Each fastener shall be tightened to provide, when all fasteners in the joint are tight, at least the minimum tension shown in Table 3 for the size and grade of fastener used.

Threaded bolts shall be tightened by methods described in subparagraphs (c), (d), or (e) of this section. If required because of bolt entering and wrench operation clearances, tightening by either procedure described in subparagraphs (c) or (d) may be done by turning the bolt while the nut is prevented from rotating.

Impact wrenches, if used, shall be of adequate capacity and sufficiently supplied with air to perform the required tightening of each bolt in approximately ten seconds.

(b) *Washers.* A325 fasteners meeting the provisions of Section 2 may be installed without hardened washers when tightening is by the turn-of-nut method except as noted in Section 3. A490 bolts installed by the turn-of-nut method and A325 or A490 bolts tightened by the calibrated wrench method (i.e., by torque control) shall have a hardened washer under the element (nut or bolt head) turned in tightening and as provided in Section 3, if applicable. Two hardened washers shall be used with all A490 bolts used to connect material having a specified minimum yield point less than 40 ksi.

Where an outer face of the bolted parts has a slope greater than 1:20 with respect to a plane normal to the bolt axis, a beveled washer shall be used to compensate for the lack of parallelism.

(c) *Turn-of-Nut Tightening.* When the turn-of-nut method is used to provide the bolt tension specified in paragraph 5(a), there shall first be enough bolts brought to a "snug tight" condition to insure that the parts of the joint are brought into good contact with each other. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the joint shall then be tightened additionally by the applicable amount of nut rotation specified in Table 4, with tightening progressing systematically from the most rigid part of the joint to its free edges. During this operation there shall be no rotation of the part not turned by the wrench.

(d) *Calibrated Wrench Tightening.* When calibrated wrenches are used, they should be set to provide a tension at least 5% in excess of the minimum bolt tension specified in 5(a). The wrenches shall be calibrated at least once each working day for each bolt diameter being installed. Wrenches shall be recalibrated when significant changes are made in the equipment or when a significant difference is noted in the surface condition of the bolts, nuts or washers. Calibration shall be accomplished by tightening, in a device capable

Table 3 Fastener Tension

Bolt Size, in Inches	Minimum Fastener Tension[a] in Thousands of Pounds (kips)	
	A325 Bolts	A490 Bolts
½	12	15
⅝	19	24
¾	28	35
⅞	39	49
1	51	64
1⅛	56	80
1¼	71	102
1⅜	85	121
1½	103	148

[a] E [illegible] 70 percent of specified minimum tensile strengths of bolts, rounded off to the near

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° (one twelfth full turn) over or under. For coarse thread heavy hex structural bolts of all sizes and length and [illegible] hex semi-finished nuts.

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

of indicating actual bolt tension, three typical bolts of each diameter from the bolts being installed.

When adjusting the wrenches to provide the required tension, it shall be verified during actual installation in the assembled steelwork that the calibration selected does not produce a nut or bolt head rotation from snug tight greater than that permitted in Table 4. If manual torque wrenches are used, nuts shall be in tightening motion when torque is measured.

When using calibrated wrenches to install several bolts in a single joint, the wrench shall be returned to "touch up" bolts previously tightened, which may have been loosened by the tightening of subsequent bolts, until all are tightened to the prescribed amount.

(e) *Tightening by Use of a Direct Tension Indicator.* Tightening by this means is permitted provided it can be demonstrated by an accurate direct measurement procedure that the bolt has been tightened in accordance with Table 3.

6 Inspection

(a) The Inspector shall determine that the requirements of Sections 2, 3 and 5 of this specification are met in the work. When the calibrated wrench method of tightening is used, the Inspector shall have full opportunity to witness the calibration tests prescribed in paragraph 5(d).

(b) The Inspector shall observe the installation of bolts to determine that the selected procedure is properly used and shall determine that all bolts are tightened. Bolts installed by the turn-of-nut method may reach tensions above the value given in Table 3 but this shall not be cause for rejection.

(c) When there is need for more inspection of bolt tension in the turn-of-nut and calibrated wrench methods than that provided in paragraph 6(b), the following arbitration inspection shall be used unless a more extensive or different procedure is specified in the inquiry and order for the work:

1. The Inspector shall use an *inspecting wrench* which may be either a torque wrench or a power wrench that can be adjusted in accordance with the requirements of paragraph 5(d).

2. Three bolts of the same grade, size* and condition as those under inspection shall be placed individually in a calibration device capable of indicating bolt tension. The surface under the part to be turned in tightening each bolt shall be like that under the corresponding part in the structure; i.e., there shall be a washer under the part turned if washers are so used in the structure or, if no washer is used, the material abutting the part turned shall be of the same specification as that in the structure.

3. When the *inspecting wrench* is a torque wrench, each bolt specified in paragraph 6(c)2 shall be tightened in the calibration device by any convenient means to an initial condition equal to approximately 15% of the required fastener tension and then to the minimum tension specified for its size in paragraph 5(a). Tightening beyond the initial condition must not produce greater nut rotation than that permitted in Table 4. The *inspecting wrench* then shall be applied to the tightened bolt and the torque necessary to turn the nut or head 5 degrees (approximately 1 inch at 12 inch radius) in the tightening direction shall be determined. The average torque measured in the tests of three bolts shall be taken as the *job inspecting torque* to be used in the manner specified in paragraph 6(c)5.

4. When the *inspecting wrench* is a power wrench it shall be adjusted so that it will tighten each bolt specified in paragraph 6(c)2 to a tension at least 5% but not more than 10% greater than the minimum tension specified for its size in paragraph 5(a). However, this power wrench setting must not produce greater nut rotation from the snug condition than that permitted in Table 4. This setting of wrench shall be taken as the *job inspecting torque* to be used in the manner specified in paragraph 6(c)5.

5. Bolts represented by the sample prescribed in paragraph 6(c)2 which have been tightened in the structure shall be inspected by applying, in the tightening direction, the *inspecting wrench* and its *job inspecting torque* to 10% of the bolts, but not less than two bolts, selected at random in each connection. If no nut or bolt head is turned by this application of the *job inspecting torque*, the connection shall be accepted as properly tightened. If any nut or bolt head is turned by the application of the *job inspecting torque*, this torque shall be applied to all bolts in the connection, and all bolts whose nut or head is turned by the *job inspecting torque* shall be tightened and re-inspected, or alternatively, the fabricator or erector, at his option may re-tighten all of the bolts in the connection and then re-submit the connection for the specified inspection.

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* Length may be any length representative of bolts used in the structure.

COMMENTARY

C1 Scope

When first approved by the Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation, January, 1951, the Specification for Assembly of Structural Joints Using High-Strength Bolts merely permitted the substitution of a like number of A325 high-strength bolts for hot-driven ASTM A141* steel rivets of the same nominal diameter. It was required that all contact surfaces be free of paint. As revised in 1954, the omission was required to apply only to "joints subjected to stress reversal, impact or vibration, or to cases where stress redistribution due to joint slippage would be undesirable." This relaxation of the earlier provision recognized the fact that, in a great many cases, movement of the connected parts that brings the bolts into bearing against the sides of their holes is in no way detrimental. When the nature of the loading—whether

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* Presently identified as A502, Grade 1.

static or cyclic—is such that fatigue-type failure or reversal of movement will not occur, the high clamping force in the bolts provides a rigid assembly in the "slipped" position and the shear strength of the high-strength bolts, when threads are excluded from contact surface shear planes, is substantially greater than that of hot-driven rivets required to function under similar circumstances. Since allowable stresses as well as the requirements for treatment of contact surfaces appropriate to these service conditions are different, the present specification recognizes two kinds of shear connections, designated as *friction-type* and *bearing-type*, respectively.

Just how much stronger the high-strength bolts are in resisting actual shearing forces and what effect the higher stresses in the bolts have upon the strength of the connected parts have been the subjects of extensive study in the bolt sizes generally used in construction sponsored by the Research Council since 1954. The results of these studies, together with improvements in installation practices which are the outgrowth of extensive experience in the use of high-strength bolts, formed the background for the 1960 edition. The 1962 revision reflected the results of additional research which had shown that washers may be omitted from A325 bolt assemblies. This revision incorporates the results of research conducted since that time, especially on A490 bolts.

The increasing use of high-strength steels has created the need for bolts substantially stronger than A325, in order to resist, with well-proportioned joints, the much greater forces that they support. To meet this need, a new ASTM standard, A490, has been developed.

When provisions for the use of these bolts were included in the Specification in 1964 it was required that they be tightened to their specified proof load, as was required for the installation of A325 bolts. However, the ratio of proof load to specified minimum tensile strength is approximately 0.7 for A325 bolts, whereas it is 0.8 for A490 bolts. Calibration studies have shown that high strength bolts have ultimate load capacities in torqued tension which vary from about 80% to 90% of the direct tensile strength.[1] Hence, if minimum strength bolts were supplied and they experienced the maximum reduction due to torquing, there is a possibility that these bolts could not be tightened to proof load by any method of installation. Also, statistical studies have shown that, tightening to the 0.8 ratio under calibrated wrench control may result in some "twist-off" bolt failures during installation or in some cases a slight amount of undertightening.[2] Therefore the required installed tension for A490 bolts has been reduced to 70 percent of the specified minimum tensile strength. For consistency, but with only minor change, the initial tension required for A325 bolts has also been set at 0.7 of their specified minimum tensile strength and at the same time the values in Table 3 have been rounded off to the nearest kip.

Because greater clamping force is used with A490 bolts it is required that hardened washers, conforming to the requirements of ASTM Specification A325, be installed under both the nut and bolt head when A490 bolts are used in steels having a yield point less than 40 ksi and under the turned element when they are used in higher-strength steels.

The ASTM specification A325 now provides for three types of high strength structural bolts.

Type 1. Bolts of medium carbon steel, supplied in sizes ½-in. to 1½-in., inclusive.
Type 2. Bolts of low carbon martensite steel, supplied in sizes ½-in. to 1-in., inclusive.
Type 3. Bolts having atmospheric corrosion resistance and weathering characteristics comparable to that of A588 and A242 steels, supplied in sizes ½-in. to 1½-in., inclusive.

When the type of bolt is not specified, Type 1 bolts shall be supplied. However, since the mechanical properties of all three types of bolts are comparable, the manufacturer may supply Type 2 or Type 3 bolts if agreed upon by the purchaser.

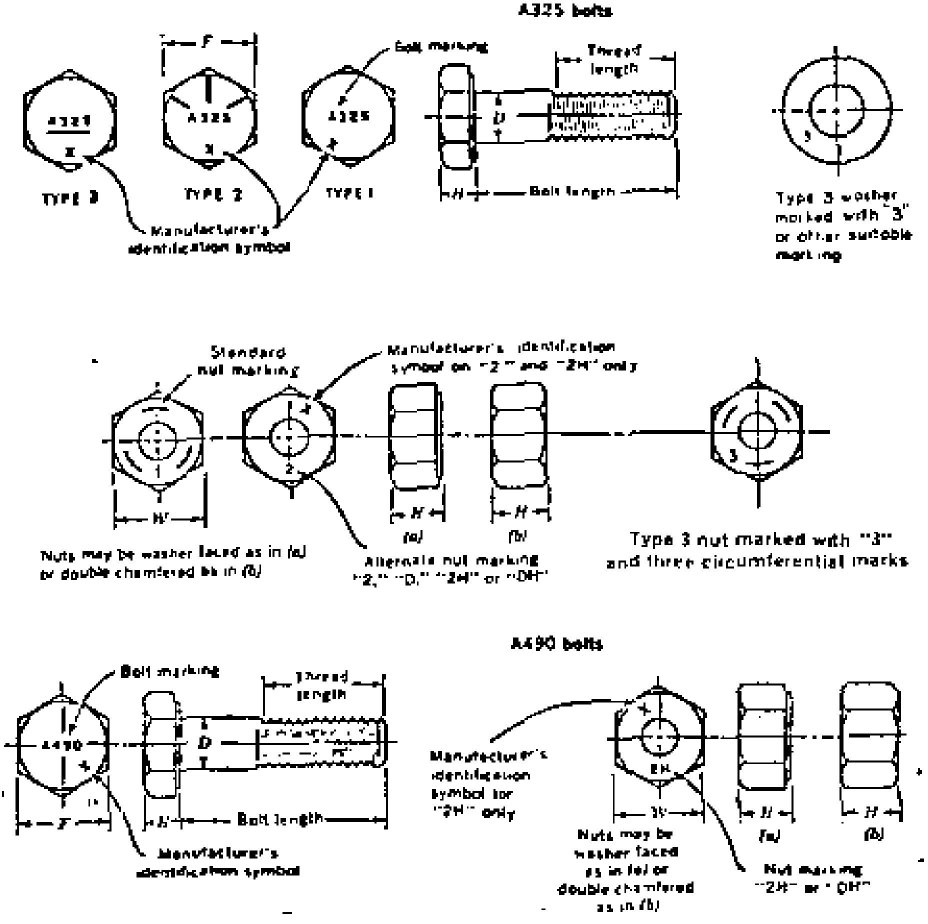

Fig. 1

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[1] "Calibration of Alloy Steel Bolts," by Christopher, R. J., Kulak, G. L., and Fisher, J. W., *Journal of the Structural Division*, ASCE, Vol. 92, No. ST2, Proc. Paper 4768, April, 1966, pp. 19–40.

[2] "Specification of Minimum Preloads for Structural Bolts," by Gill, P. J., Memo[illegible]um 30, G. K. N. Group Research Laboratory, England, 1966 (Unpublished [illegible]rt).

Recent research[3] has demonstrated that galvanized A325 bolts may be used for friction-type connections, providing the contact surfaces are properly prepared (see Section 3c). However, it may be necessary to provide a lubricant to insure adequate rotational capacity during torquing and to provide the required minimum clamping force in the bolts. Research has demonstrated that hot-dip galvanized A490 bolts should not be used.[4] Other types of A490 bolt finishes have not been studied.

C2 Bolts, Nuts and Washers

In this edition of the specification a single style of fastener, available in two strength grades (A325 and A490) is described as a principal style, but conditions for acceptance of other types of fasteners are provided.

Heavy hex structural bolts manufactured to ASTM Specification A325, Types 1, 2 and 3, the dimensions for which are shown in Table 5 and Figure 1, are identified on the top of the head by the legend "A325", and the manufacturer's symbol. In addition, Type 1 bolts, at the option of the manufacturer, may be marked with three radial lines 120 degrees apart. Type 2 bolts shall be marked with three radial lines 60 degrees apart. Type 3 bolts shall have the A325 underlined and the manufacturer may add other distinguishing marks indicating that the bolt is of a weathering type. Bolts manufactured to ASTM Specification A490 are marked with the legend "A490" and the manufacturer's symbol. Heavy hex nuts for A325 bolts are identified on at least one face by the manufacturer's mark and the number "2" or "2H"; by three equally spaced circumferential lines; or by the legend "D" or "DH". Heavy hex nuts for A325 Type 3 bolts shall be marked on one face with three circumferential marks and the numeral 3, in addition to any other distinguishing marks the manufacturer may elect to use. Heavy hex nuts for use on A490 bolts are identified with the legend "2H" and the manufacturer's mark; or by the legend "DH". Washers for A325 Type 3 bolts shall be marked on one face near the outer edge with the numeral 3, or other distinguishing marks indicating that the washer is of a weathering type. The marking on bearing surfaces of nuts and washers shall be depressed.

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

Heavy hex structural bolts have shorter thread lengths than other standard bolts. By making the body length of the bolt the control dimension it has been possible to exclude the thread from all shear planes, except in the case of thin outside parts adjacent to the nut. Depending on the amount of bolt length added to adjust for incremental stock lengths, the full thread may extend into the grip as much as 3/8-inch for 1/2-inch, 5/8-inch, 3/4-inch, 7/8-inch, 1 1/4-inch and 1 1/2-inch diameter bolts and as much as 1/2-inch for 1-inch, 1 1/8-inch, and 1 3/8-inch diameter bolts. Inclusion of some of the thread run-out into the plane of shear is permissible. At the other extreme, care should be taken to provide sufficient thread for nut tightening to keep the nut from jamming into the thread run-out. When the thickness of an outside part adjacent to the nut is less than these values, it may be necessary to call for the next increment of bolt length together with a sufficient number of flat circular washers to insure full seating of the nut. Then the higher working value in shear permitted in bearing-type joints can still be the basis for determining the number of bolts in the connection.

In order to determine the required bolt length, the value shown in Table 6 should be added to the grip (that is, the total thickness of all connected material, exclusive of washers).

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

The preceding values are generalized, with due allowance for manufacturing tolerances, to provide for full thread engagement of a heavy hex nut, when installed. For each hardened flat washer that is used, add 5/32-inch, and for each beveled washer add 5/16-inch. The length determined by the use of Table 6 should be adjusted to the next longer 1/4-inch.

The circular washer dimensions shown in Table 1 are somewhat reduced from those tabulated in 1962 and earlier editions. They have been developed on the principle that the primary function of the washer is to provide a non-galling surface under the part turned in tightening. As discussed more fully under Section C5 of this Commentary, tests have shown that washers play only a minor role in distributing the pressure due to bolt tension, except where oversize or short slotted holes are used. Hence, no consideration is given to this function and the minimum thickness for com-

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[3] "High Strength Bolting of Galvanized Structural Connections," University of Illinois Engineering Experiment Station Bulletin .....

[4] "Studies of Hydrogen Stress Cracking and Stress-Corrosion Cracking of High-Strength Bolts," Boyd, W. K., *Journal of the Structural Division*, ASCE.

monly used washers has been reduced by one or two gages. The maximum thickness is now alike for all washers up to and including the 1½-inch size, so that these washers can be produced from a single stock of material.

In order to span and fully cover long slotted holes, structural washers or bars are required.

C3 Bolted Parts

Joints which must transmit the forces in adjacent parts by means of shear are divided into two categories in the current specification; *friction-type* and *bearing-type*. High initial bolt tension provides worthwhile advantages, therefore the same initial tensioning is recommended for *bearing-type* connections as for the *friction-type*. Among these benefits are overall joint rigidity, a better stress pattern and security against nut loosening.

Since its first publication the Specification has permitted the use of bolt holes 1/16-in. larger than the bolts installed in them. More recently research[4] has shown that, where greater latitude is needed in meeting dimensional tolerances during erection, somewhat larger holes can be permitted for bolts ⅝-in. diameter and larger without adversely affecting the performance of shear connections assembled with high strength bolts. Provisions based upon these findings are now included in the Specification. Since an increase in hole size generally reduces the net area of a connected part, their use is subject to approval by the designer.

Table 7 Oversize and Slotted Holes

Bolt Dia. (in.)	Maximum Hole Size (in.)		
	Oversize Holes	Short Slotted Holes	Long Slotted Holes
⅝	13/16	11/16 x ⅞	11/16 x 1 9/16
¾	15/16	13/16 x 1	13/16 x 1⅞
⅞	1 1/16	15/16 x 1⅛	15/16 x 2 3/16
1	1¼	1 1/16 x 1 5/16	1 1/16 x 2½
1⅛	1 7/16	1 3/16 x 1½	1 3/16 x 2 13/16
1¼	1 9/16	1 5/16 x 1⅝	1 5/16 x 3⅛
1⅜	1 11/16	1 7/16 x 1¾	1 7/16 x 3 7/16
1½	1 13/16	1 9/16 x 1⅞	1 9/16 x 3¾

Extensive research conducted over the years has shown that various surface treatments can provide the frictional resistance required in *friction-type* connections. The specifications for several of these treatments are listed in Section 3 of this Specification.

In order to provide adequate frictional resistance in *friction-type* galvanized connections, the contact surfaces within the joints must be wire brushed or blasted prior to assembly. The wire brushing treatment should be a light application of manual or power brushing that marks or scores the surface, but removes relatively little of the zinc coating. The blasting treatment should be a light "brush-off" treatment which will produce a dull gray appearance. However, neither treatment should be severe enough to produce any break or discontinuity in the zinc surface.

C4 Allowable Working Stresses

While the provisions contained in the Council specification to a limited extent affect general design considerations, it is not the intent to present a complete design specification. Only those features influenced by the properties of high-strength bolts, as distinct from other types of fasteners, are included. Working stresses applicable to bridges and to buildings (two values differing by about 10%) reflect the historic difference in basic stress between the AREA and AASHO Specifications governing bridge design and the AISC Specification governing the design of buildings and similar structures. Except as modified by the provisions of the Council's specification, it is assumed that all of the applicable provisions of the standard specifications under which the structure is designed will be observed.

Tension

The working stresses recommended are intended to apply to the calculated bolt load plus any tension resulting from prying action produced by deformation of the connected parts. When subjected in tension to the recommended working value (approximately equal to two-thirds of the initial tightening force), high-strength bolts will experience little if any actual change in stress. Since the tensile strength of the A490 bolt is approximately one-third greater than the corresponding average value for the A325 bolt, this ratio has been used to set the allowable tensile stress for the A490 bolt.

Tests[4] on properly tightened A325 bolts have demonstrated that their fatigue strength is not adversely affected by repeated applied tension of this amount.

Similar studies on A490 bolts are under way. Pending completion of these studies the allowable working stress in tension for A490 bolts, given in Section 4(a), is intended for static loading only and no recommendation covering cyclic applied loading in tension is made.

Shear: Friction-Type Connections

No change has been made in the recommended working value for A325 bolts used in *friction-type* joints. They are, as heretofore, given the "shear" value recommended in the applicable design specification for hot-driven ASTM A502, Grade 1 steel rivets of the same nominal diameter. The one-third increase in required tightening tension mentioned under *Tension* is the justification for the one-third increase in working stress for A490 bolts used in *friction-type* connections. Resistance to slip is dependent upon the amount of bolt clamping force and the nature of the contact surfaces in a given connection, and is independent of the working stress for which the connected parts are proportioned.

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[4] "Bolted Joints With Oversize or Slotted Holes," by Ronald N. Allen and John W. Fis SCE Journal, Vol. 94, ST9, September, 1968.

[4] "Research on Bolted Connections," by William H. Munse, Transa ASCE, Vol. 121, 1956, pp. 1255–1266.

Connections having contact surfaces of unrusted mill scale offer the least resistance to slip of any unpainted joints; rusted surfaces which have been well cleaned may provide up to two times as much resistance. The recommended "shear" value using A325 bolts to connect parts having a specified yield point of about 33 ksi, based on numerous tests[1,4,8,10] correlates with a slip coefficient of 0.35. Similar observations have been made in tests of joints of higher-strength steels.[11] While lower coefficients have been observed in some laboratory tests of joints having contact surfaces of tight unrusted mill scale, or surfaces made smooth by grinding, a slip factor of 0.35 is more representative of values likely to be encountered in actual construction.

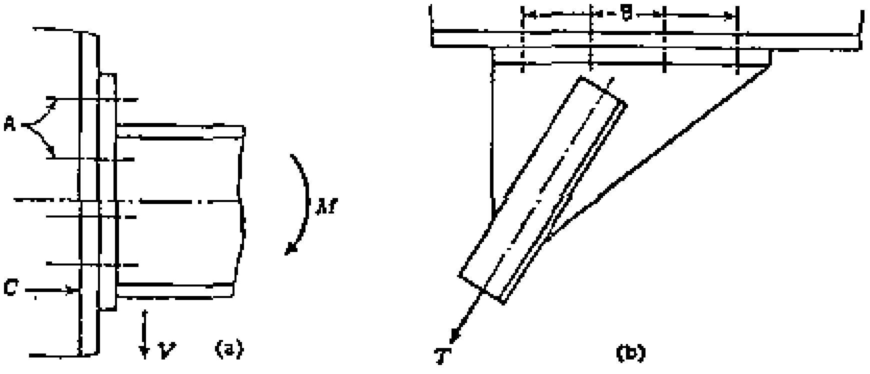

Fig. 2

Applying this value to the recommended minimum bolt tension, the factor of safety against slip can be computed as

$$N = \frac{(0.35)\ (\text{minimum bolt tension})}{(\text{allowable shear stress})\ (\text{nominal bolt area})} \qquad (1)$$

For ⅞-inch and 1-inch A325 bolts, N equals 1.68 for bridges designed in accordance with the AASHO and AREA Specifications, and 1.52 for structures designed in accordance with the AISC Specification. These factors of

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[1] "High-Strength Bolts in Structural Joints: A Symposium: Slip of Joints under Static Loads," by R. A. Hechtman, D. R. Young, A. G. Chin, and E. R. Savikko, *Transactions*, ASCE, Vol. 120, 1955, pp. 1335–1352.

[4] "Effects of Fabrication Techniques," by Desi D. Vasarhelyi, Said Y. Beano, Ronald B. Madison, Zung-An Lu, and Umesh C. Vasishth, *Transactions*, ASCE, Vol. 126, Part II, 1961, pp. 764–796.

[8] "Static Tension Tests of Compact Bolted Joints," by Robert T. Foreman and John L. Rumpf, *Transactions*, ASCE, Vol. 126, Part II, 1961, pp. 228–256.

[10] "Long Bolted Joints," by R. A. Bendigo, R. H. Hansen, and J. L. Rumpf, *ASCE Journal*, Vol. 89, ST6, December, 1963.

[11] "Static Tension Tests of A440 Steel Joints Connected with A325 Bolts," by J. W. Fisher, P. O. Ramseier, and L. S. Beedle, Publications, IABSE, Vol. 23, 1963.

safety against slip compare with design factors of safety against yield of the connected parts of 1.83 and 1.67, respectively. For other sizes of A325 bolts, the values of N are within 10% of those for ⅞-inch and 1-inch bolts. For A490 bolts, the N values are approximately the same as for A325 bolts.

Under repeated loading the factor of safety against slip indicates the margin against the condition where a reduced fatigue strength may develop. Under static load conditions it may represent the margin against a one-time displacement movement, as under lateral shock or maximum wind loading, which is seldom likely to be reversed. A factor of safety against slip, lower than that implicit in the design stress used in proportioning the connected parts, is acceptable except where there must not be movement under such overloads as may occur within the allowable design stress factor of safety.

When the allowable "shear" value is increased one-third for wind, the value of N in the above equation approaches unity. If the satisfactory performance of the structure depends upon joints which must not move, the designer should so proportion these joints as to satisfy himself that the margin against slip is adequate.

Connections of the type shown in Figure 2(a), in which some of the bolts (A) lose a part of their clamping force due to applied tension, suffer no overall loss of frictional shear resistance. The bolt tension produced by the moment is coupled with a compensating compressive force (C) on the other side of the axis of bending. In a connection of the type shown in Figure 2(b), however, all of the fasteners (B) receive applied tension which reduces the initial compression at the contact surface. If bolts are used, and slip under load cannot be tolerated, the working value of the bolts in shear should be reduced in proportion to the ratio of residual tension to initial tension.

Because bolts in *friction-type* connections do not depend upon bearing against the sides of their holes, those provisions of the general design specifications intended to guard against high bearing stresses, and bending of the bolt due to bearing, are waived.

Shear: Bearing-Type Connections

In connections where the bolts may bear against the holes in the connected parts, the allowable stress of bolts is dependent upon the presence or absence of bolt threading at the plane of contact surfaces where shearing occurs. If the unthreaded shank of an A325 bolt is available to resist this shear at all planes where it occurs, tests[4,10] have shown that a shear stress equal to 20 ksi for bridges and 22 ksi for buildings (based on nominal fastener area) affords at least as large a factor of safety against high strength bolt shear failure as that provided in the standard design specification for rivets. On the other hand, it was found that failure occurs at 15% less load when threading is present at one of the two shear planes of an enclosed part, and at 30% less load when threads are present in both shear planes. This latter failure load could be expected also for single-shear joints with threads in the shear plane. Similar observations have been made from tests using ordinary bolts. They merely reflect the ratio of area at the root of thread to the nominal bolt area. The allowable shear stresses for A325 bolts with thread in a shear plane (13.5 ksi for bridges and 15 ksi for buildings as shown in Table 2) are developed by applying the above 30% reduction to the stresses allowed in unthreaded shanks.

The shear stresses allowed for A490 bolts in *bearing-type* connections have been similarly determined from tests[13,14,15] to give them at least as much factor of safety against failure as is provided for A502 rivets.

For both the A325 and A490 bolts, it may be noted that no special allowance is made for the condition where a bolt in double shear has unthreaded shank in one shear plane and threaded section in the other. This does not deny designers the advantage of such an analysis. It recognizes, however, that any use of the advantage requires knowledge of bolt placement that is not ordinarily available to designer or detailer, and that the fully conservative procedure is to use the lower allowable shear stress for all shear planes when the joint detail allows bolt thread in any shear plane of the joint.

Bearing

Tests[16,17,18] have shown that bearing pressure on rivets in double or single shear, computed on the basis of an area equal to the product of the part thickness and nominal rivet diameter, had no significant effect on the strength of the connected parts of A7 steel when this pressure was not more than 2.25 times the tensile stress applied to the net area of these parts. It would appear that the ratio of fastener spacing normal to the line of force, to fastener diameter, rather than unit pressure *per se*, is the critical factor, and that computed bearing stress is simply a convenient index of effective net section. In consequence, no increase in allowable bearing value seems warranted when high-strength bolts are substituted for rivets.

When there are not more than two bolts in the line of stress and the pressure from the bolt is directed toward the end of a connected part, an increase in end distance, above that required for rivets under similar circumstances, is recommended. To insure that the end fastener will not tear out of the connected part before the full tensile strength of the net section is attained, it has long been required that the end distance of a connected part having substantially the same mechanical properties as the connecting rivets be not less than the nominal area of the rivet divided by the part thickness and multiplied by the number of shears applied to the part. This rule is retained for use with high-strength bolts, but the end distance is increased in proportion to the ratio of bolt tensile strength to the tensile strength of the part. Above a length equal to 1½ times the transverse bolt spacing, failure by rupture along the net plate section, at full fastener efficiency, is assured.

C5 Installation

Tests[19] have shown that a hardened washer is not needed to prevent minor bolt relaxation resulting from the high stress concentration under the bolt head or nut in connections assembled with A325 bolts. Such relaxations were less than 5% of the initial tension; took place within hours of bolt tightening, after which further loss of tension was negligible; and were substantially the same with and without the use of washers. Tests[19] have also shown that any galling which may take place where nuts for A325 bolts are tightened directly against the connected parts is not detrimental to the static or fatigue strength of the joint. However, to minimize irregularity in the torque-tension ratio where bolts are tightened by the calibrated wrench method, a washer is still required under the nut or bolt head which is turned in tightening. Otherwise, the use of flat circular washers is no longer required with A325 bolts installed in nominal diameter holes. They are required with A490 bolts in steel parts having a specified minimum yield point less than 40 ksi, to reduce galling and brinnelling of these parts. In high-strength steel they are only required to prevent galling of the rotated part. For repair work on existing structures, especially where bolts are used to replace rivets, the use of hardened washers under the bolt head and nut may be required to minimize the effect of surface irregularities adjacent to, and enlargement of, the holes.

Where oversize or short slotted holes are used, standard hardened washers are required to provide adequate bearing area. These washers are to be placed on the exposed face of the oversized or short slotted hole.

Where long slotted holes are used, experimental evidence has shown that a plate washer or continuous bar of at least 5/16-in. thickness is necessary to provide adequate bearing. This washer or bar shall be of structural grade material but need not be hardened. However, if hardened washers are required to satisfy Specification provisions, the hardened washer shall be placed over the outer surface of the plate washer or bar.

Bolts properly installed and inspected by torquing can sustain additional direct tension loads in excess of the initial tension without any apparent reduction in their ultimate strength. Because of this reserve strength, it is apparent that if the fastener does not fail while being installed, it should not fail thereafter, provided the loads to which it is subjected do not exceed those for which it has been designed.

Without preference, the Council endorses both the calibrated wrench and the turn-of-nut methods for bolt tightening.

Earlier editions of the Council's specifications have listed torque values described as the approximate equivalent of the minimum bolt tension specified for various size bolts. It was explained that these values were no more than observed experimental averages, and that the value to be used, both in installing bolts and in inspection procedures, should be that determined by the actual condition of the application. This point cannot be emphasized too much. The present specification requires that both torque and impact wrenches be calibrated, by means of a device capable of measuring the actual tension produced by a given wrench effort applied to a representative sample, when the tightening of bolts is controlled on the basis of calibrated wrench operation.

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[13] "High-Strength Bolts Subjected to Combined Tension and Shear," by E. Chesson, Jr., N. L. Faustino, and W. H. Munse, *ASCE Journal*, Vol. 91, ST5, October, 1965.

[14] "Shear Strength of High Strength Bolts," by James J. Wallaert and John W. Fisher, *ASCE Journal*, Vol. 91, ST3, June, 1965.

[15] "A440 Steel Joints Connected by A490 Bolts," by Gordon H. Sterling and John W. Fisher, *ASCE Journal*, Vol. 92, ST3, June, 1966.

[16] "Bearing Ratio Effect on Static Strength of Riveted Joints," by Jonathan Jones, *Transactions*, ASCE, Vol. 123, 1958, pp. 964-972.

[17] "The Effect of Bearing Pressure on the Static Strength of Riveted Connections," Bulletin No. 454, Univ. of Illinois, Engrg. Experiment Sta., Urbana, Ill., July 1959.

[18] "Effect of Bearing Pressures on Fatigue Strength of Riveted Connections," by E. Chesson, Jr., J. F. Parola, and W. H. Munse, Univ. of Illinois, Engrg. E[illegible] Sta. Bulletin No. 481, 1965.

[19] "Studies of The Behavior of High-Strength Bolts and Boltec [illegible] nts," by E. Chesson, Jr., and W. H. Munse, Univ. of Illinois Engrg. Experiment Sta. Bulletin No. 469, 1964.

Hydraulic calibrating devices capable of indicating bolt tension undergo a slight deformation under large bolt heads. Hence the nut rotation corresponding to a given tension reading may be somewhat larger than it would be if the same bolt were tightened against a solid steel abutment. Stated differently, the reading of the calibrating device tends to under-estimate the tension which a given rotation of the turned element would induce in a bolt in an actual joint. This should be borne in mind when using such devices to establish a tension-rotation relationship.

Instead of suggesting one full turn of the nut from a finger-tight position,[19] when tightening is controlled by the turn-of-nut prescription, a somewhat smaller rotation, from a *snug-tight* condition, is now specified in Table 4.[1,20,21,22] On an average, the bolt tension provided by either prescription is approximately the same. However, measuring the nut rotation from a snug-tight condition, which necessitates first drawing the several parts of the connection tightly together, has been found to produce more uniform bolt tension.

Tests[22] have shown that A490 bolts longer than eight diameters or 8 inches require a somewhat greater nut rotation in order to achieve the bolt tension shown in Table 3. Although the need does not exist with A325 bolts, the ⅔ turn provision has been applied to the A325 bolts as well, in the interest of uniformity in field practice.

The percentage of bolts in a given connection which must be made snug-tight in order to compact the joint will depend upon the stiffness of the several connected parts and their initial straightness. In extreme cases it may be necessary to snug-up bolts in all of the holes not used for pinning, in order to seat the parts.

After the parts are suitably drawn together, bolts are installed in any remaining open holes, tightened to a snug-tight condition, and all nuts are then rotated by the prescribed amount, after which bolts are installed in the holes originally pinned, and tightened using the same procedure.

Tightening of the bolts in a joint should commence at the most rigidly fixed or stiffest point, and progress toward the free edges, both in the initial snugging up and in the final tightening. During tightening, the bolt head or the nut should be held by a hand wrench to prevent turning.

C6 Inspection

Bolts, nuts and washers are normally received with a light residual coating of oil which should not be removed. This coating is not detrimental even to friction-type connections and need not be removed.

Bolts tightened by the turn-of-nut method may have the outer face of the nut match-marked with the protruding bolt point before final tightening, thus affording the inspector visual means of noting the actual nut rotation. Such marks can be made by the wrench operator with a crayon or dab of paint, after the bolts have been brought up snug tight.

The sides of bolt heads and nuts tightened with an impact wrench will appear slightly peened and thus indicate that the wrench has been applied to the fastener.

If a torque wrench is used to inspect bolts, the procedure to be followed is described in detail in Section 6(c) of the Specification. Because of the variability of the torque-tension relationship, a range of tension from +5% to +10% was utilized to adjust the inspecting power wrench to the minimum job inspecting torque.

Where no washers are used, torque readings will be relatively high and may vary considerably. For this case the use of a torque multiplier device may be necessary.

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[19] "Tightening High-Strength Bolts," by F. P. Drew, Proc. Sep. No. 786, ASCE, Vol. 81, August, 1955.

[20] "Installation and Tightening of High-Strength Bolts," by E. F. Ball and J. J. Higgins, *Transactions*, ASCE, Vol. 126, 1961, pp. 797–820.

[21] "Calibration of A325 Bolts," by J. L. Rumpf and J. W. Fisher, *ASCE Journal Structural Division*, Vol. 89, No. ST6, Proc. Paper 3731, December, 1963, pp. 215–234.

[22] "Calibration Tests of A490 High-Strength Bolts," by G. H. Sterling, E. W. J. Troup, E. Chesson, and J. W. Fisher,