I/3 Properties:

Stress-Strain Curves for Specified Minimum Strength Properties

The representative stress-strain curves presented in this chapter are based on the minimum mechanical properties guaranteed for the steels indicated. In general, tensile test results exceed the specified minimum guaranteed values for each steel.

The curves are indicative of the stress-strain patterns to be expected from testing of specimens. Many factors influence a test, such as: composition of the heat of steel, location of the coupon, speed of testing, accuracy of testing equipment, individual performing the test, use of different testing machines, etc. Therefore, all test coupons will not produce identical results, even though all tests follow the procedure outlined by "Standard Methods and Definitions for Mechanical Testing of Steel Products," ASTM Designation A370.

The steels plotted, their minimum yield points (or yield strengths) and minimum tensile strengths are as follows:

USS "T-1" (ASTM A514, Grade F) constructional alloy steel has a minimum yield strength, by extension under load or by 0.2% offset, of 100,000 psi; and a tensile strength from 115,000 to 135,000 psi for plates and from 115,000 to 140,000 psi for bars in thicknesses from 3/16 to 2½ in., inclusive, for both plates and bars. For plate thicknesses over 2½ in. thru 4 in., "T-1" steel has a minimum yield strength of 90,000 psi.

USS "T-1" type A (ASTM A514, Grade B) constructional alloy steel has a minimum yield strength, by extension under load or by 0.2% offset, of 100,000 psi; and a tensile strength from 115,000 to 135,000 psi for plates and from 115,000 to 140,000 psi for bars in thicknesses from 3/16 to 1¼ in., inclusive, for both plates and bars.

USS "T-1" type B (ASTM A514, Grade H) constructional alloy steel has a minimum yield strength, by extension under load or by 0.2% offset, of 100,000 psi; and a tensile strength from 115,000 to 135,000 psi for plates and from 115,000 to 140,000 psi for bars in thicknesses from 3/16 to 2 in., inclusive, for both plates and bars.

Summary of USS Constructional Steels for Bridges

Availability By Yield Point		
Yield Point Minimum PSI	Plates	Structural Shapes†
100,000*	"T-1" to 2½ in., incl "T-1" type A to 1¼ in., incl "T-1" type B to 2 in., incl	— — —
90,000*	"T-1" over 2½ to 8 in., incl	—
50,000	COR-TEN B to 4 in., incl EX-TEN 50 to 2 in., incl	COR-TEN B in ASTM Groups 1, 2, 3, 4 and 5 EX-TEN 50 in ASTM Groups 1, 2, 3 and 4
36,000	A36 to 8 in., incl	All Sections

*Yield Strength

†For information on structural shape groupings refer to ASTM Designation A6-74 which appears in Chapter 5 of this volume.

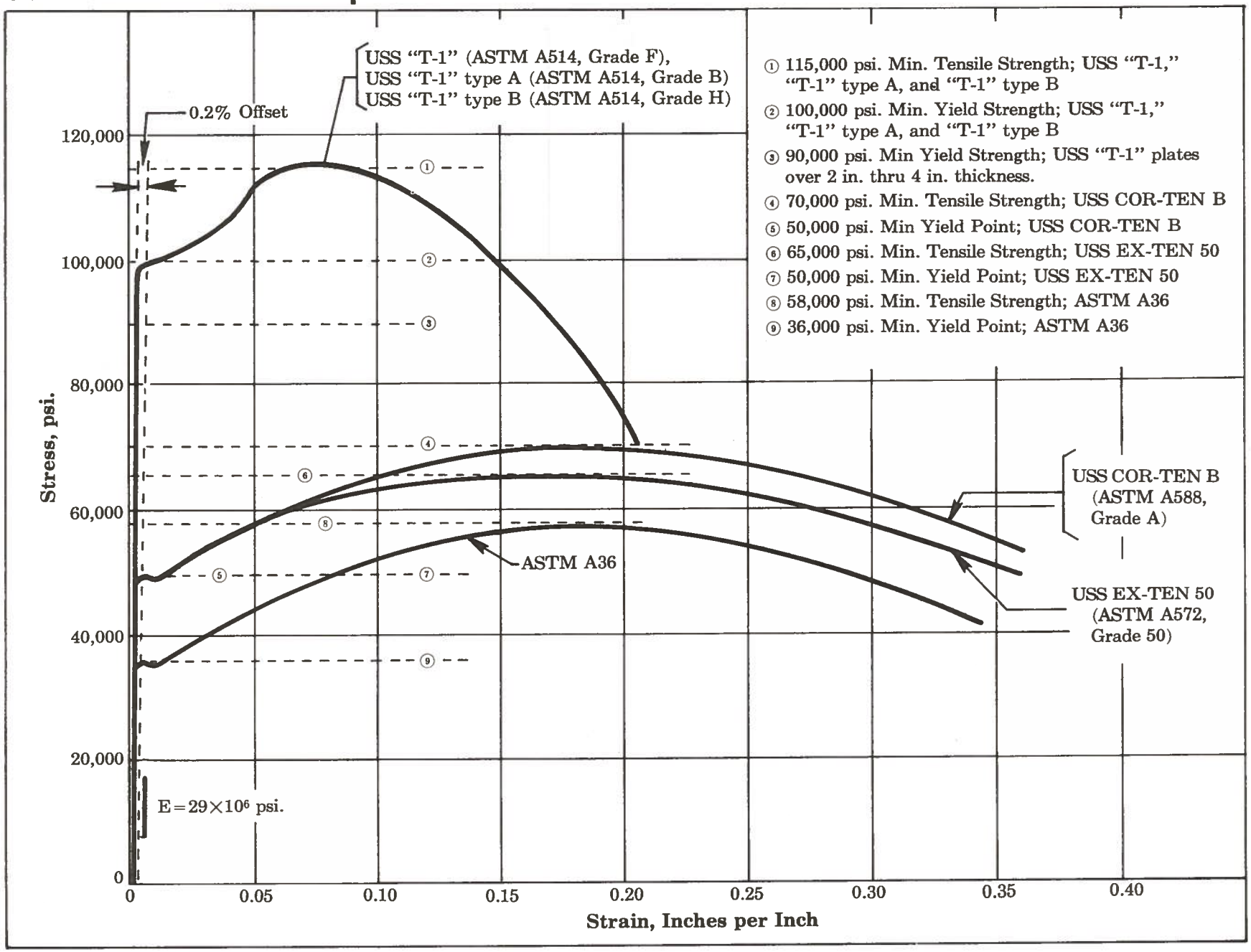
USS COR-TEN B (ASTM A588, Grade A) high-strength low-alloy structural steel has a minimum yield point of 50,000 psi and a minimum tensile strength of 70,000 psi in plate and bar thicknesses to 4 in., inclusive, and for all structurals and wide-flange shapes in ASTM Groups 1, 2, 3, 4 and 5.

USS EX-TEN 50 (ASTM A572 Grade 50) high-strength low-alloy structural steel has a minimum yield point of 50,000 psi and a minimum tensile strength of 65,000 psi in thicknesses to 2 in. inclusive, for plates and bars, and for all structurals and wide-flange shapes in Groups 1, 2, 3 and 4.

ASTM A36 structural carbon steel has a minimum yield point of 36,000 psi and a tensile strength from 58,000 to 80,000 psi for all products.

For information on mechanical and other properties of USS "T-1," COR-TEN and EX-TEN steels in greater thicknesses see "Summary of Constructional Steels for Bridges—Availability by Yield Point" and the property sheets for the specific steels on the following pages.

Stress-Strain Curves for Specified Minimum Values



USS Ex-Ten Steels

USS EX-TEN High-Strength Low-Alloy Steel Plate, Bar and Shapes

General Description

USS EX-TEN Steels are a series of general purpose high-strength low-alloy steels designed to offer optimum combinations of properties at economical costs. The availability of a wide range of minimum yield points from 42 thru 70 ksi (290 thru 485MPa) permits designers to match materials and costs more closely to specific design requirements.

Use of these stronger steels . . . which make possible reduction of material thickness and weight . . . can provide significant cost savings.

USS EX-TEN Steel Plate, Bar and Structural Shapes are normally supplied in the as-rolled condition.

Typical Applications

USS EX-TEN Steel Plate, Bar and Structurals are used for bridges, buildings, towers, automotive and truck parts, railroad freight cars, construction equipment, agricultural machinery, line pipe and various other applications.

Corrosion Resistance

Atmospheric corrosion resistance of USS EX-TEN Steel Plate, Bar and Structurals is the same as that for carbon steel. Copper may be specified at 0.20% min, in which case the atmospheric corrosion resistance is twice that of structural carbon steel without copper.

Specifications

USS EX-TEN Steel Plate, Bar and Structurals can be produced to the requirements of any one of the following specifications when so ordered:

ASTM A572; ASTM A709, Grade 50; SAE J410c; or MIL-S-13281 B (MR), Class B.

Chemical Composition, % (Cast or Heat Analysis) — **Mechanical Properties** — **Size Availability**

Plate and Bar

EX-TEN Grade	Composition(1) C max	Composition(1) Mn max	Yield Point, min ksi (MPa)	Tensile Strength, min ksi (MPa)	Elongation in 2 in. (50 mm), min, %	Elongation in 8 in. (200 mm), min, %	Thickness, in. (mm), incl: To 3/8 (9.5)	Over 3/8 (9.5) to 1¼ (32)	Over 1¼ (32) to 2 (50)	Over 2 (50) to 4 (100)	Over 4 (100) to 8 (200)
42	0.21*	1.35	42.0 (290)	60.0 (410)†	24	20					
45	0.22	1.35	45.0 (310)	60.0 (410)†	22	19					
50	0.23	1.35	50.0 (345)	65.0 (450)†	21	18					
55	0.25	1.35	55.0 (380)	70.0 (480)	20	17			(Thru 1½)		
60	0.26	1.35	60.0 (415)	75.0 (520)	18	16					
65	0.26**	1.35	65.0 (450)	80.0 (550)	—	15					
70	0.26	1.35	70.0 (485)	85.0 (590)	—	14	Plates Only				

Structural Shapes							Structural Shapes Size Groupings per ASTM A6
42	0.21	1.35	42.0 (290)	60.0 (410)†	24 (a)	20	1, 2, 3, 4 and 5
50	0.23	1.35	50.0 (345)	65.0 (550)†	21 (a)	18	1, 2, 3 and 4
60	0.26	1.35	60.0 (415)	75.0 (520)	18	16	1 and 2

(1) All EX-TEN Steels have P 0.04 max; S 0.05 max; Si 0.30 max; and Cb 0.01 min, or V 0.02 min (singly or in combination); or V 0.02 min, and N 0.015 max.

*C is 0.24 max for EX-TEN 42 Steel plates and bars in thicknesses over 4 to 8 in. (100 to 200 mm) incl.

**C is 0.23 max and Mn is 1.65 max for plates and bars in thicknesses over ½ in. (12.7 mm) to 1¼ in. (32 mm) inclusive.

Test specimens, bend test requirements, procedures, and elongation modifications conform to ASTM specifications. Mechanical properties shown here do not apply to annealed or normalized products.

†These tensile strengths are also available when so ordered:
EX-TEN 42 Steel—63 min, ksi (430 MPa)
EX-TEN 45 Steel—65 min, ksi (450 MPa)
EX-TEN 50 Steel—70 min, ksi (480 MPa)

(a) For wide flange shapes over 426 lb/ft (633 kg/m), elongation in 2 in. (50 mm) of 19 percent minimum applies.

USS Ex-Ten Steels

Weldability

USS EX-TEN Steel Plate, Bar, and Structurals can be welded using good shop or field practice by the usual methods; shielded metal-arc, submerged-arc, flux-cored arc, gas metal-arc and resistance welding. See table at the right for suggested welding practice.

Gas Cutting

EX-TEN Steels can be gas cut using good shop practices in accordance with those suggested in the AWS Handbook. Some degree of preheating is required for gas cutting. It is suggested that the preheat temperatures listed at the right for low hydrogen electrodes be used for cutting EX-TEN 42 Steel in the indicated thickness to 4 in. (100 mm), incl. For thicknesses over 4 in. (100 mm), a 300°F (150°C) min preheat temperature is suggested for this grade. For the other EX-TEN Steels, a min preheat temperature of 150°F (65°C) is suggested for thicknesses over 2 in. (50 mm), and 50°F (10°C) is suggested for lighter thicknesses.

Formability

USS EX-TEN Steels can be cold formed with conventional equipment using good shop practice. Because of the higher strength of this steel, slightly greater forming pressures and more liberal bending radii are required than normally used for carbon steel. Bends with the axis transverse to the major rolling direction are preferred and more liberal bending radii may be advisable when the bend axis is parallel to the rolling direction. See the table below for suggested fabricating practice for cold forming.

Cold Forming Radii—Plate

EX-TEN Grade	Thickness	Suggested Minimum Inside Radius
42	To ½ in. (12.7 mm) max	2t
45		2t
50		2½t
55		3t
60		3½t
65		4t
70		6t

Hot forming is recommended for plates over ½ in. (12.7 mm) thick. However, hot forming may result in the lowering of the as-rolled mechanical properties.

Typical Engineering Properties—Plate, Bar and Structurals

Compressive yield point	Equal to tensile yield point
Shearing strength	70% tensile strength
Modulus of Elasticity, ksi (MPa)	28 to 30 × 10^3 (200000)
Coefficient of expansion, in./in./°F (°C) in the range of −50 to +150°F (−45 to 65°C)	6.5 x 10^{-6} (11.7 x 10^{-6})

The values shown above are only "typical engineering properties" and are not specification requirements. United States Steel does not guarantee these properties.

Suggested Welding Practice

EX-TEN Grade	Thickness of Thickest Part at Point of Welding, in. (mm) incl	Low-Hydrogen Process: Min Preheat or Interpass Temp, °F (°C)	Low-Hydrogen Process: Electrode	Other Than Low Hydrogen: Min Preheat or Interpass Temp, °F (°C)	Other Than Low Hydrogen: Electrode
42	To 1 (25)	50 (10)	AWS A5.1 mild-steel covered electrodes (E7016, E7018 or E7028) or AWS A5.17 mild-steel bare electrodes and fluxes, AWS A5.18 mild-steel bare electrodes and gases, AWS A5.20 mild-steel flux-cored electrodes	50 (10)	AWS A5.1 E60XX or E70XX
	Over 1 to 1½ (25 to 38)	50 (10)		200 (93)	
	Over 1½ to 2 (38 to 50)	50 (10)		Not recommended	
	Over 2 (50)	150 (65)			
45	To ¾ (19)	50 (10)		50 (10)	AWS A5.1 E60XX or E70XX
	Over ¾ to 1½ (19 to 38)	50 (10)		200 (93)	
	Over 1½ to 2 (38 to 50)	100 (40)			
50	To ⅜ (9.5)	50 (10)		50 (10)	AWS A5.1 E60XX or E70XX
	Over ⅜ to ¾ (9.5 to 19)	50 (10)		100 (38)	
	Over ¾ to 1 (19 to 25)	50 (10)		200 (93)	
	Over 1 to 1½ (25 to 38)	100 (40)		200 (93)	
	Over 1½ to 2 (38 to 50)	100 (40)		Not recommended	
	Over 2* (50)	200 (95)		Not recommended	
55	To ⅜ (9.5)	50 (10)		50 (10)	AWS A5.1 E70XX
	Over ⅜ to ¾ (9.5 to 19)	100 (40)		100 (38)	
	Over ¾ to 1½ (19 to 38)	200 (95)		Not recommended	
60	To ⅜ (9.5)	50 (10)		50 (10)	AWS A5.1 E70XX
	Over ⅜ to ½ (9.5 to12.7)	100 (40)		200 (93)	
	Over ½ to ¾ (12.7 to 19)	150 (65)		200 (93)	
	Over ¾ to 1¼ (19 to 32)	200 (95)		Not recommended	
65	To ⅜ (9.5)	50 (10)	AWS A5.5 low-alloy steel covered electrodes (E80XX-B1, -C1, -C2, or -C3) or bare electrodes and fluxes or gases or flux-cored electrodes of equivalent strength	Not recommended	
	Over ⅜ to ½ (9.5 to12.7)	100 (40)			
	Over ½ to ¾ (12.7 to 19)	150 (65)			
	Over ¾ to 1¼ (19 to 25)	200 (95)			
70	To ⅜ (9.5)	50 (10)		Not recommended	

*Applicable only to flanges of heavy structural shapes.

Note 1—Preheat temperatures above the minimums shown may be required for highly restrained welds. For such welds, temperatures as high as 250 to 350°F (120 to 175°C) may be necessary.

Note 2—No welding should be done when ambient temperature is below 0°F (−20°C). If steel temperature is below 50°F (10°C), preheating to 50°F min (10°C), or to indicated preheat temperature, whichever is higher, should be performed.

Note 3—Low-hydrogen electrodes, as well as the flux for submerged-arc welding, and the gases for gas-metal-arc and flux-cored-arc welding must be properly dry.

USS Cor-Ten B Steel

Description and Application

USS COR-TEN B Steel provides 50 ksi (345 MPa) minimum yield point in plates, bars, and structural shapes through 4 in. (100 mm) thick for a wide variety of applications.

For information on typical engineering properties and formability, see back cover.

Corrosion Resistance

COR-TEN B Steel has approximately 4 times the atmospheric corrosion resistance of structural carbon steel. Because of this greater resistance to atmospheric corrosion, paint and other protective coatings will last longer on COR-TEN B Steel than on carbon steel.

Weldability

COR-TEN B Steel can be welded, using good shop or field practice, by all usual methods: shielded metal-arc, submerged-arc, flux-cored arc, gas metal-arc, and resistance welding.

Gas Cutting

COR-TEN B Steel can be gas cut using good shop or field practices in accordance with those suggested in the AWS Handbook. Some degree of preheating is required for gas cutting. It is suggested that preheat temperatures listed in the welding table be used.

USS COR-TEN B Chemical Composition, percent (Cast or Heat Analysis)

C	Mn	P	S	Si	Cu	Ni	Cr	V
0.10/0.19	0.90/1.25	0.04 max	0.05 max	0.15/0.30	0.25/0.40	0.65 max	0.40/0.65	0.02/0.10

Fine-grain practice

USS COR-TEN B Mechanical Properties—Plates, Bars, Structurals

Thickness, inches (mm)	Plates & Bars to 4(100) incl; Structurals in ASTM Groups 1, 2, 3, 4 and 5	Plates over 4 (100) to 5 (125) incl	Plates over 5 (125) to 8 (200) incl	Bars over 4 (100) to 9½ (240) incl
Yield Point, min, ksi (MPa)	50.0 (345)	46.0(315)	42.0(290)	45.0(310)
Tensile Strength, min, ksi (MPa)	70.0 (480)	67.0(460)	63.0(430)	66.0(460)
Elongation in 2 in. (50 mm), min, %	21*	21	21	21
Elongation in 8 in. (200 mm), min, %	18	—	—	—

Specified minimum yield point and tensile strength shall be reduced by 5 ksi (35 MPa) for any annealed or normalized products; however, upon negotiation, a 50 ksi (345 MPa) minimum yield point can be provided in normalized plates with a modified COR-TEN B Steel composition.

*Elongation in 2 in. for W shapes over 426 lb/ft (633 kg/m) is 18 percent minimum.

Test specimens, procedures, and elongation modifications conform to ASTM specifications.

Specifications—USS COR-TEN B Steel can be produced to the requirements of ASTM specification A588 Grade A and A709 Grade 50W when so ordered.

USS COR-TEN B Suggested Welding Practices

Electrode	Thickness in. (mm), incl	Suggested min Preheat or Interpass Temp., °F (°C)
For general structural applications: AWS A5.1 low-hydrogen type mild-steel covered electrodes (E7016, E7018 or E7028) or AWS A5.17 mild-steel bare electrodes and fluxes AWS A5.18 mild-steel bare electrodes and gases AWS A5.20 mild-steel flux-cored electrodes	To 1 (25) Over 1 to 2 (25 to 50) Over 2 to 9½ (50 to 240)	50 (10) 100 (40) 200 (95)
For bare steel applications: SINGLE-PASS WELDS may be made using mild steel welding materials above, provided procedure used insures suitable composition enrichment. MULTIPLE-PASS WELDS should be made using AWS A5.5 E80XX -B1, -B2, -C1, -C2, -C3, or G* low-hydrogen-type low-alloy steel covered electrodes for shielded metal-arc welding, or an electrode or electrode-flux combination for submerged-arc, gas metal-arc or flux-cored arc welding that provides filler metal similar to that of the above-mentioned electrodes for shielded metal-arc; these filler metals for multiple-pass welds may also be used for single-pass welds; also, multiple-pass welds may be partially made with mild steel electrodes and completed with alloy steel electrodes.	To 1 (25) Over 1 to 2 (25 to 50) Over 2 to 9½ (50 to 240)	50 (10) 100 (40) 200 (95)

*Weld deposit, %: 0.12 max C, 0.50/1.30 Mn, 0.03 max P, 0.04 max S, 0.35/0.80 Si, 0.30/0.75 Cu, 0.40/0.80 Ni, and 0.45/0.70 Cr.

Note 1—Preheat temperatures above the minimum shown may be required for highly restrained welds. For such welds, temperatures as high as 250 to 400°F (120 to 205°C) may be necessary.

Note 2—No welding should be done when ambient temperature is below 0°F (−20°C). If steel temperature is below 50°F (10°C), preheating to 50°F (10°C) minimum or to indicated preheat temperature, whichever is higher, should be performed.

Note 3—Low-hydrogen electrodes for manual-arc welding, as well as fluxes for submerged-arc welding and gases for gas metal-arc welding, must be properly dry.

USS Cor-Ten Steels

Formability

USS COR-TEN Steels can be cold-formed using conventional equipment and good shop practices. Slightly greater forming pressures and more liberal bending radii are required than are normally used for carbon steel. Bending with the axis transverse to the major rolling direction is preferred. Suggested minimum cold-forming radii for COR-TEN A, B, and C Steels are given at right. More liberal bending radii may be advisable when the bend axis is parallel to the rolling direction. Hot forming is recommended for angle bending over ½ in. (12.7 mm) thick. Hot forming may lower mechanical properties, in which case they would be similar to those for annealed or normalized material.

USS COR-TEN Steels Typical Engineering Properties

Compressive Yield Point	equal to tensile yield point
Shear Strength	equal to 70% of tensile strength
Modulus of Elasticity, ksi (MPa)	28 to 30 x 10^3 (200,000)
Coefficient of Expansion, in./in./°F (mm/mm/°C) in the range of −50 to +150°F (−45 to +65°C)	6.5 x 10^{-6} (11.7 x 10^{-6})
Charpy V-notch impact transition temperature, °F (°C) typical longitudinal 15 ft-lb (20 joule) values	
COR-TEN A Steel [as-rolled ½-in. (12.7 mm) thick plate]	−15 (−26)
COR-TEN B Steel [as-rolled 1-in. (25 mm) thick plate]	−10 (−23)

The values shown above are only "typical engineering properties" and are not specification requirements. United States Steel does not guarantee these properties.

USS COR-TEN Steels Cold-Forming Radii

Thickness in. (mm) incl	Suggested Minimum Inside Radius		
	COR-TEN A	COR-TEN B	COR-TEN C
To 1/16 (1.6)	1t	—	—
Over 1/16 To ¼ (1.6 to 6.4)	2t	—	3½t
Over ¼ To ½ (6.4 to 12.7)	3t	3t	3½t

Effective date August, 1975

The information on this card is subject to change without notice.

Contact the nearest U.S. Steel Sales Office for the latest information on this product.

Note: The values stated in customary U.S.A. units are to be regarded as standard. The metric (SI) units in parentheses are for information only.

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600 Grant Street, Pittsburgh, Pa. 15230 U.S.A.

USS T1 Constructional Alloy Steels

USS "T-1," USS "T-1" type A, USS "T-1" type B

General Description

The family of USS "T-1" Steels is a group of quenched and tempered constructional alloy steels with an unusal combination of advantages. The most important advantages are high yield strength (about 3 times that of structural carbon steel), weldability and low atmospheric temperature toughness. Designed for a wide range of structural uses, as well as for machinery and equipment, these USS constructional alloy steels offer you a selection to help you approach the optimum in strength, toughness, corrosion resistance, impact abrasion resistance, and long-term economy.

Typical Applications

Structural and Pressure Vessel Quality Plate: for general use where their great strength permits reduction in gross design weight because smaller cross sections can be specified . . . fabricated bridge, tower and building members; components for earthmoving or transport equipment; booms, dippersticks, and bucket parts for power shovels or cranes; penstocks, turbine scroll cases and unfired pressure vessels. With copper added, they may be used for exposed, unpainted structures provided that proper design, fabrication and erection practices are followed. "T-1" Steels are not recommended for use in any service at temperatures lower than —50°F (—46°C) or higher than 800°F (425°C). But, for American Association of State Highway and Transport Officials (AASHTO) bridge applications, the "T-1" Steels can be furnished to the supplementary toughness requirements described in AASHTO Spec. M-244, Zone 3, which applies to service down to —60°F(—51°C), when so ordered.

Impact-Abrasion Resistant Plate is heat-treated to 321, 340 or 360 minimum Brinell Hardness (BHN) for severe impact abrasion service, such as in truck and hopper body liners, chutes, wear plates, industrial fan blade liners. For availability see Page 7.

Bar, and Seamless Tubular Products: serve a wide variety of structural uses.

The information on this card is subject to change without notice.

Contact the nearest U.S. Steel Sales Office for the latest information on this product.

USS T1 Constructional Alloy Steel

Description

USS "T-1" Steel . . . the pioneer grade in the quenched and tempered constructional alloy steel family . . . features the largest range of thicknesses for both dynamic and static load designs, and 4 to 6 times the atmospheric corrosion resistance of carbon steel. It is sold in the quenched and tempered condition to a specific chemical composition and specified minimum mechanical properties or to minimum Brinell Hardnesses. Applicable public specifications are listed under "Availability" on Pages 7 and 8.

When so ordered "T-1" Steel plates can be produced to:

ASTM A514
ASTM A709
ASTM A517
AASHTO M244

USS "T-1" Steel Chemical Composition, percent (cast or heat analysis). Plates thru 4" (100 mm) thick, Bars thru 6" (150 mm)

C	Mn	P	S	Si	Ni
0.10/0.20	0.60/1.00	0.035 max	0.040 max	0.15/0.35	0.70/1.00

Cu	Cr	Mo	V	B
0.15/0.50	0.40/0.65	0.40/0.60	0.03/0.08	0.0005/0.006

USS "T-1" Steel Chemical Composition, percent (cast or heat analysis). Plates over 4" (100 mm) thick, Bars over 6" (150 mm)

C	Mn	P	S	Si	Ni
0.14/0.21	0.95/1.30	0.035 max	0.040 max	0.15/0.35	1.20/1.50

Cr	Mo	V
1.00/1.50	0.40/0.55	0.03/0.08

USS "T-1" Steel Mechanical Properties—Plate

Thickness, inches (mm)	3/16 (4.8) thru 2½ (63)		Over 2½ thru 4 (100)		Over 4 thru 8 (200)
Yield Strength, min ksi (MPa)	100 (690)		90 (620)		90 (620)
Tensile Strength, ksi (MPa)	115/135[1] (790/930)		105/135[1] (720/930)		105/135 (720/930)
	Long.	Trans.	Long.	Trans.	Long.
Elongation in 2 in., (50 mm) min %	18	16	17	15	16
Reduction of Area, min, %					
¾ in. (19 mm) and under	40[3]	35[3]			
over ¾ in. (19 mm)	50[2] 40[3]	45[2] 35[3]	50[2]	45[2]	45[2]

Test specimens, procedures and elongation modifications conform to ASTM specifications.

(1) Range lowered 5 ksi (30 MPa) in ASTM A514, Type F.

(2) Measured on ½ in. (12.7 mm) diameter specimen (Fig 6 ASTM A370).

(3) Measured on 1½ in. (38 mm) wide full thickness rectangular specimen (Fig. 4 ASTM A370), which is mandatory for thicknesses ¾ in. (19 mm) and under.

Impact Values, min ft/lb (J), Charpy V-notch, Avg. 3 Specimens

Thickness, in. (mm)	7/16 thru 8 (11.1 thru 200)	
Temperature, °F (°C)	0 (—18) or higher	below 0 to —50 (—18 to —46)
Min. Ft-Lb (J) Long.	30 (41)	20 (27)
Min. Ft-Lb (J) Trans.	20 (27)	15 (20)

Modified values are applicable for sub-size specimens per ASTM A20.

USS T1 type A Constructional Alloy Steel

USS "T-1" type A Steel Chemical Composition, percent (cast or heat analysis)				
C†	Mn	P	S	Si
0.12/0.21	0.70/1.00	0.035 max	0.040 max	0.20/0.35
Cr	Mo	V	Ti	B
0.40/0.65	0.15/0.25	0.03/0.08	0.01/0.03	0.0005/0.005

When added corrosion resistance is desired, 0.20/0.40 Cu may be specified.

†Carbon 0.15/0.21 will be furnished when ordered to ASTM A517, Grade B or ASME SA517 Grade B.

USS "T-1" type A Steel Mechanical Properties—Plate		
Thickness, inches (mm)	Thru 1¼ (32)	
Yield Strength, min ksi (MPa)	100 (690)	
Tensile Strength, ksi (MPa)	115/135(1) (790/930)	
	Long.	Trans.
Elongation in 2 in. (50 mm), min, %	18	16
Reduction of Area, min, %		
¾ in. (19 mm) and under	40(3)	35(3)
over ¾ in. (19 mm)	50(2)	45(2)

Test specimens, procedures and elongation modifications conform to ASTM specifications.

(1) Range lowered 5 ksi (30 MPa) in ASTM A514, Type B.

(2) Measured on ½ in. (12.7 mm), diameter specimen (Fig. 6 of ASTM 370).

(3) Applies to plates. Measured on 1½ in. (38 mm), wide full thickness rectangular specimens (Fig. 4 ASTM A370), which is mandatory for thickness ¾ in. (19 mm), and under.

Impact Values, min ft/lb (J), Charpy V-notch, Avg. 3 Specimens	
Thickness, inches (mm)	7/16 thru 1¼ (11.1 thru 32)
Temperature, °F (°C)	—50 (—46) or higher
Min Ft-Lb (J) Long.	15 (20)
Min Ft-Lb (J) Trans.	15 (20)

Modified values are applicable for thicknesses under 7/16 in.

Description

USS "T-1" type A Constructional Alloy Steel is a low carbon, quenched and tempered grade which provides, in thicknesses thru 1¼ inches (32 mm), the same strength as USS "T-1" Steel. A lower alloy modification of the original "T-1" Steel composition, type A is therefore lower priced.

USS "T-1" type A Steel plate is furnished to the chemical composition and the heat-treated mechanical properties shown in the tables at the left.

Availability—See Pages 7 and 8.

When so ordered "T-1" type A Steel plates can be produced to:

ASTM A514
ASTM A709
ASTM A517
AASHTO M244

USS T_1 type B Constructional Alloy Steel

Description

USS "T-1" type B Constructional Alloy Steel is a low-carbon, quenched and tempered grade which provides, in thicknesses thru 2 inches (50 mm), the same strength as USS "T-1" Steel. The alloy composition of "T-1" type B Steel is leaner than that of "T-1" but richer than that of "T-1" type A; therefore, its price is in-between. USS "T-1" type B Steel plate is furnished to the chemical composition and the heat-treated mechanical properties shown in the tables at the right. Properties for other "T-1" type B Steel products are given on the following pages.

Availability—See Pages 7 and 8.

When so ordered "T-1" type B Steel plates can be produced to:

ASTM A514
ASTM A709
ASTM A517
AASHTO M244

USS "T-1" type B Steel Chemical Composition, percent (cast or heat analysis)

C	Mn	P	S	Si
0.12/0.21	0.95/1.30	0.035 max	0.040 max	0.20/0.35
Ni	Cr	Mo	V	B
0.30/0.70	0.40/0.65	0.20/0.30	0.03/0.08	0.0005 min

When added corrosion resistance is desired, 0.20/0.40 Cu may be specified.

USS "T-1" type B Steel Mechanical Properties—Plate

Thickness, inches (mm)	Thru 2 (50)	
Yield Strength, min ksi (MPa)	100 (690)	
Tensile Strength, ksi (MPa)	115/135(1) (790/930)	
	Long.	Trans.
Elongation in 2 in. (50 mm), min, %	18	16
Reduction of Area, min, %		
¾ in. (19 mm) and under	40(3)	35(3)
over ¾ in. (19 mm)	40(3) 50(2)	35(3) 45(2)

Test specimens, procedures and elongation modifications conform to ASTM specifications.

(1) Range lowered 5 ksi (30 MPa) in ASTM A514, Type H.

(2) Measured on ½ in. (12.7 mm) diameter specimen (Fig. 6 ASTM A370).

(3) Measured on 1½ in. (38 mm), wide full thickness rectangular specimen (Fig 4 ASTM A370), which is mandatory for thicknesses ¾ in. (19 mm), and under.

Impact Values, min ft/lb (J) Charpy V-notch, Avg. 3 Specimens

Thickness, inches (mm)	7/16 thru 2 (11.1 thru 50)	
Temperature, °F (°C)	10 (—12) or higher	Under 10 to —50 (—46)
Min Ft-Lb (J) Long.	20 (27)	15 (20)
Min Ft-Lb (J) Trans.	15 (20)	—

Modified values are applicable for sub-size specimens per ASTM A20.

USS "T-1" Steel—Typical Physical and Engineering Properties

The values shown below are only typical engineering properties and are not specification requirements. U.S. Steel does not guarantee these properties.

Density, lb/cu ft (kg/m³)	490 (7850)
Electrical Resistivity, microhm—cm	18 to 26
Modulus of Elasticity, Tension, psi (MPa) Compression psi (MPa)	 28 to 30 x 10^6 (19 to 21 x 10^4) 28 to 30 x 10^6 (19 to 21 x 10^4)
Coefficient of Expansion, in./in./°F (mm/mm/°C) in the range of —50 to +150°F (—46 to +65°C)	6.5 x 10^{-6} (11.7 x 10^{-6})
Shear Strength Yield Ultimate	 Approx. 58% of tensile yield Approx. 75% of tensile ultimate
Fatigue Strength Rotating beam endurance limit, polished specimen	 Approx. 50% of tensile ultimate

Drop-Weight Test, NDT*

Steel	Thickness, in. (mm) incl	Temperature, °F (°C)
"T-1"	½ to 2½ (12.7 to 63)	—30 to —130 (—34 to —90)
"T-1" type A	½ to 1¼ (12.7 to 32)	—5 to —60 (—20 to —51)
"T-1" type B	1⅜ (35)	—40 (—40)†

Explosion-Bulge Test, FTE**

Steel	Thickness, in. (mm) incl	Temperature, °F (°C)
"T-1"	½ to 2 (12.7 to 63)	—40 to —60 (—40 to —51)
"T-1" type A	½ to 1 (12.7 to 25)	—5 to —60 (—20 to —51)
"T-1" type B	1⅜ (35)	—10 (—23)†

*Nil-ductility-transition temperature. **Fracture-transition-elastic temperature.
†Single Test Results.

USS "T-1" Steels Longitudinal Mechanical Properties—Bars

Thickness, inches (mm)	Thru 4 (100), rd or sq, Flats thru 2½ (63)	Over 4 (100) thru 7 (175) rd or sq, Flats over 2½ (63)	Over 7 (175) thru 9½ (240) rd
Yield Strength, min, ksi, (MPa)	100 (690)	95 (660)	90 (620)
Tensile Strength, ksi, (MPa)	115/140 (790/970)	105/135 (720/930)	105/135 (720/930)
Elongation in 2 in. (50 mm), min, %	18(1)	16	16
Reduction of Area, min, %	55(2)	45	45

Test specimens and procedures conform to ASTM specifications.
(1) Elongation for thicknesses of flats under ¼ in. (6.4 mm), is 15% min.
(2) Reduction of area for ¾ in. (19 mm), and under is 45% min.

Heat Treatment

USS "T-1" Constructional Alloy Steels are water-quenched from 1650/1750°F (900/955°C) and tempered at 1100/1275°F (590/690°C).

Corrosion Resistance

USS "T-1" Steel has 4 to 6 times the atmospheric corrosion resistance of structural carbon steel. "T-1" type A Steel and "T-1" type B Steel have 3 times the atmospheric corrosion resistance of structural carbon steel, and this increases to 4 times when 0.20/0.40% copper is specified.

Properties, Characteristics, and Data Common to All Grades of the "T-1" Constructional Alloy Steels

Formability

USS "T-1" Steels can be cold-formed. Suitable bending radii and increased power must be employed because of the higher strength of "T-1" Steels compared to that of structural carbon steel. Suggested minimum bending radii are given in the accompanying table.

For brake-press forming the lower die span should be at least 16 times the plate thickness.

CAUTION

The "T-1" Steels cannot be hot-formed without impairing their mechanical properties. If hot forming is necessary the "T-1" Steels must be quenched and tempered after hot forming in accordance with instructions from the steel producer.

BHN Plate: moderate bending can be accomplished on plate treated to 321, 340 or 360 minimum BHN by using a radius of 10t or greater. Such forming must be done with the axis of the bend transverse to the final rolling direction. Extreme caution is advised to minimize the possibility of breakage.

For greater ease in forming high-Brinell plate, the "T-1" Steels may be ordered to a controlled Brinell of 321/363.

Weldability

USS "T-1" Steels can be welded satisfactorily by all major welding processes when proper procedures are used. (A booklet and welding calculator, "How to Weld USS 'T-1' Constructional Alloy Steels," is available from your nearest U. S. Steel Sales Office.)

Oxygen Cutting and Plasma Arc Cutting

"T-1" Steels can be oxygen cut or plasma-arc cut using good shop or field practices in accordance with those suggested in the AWS Handbook. Cutting of this material generally does not require preheating in thicknesses up to and including 4 in. (100 mm), but the steel temperature should not be lower than 50°F (10°C) during cutting. For thicknesses over 4 in. (100 mm), preheat temperatures between 300 and 400°F (150 and 205°C)—not higher—are suggested. "T-1" Steels must be quenched and tempered prior to any oxygen cutting, plasma-arc cutting or welding.

USS "T-1" Steels Cold Forming Radii Plates

Thickness, Inches (mm)	Suggested Minimum Inside Radius
Thru 1 (25)	2t
Over 1 (25) thru 2 (50)	3t

Note: For improved formability "T-1" Steels up to 2½ in. (63 mm), incl can be ordered with yield strength range 100-115 ksi (690-790 MPa) with tensile strength for information only.

Suggested Welding Practices for "T-1" Steels

Welding Process	Electrode
Shielded Metal-Arc	E11018-M per AWS A5.5-69; lower strength low-hydrogen electrodes, depending on design stress, may also be suitable if dried to moisture level of E11018 electrode; a higher strength electrode, such as E12018-M may be necessary for thin plates of "T-1" type A Steel.
Submerged-Arc	Electrode-flux combinations designated F116-EF5-F5 (for example Linde 100 wire and 709-5 flux) or F116-EM12K-F5 (for example Lincoln L61 wire and A1010X10 flux) per AWS A5.23-76; electrode-flux combinations depositing lower strength and/or less tough filler metal may also be suitable depending on design stress and application.
Gas Metal-Arc	Mn-Ni-Cr-Mo wire and argon-O_2 gas (for example, Airco AX-110, Linde 120, or Arcosarc 110T).

Suggested Minimum* Preheat or Interpass Temperature, °F (°C)			
Plate Thickness in. (mm)	Shielded Metal-Arc Gas Metal-Arc Flux-Cored-Arc or Gas Tungsten-Arc Welding	Submerged-Arc Process	
		Alloy or Carbon Steel Wire, Neutral Flux	Carbon-Steel Wire, Alloy Flux
Up to ½ (12.7), incl.	50 (10)†	50 (10)†	50 (10)†
Over ½ (12.7) to 1 (25), incl.	50 (10)†	50 (10)†	200 (90)
Over 1 (25) to 2 (50), incl.	150 (65)	150 (65)	300 (150)
Over 2 (50)	200 (90)	200 (90)	400 (205)

*A preheat temperature above the minimum shown may be required for highly restrained welds; low-hydrogen electrodes for shielded metal-arc welding, as well as fluxes for submerged-arc welding and gases for gas-metal-arc welding, must be properly dry.

†Welding a steel section which is at an initial temperature below 100°F (38°C) may require localized preheating to remove moisture from the surface of the steel.

Maximum Heat Input: Per table for "T-1" Steel and table for "T-1" type A and B Steels in "How to Weld USS 'T-1' Constructional Alloy Steels," United States Steel Corporation, latest edition.

Bar

"T-1 Steel" is available in the same full size range as carbon steel bar produced by U. S. Steel, and is furnished in the quenched and tempered condition.

A wide range of "T-1" bar sizes can be furnished to a minimum hardness of 321 Bhn.

"T-1" type A Steel is furnished in rounds, squares and flats, in the following sizes:

ROUNDS AND SQUARES:
Through 1¾ in. (44 mm) thick.

FLATS:
Flats 1¾ in. (44 mm) thick and less can be supplied in widths through 2 in. (50 mm). Flats 1¼ in. (32 mm) thick and less can be supplied in widths 2 in. (50 mm) and greater.

"T-1" type B Steel is furnished in rounds, squares and flats, in the following sizes:

ROUNDS AND SQUARES:
Through 2½ in. (63 mm) thick.

FLATS:
Flats 2½ (63 mm) thick and less can be supplied in widths through 4 in. (100 mm). Flats 2 in. (50 mm) thick and less can be furnished in widths 4 in. (100 mm) and greater.

Semi-Finished Products

"T-1", "T-1" type A, and "T-1" type B Steels can be furnished in the non-heat-treated condition for forging and other hot-forming methods. These are available as slabs and ingots, and in billets 4 in. (100 mm) to 12 in. (300 mm) square.

Semi-Finished products furnished in the non-heat-treated condition are sold with the understanding they will not be referred to as "T-1", "T-1" type A, or "T-1" type B steels until they have been quenched and tempered in accordance with the steel producers instructions.

All products must be quenched and tempered prior to oxygen cutting, plasma-arc cutting, or welding.

Tubular Shapes

"T-1" and "T-1" type A Steels

ROUND TUBING

Hot-finished seamless tube is available with OD's from 2 to 14 inch (50 to 356 mm), in a range of wall thicknesses from 0.165 to 1.000 in. (4 to 25 mm).

Cold-finished seamless tube is available with OD's from 2 to 8.625 inch (50 to 220 mm) in a range of wall thicknesses to 0.625 in. (16 mm) max.

SQUARE TUBING

Available in cold-finished tubing from 1⅝ to 6¾ inch (41 to 171 mm) with wall thicknesses up to 0.500 inch (12 mm) max.

Note: For sizes other than above, including rectangular tubing, please inquire.

USS
United States Steel
600 Grant St., Pittsburgh, Pa. 15230

Effective Date September, 1976

Note: The values stated in customary English units are to be regarded as standard. The SI (metric) units are for information only and are not necessarily direct conversions.

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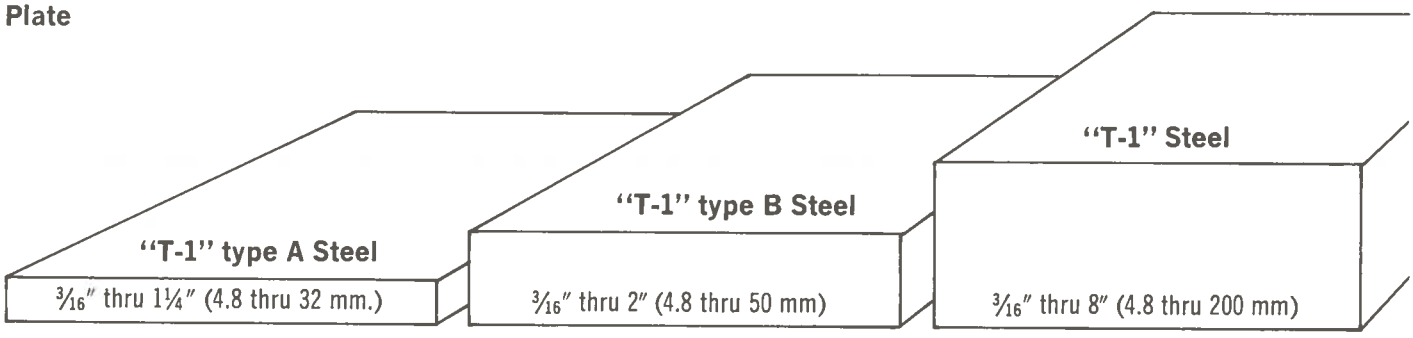
Availability of USS T1 Constructional Alloy Steels

Plate



Structural Quality Specifications

1.

ASTM A514 Type B
ASTM A709 Grade 100 & 100W
AASHTO M244 type B
"T-1" type A Steel—Structural Quality

ASTM A514 Type H
ASTM A709 Grade 100 & 100W
AASHTO M244 type H
"T-1" type B Steel—Structural Quality

ASTM A514 Type F—thru 4" (100 mm)
ASTM A709 Grade 100 & 100W—thru 4" (100 mm)
AASHTO M244 type F—thru 4" (100 mm)
"T-1" Steel—Structural Quality—thru 8" (200 mm)

Pressure Vessel Quality Specifications

2.

ASTM A517 Type B
ASME SA517 Grade B
"T-1" type A Steel—Pressure Vessel Quality

ASTM A517 Type H
"T-1" type B Steel—Pressure Vessel Quality

ASTM A517 Type F—thru 2½" (63 mm)
ASME SA517 Grade F—thru 2½" (63 mm)
"T-1" Steel—Pressure Vessel Quality—thru 8" (200 mm)

Abrasion Resistant Quality

3.

321 min BHN—thru 1¼" (32 mm)
Controlled Brinell 321/363 thru 1¼" (32 mm)
340 min BHN—thru 1" (25 mm)
360 min BHN—thru ¾" (19 mm)

321 min BHN—thru 2" (50 mm)
Controlled Brinell 321/363 thru 2" (50 mm)
340 min BHN—thru 1½" (38 mm)
360 min BHN—thru 1" (25 mm)

321 min BHN—thru 6" (150 mm)
Controlled Brinell 321/363 thru 6" (150 mm)
340 min BHN—thru 2" (50 mm)
360 min BHN—thru 1½" (38 mm)