



Designation: A 686 – 92 (Reapproved 1999)

Standard Specification for Tool Steel, Carbon¹

This standard is issued under the fixed designation A 686; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the chemical, mechanical, and physical requirements for available wrought carbon tool steel products.

1.2 These products, which include hot- or cold-finished bar, plate, sheet, rod, wire, or forgings, are normally fabricated into tools, dies, or fixtures. The selection of a material for a particular application will depend upon design, service conditions, and desired properties.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products²

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings³

A 561 Practice for Macroetch Testing of Tool Steel Bars³

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment³

E 3 Methods of Preparation of Metallographic Specimens⁴

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron⁵

E 45 Test Methods for Determining the Inclusion Content of Steel⁴

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition⁵

2.2 Military Standard:

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage⁶

2.3 Federal Standards:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)⁶

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products⁶

3. Classification

3.1 Material in accordance with this specification is classified by chemical composition. Types correspond to respective AISI designations.

3.1.1 *Carbon Tool Steels, Identification W*—Types W1, W2, and W5 are often referred to as water hardening tool steels since they require rapid quenching rates to attain the necessary hardness. Except in very small sizes they will harden with a hard case and a soft core.

3.1.1.1 Type W1 is an unalloyed carbon steel available in several carbon ranges.

3.1.1.2 Type W2 is characterized by a nominal vanadium content of 0.25 % and is also available in several carbon ranges.

3.1.1.3 Type W5 is characterized by a nominal chromium content of 0.50 %.

3.1.1.4 A suffix following the type designation is added to denote the minimum carbon content of the carbon range to be specified.

3.1.2 Types W1 and W2 are further classified by quality levels, namely, Grade A and Grade C.

3.1.2.1 Grade A is sometimes referred to as *Extra* or *Special*. It is controlled for hardenability; the chemical composition is held to closest limits; and it is subject to rigid tests to ensure uniformity. Grade A is available with three degrees of hardenability, namely, shallow hardening, regular hardening, and deep hardening.

3.1.2.2 Grade C is sometimes referred to as *Regular* or *Standard*. It is intended for applications that do not require controlled hardenability and where some latitude in uniformity is permissible.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information, as required to describe adequately the desired material:

4.1.1 Class of material (carbon tool steel),

¹ This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys, and is the direct responsibility of Subcommittee A01.29 on Tool Steels.

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² *Annual Book of ASTM Standards*, Vol 01.03.

³ *Annual Book of ASTM Standards*, Vol 01.05.

⁴ *Annual Book of ASTM Standards*, Vol 03.01.

⁵ *Annual Book of ASTM Standards*, Vol 03.05.

⁶ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.



- 4.1.2 Type (W1, W2, W5),
- 4.1.3 Suffix denoting carbon range (where applicable, such as W1–9, W2–10, etc.),
- 4.1.4 Grade and hardenability (where applicable, for example, Grade A deep hardening, and so forth),
- 4.1.5 Shape (sheet, plate, flat bar, round bar, square bar, hexagon bar, octagon, special shapes),
- 4.1.6 Dimensions (thickness, width, diameter, length),
- 4.1.7 Finish (hot rolled, forged, blasted or pickled, cold drawn, machined, ground, precision ground and polished),
- 4.1.8 Condition (annealed, unannealed, hardened and tempered, and so forth),
- 4.1.9 ASTM specification number and date of issue, and
- 4.1.10 Special requirements.

5. Materials and Manufacture

5.1 Unless otherwise specified, material covered by this specification shall be made by an electric melting process. It shall be made from ingots that have been reduced in cross section in such a manner and to such a degree as to ensure proper refinement of the ingot structure.

6. Chemical Composition

6.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentage of the elements specified and these values shall conform to the chemical composition specified in Table 1. If requested or required, the chemical composition shall be reported to the purchaser or his representative.

6.2 Analysis may be made by the purchaser from finished bars and forgings by machining off the entire cross section and drilling parallel to the axis of the bar or forging at any point midway between the center and surface in accordance with the latest issue of Method E 59. The chemical analysis of the drilling chips shall be made in accordance with the latest issue of Methods E 30. The chemical composition thus determined shall not vary from the limits specified in Table 1.

7. Hardness Properties

7.1 Annealed hardness values shall be obtained in accordance with the latest issue of Test Methods and Definitions A 370, and shall not exceed the Brinell hardness values (or equivalent Rockwell hardness values) specified in Table 2.

7.2 Specimens for determination of minimum response to hardening shall be ¼-in. (6.4-mm) thick disks cut so as to represent either the full cross-sectional area or that midway between the center and outer surface of the material. If the material form or size does not lend itself to accurate hardness determination on ¼-in. (6.4-mm) thick cross-sectional disks, then longitudinal specimens may be used for hardness testing. Examples are round bars less than ½ in. (12.7 mm) in diameter or sheet. In this case, the specimen shall be a minimum of 3 in. (76.2 mm) in length and parallel flats shall be ground on the original mill surfaces. The specimens shall be heat treated as prescribed in Table 3.

7.2.1 The hardness of the specimen after the specified heat treatment shall meet the minimum hardness value for the particular type of steel shown in Table 3. Rockwell C tests should be used where possible but light load tests may be necessary on thin specimens. These tests should be specified by agreement between seller and purchaser. The hardness value shall be obtained in accordance with the latest issue of Test Methods and Definitions A 370, and shall be the average of at least five readings taken in an area midway between the center and surface of the largest dimension of the cross-sectional specimen or along the parallel surfaces of the longitudinal specimen. The surface to be tested shall be ground sufficiently to remove any surface condition, scale, carburization, or decarburization which might affect readings.

7.2.2 Hardness penetration and fracture grain size for Grade A shall be determined on test pieces of ¾ in. (19.1 mm) diameter and 3 in. (76.2 mm) length. Two pieces for each test shall be given a preliminary treatment by heating uniformly to 1600 ± 10°F (871 ± 5°C) and holding at temperature for 40

TABLE 1 Chemical Composition, %^A

UNS Designation	Type	Grade	Carbon		Manganese		Silicon		Phosphorus, max	Sulfur, max	Chromium		Vanadium		Tungsten, max	Molybdenum, max	Copper, max	Nickel, max
			min	max	min	max	min	max			min	max	min	max				
T72301	W1	A	^B	^B	0.10	0.40	0.10	0.40	0.030	0.030	...	0.15	...	0.10	0.15	0.10	0.20	0.20
T72301	W1	C	^B	^B	0.10	0.40	0.10	0.40	0.030	0.030	...	0.30	...	0.10	0.15	0.10	0.20	0.20
T72302	W2	A	^C	^C	0.10	0.40	0.10	0.40	0.030	0.030	...	0.15	0.15	0.35	0.15	0.10	0.20	0.20
T72302	W2	C	^C	^C	0.10	0.40	0.10	0.40	0.030	0.030	...	0.30	0.15	0.35	0.15	0.10	0.20	0.20
T72305	W5	...	1.05	1.15	0.10	0.40	0.10	0.40	0.030	0.030	0.40	0.60	...	0.10	0.15	0.10	0.20	0.20

^A Chemistry limits include product analysis tolerances.

^B The carbon ranges for W1 and their respective suffix identification, sometimes referred to as tempers, are as follows:

Suffix	Carbon Range, %	Suffix	Carbon Range, %
8	0.80–0.90	10	1.00–1.10
8½	0.85–0.95	10½	1.05–1.15
9	0.90–1.00	11	1.10–1.20
9½	0.95–1.05	11½	1.15–1.25

^C The carbon ranges for W2 and their respective suffix identification are as follows:

Suffix	Carbon Range, %
8½	0.85–0.95
9	0.90–1.00
9½	0.95–1.10
13	1.30–1.50

**TABLE 2 Maximum Brinell Hardness in Annealed or Cold Drawn Condition**

Type	Annealed BHN	Cold Drawn BHN
W1	202	241
W2	202	241
W5	202	241
Drill Rod (W1, W2, or W5)		
Ordered Diameter, in. (mm)	Brinell	Rockwell
To 1/8 (3.2)	HB 341	HRC 37
Over 1/8 to 1/4 (3.2 to 6.4), incl	HB 275	HRC 28
Over 1/4 to 1/2 (6.4 to 12.7), incl	HB 241	HRC 23
Over 1/2 (12.7)	HB 207	HRB 96

min, then quenching in oil. One piece shall be reheated to $1450 \pm 10^\circ\text{F}$ ($788 \pm 5^\circ\text{C}$) and the other to $1550 \pm 10^\circ\text{F}$ ($843 \pm 5^\circ\text{C}$). Each piece shall be held in the furnace at the respective temperature for 30 min and then quenched in brine (5 to 10 % sodium chloride solution). The pieces shall be nicked with an abrasive wheel in the center of the length and fractured. The fracture face of one portion of each broken test piece shall be ground smooth and etched in 1 + 1 muriatic acid at 165°F (74°C) for measurement of the depth of penetration to be expressed in 64ths of an inch. The fracture grain size shall be determined on the remaining portion of each broken test piece by comparison of the fracture surface of the hardened case with the Shepherd Fracture Grain Size Standards.⁷ These standards consist of ten pieces of steel with fracture faces representing graduated grain sizes from the coarsest (No. 1) to the finest (No. 10). The fracture grain size is estimated to the nearest quarter number. The hardness penetration and fracture grain size for Grade A shall meet the requirements shown in Table 3.

8. Macrostructure

8.1 The macrostructure of a specimen representing the entire cross-sectional area in the annealed condition shall be prepared in accordance with the latest issue of Practice A 561. It shall exhibit a structure free of excessive porosity, segregation, slag, dirt or other nonmetallic inclusions, pipes, checks, cracks, and other injurious defects.

8.2 Macroetch severity levels for center porosity and ingot pattern, illustrated photographically in Practice A 561, shall not exceed the ratings specification in Table 4 for the appropriate material size and composition. More stringent requirements are available by agreement between seller and purchaser.

9. Decarburization

9.1 Decarburization shall be determined on a specimen representing a cross section of the material and prepared in accordance with the latest issue of Methods E 3. When examined at $20\times$ or greater magnification it shall not exceed the values given in Tables 5-9 for the appropriate size and shape of material. Lower limits of decarburization may be specified by agreement between the seller and purchaser.

9.2 Material ordered as ground and polished or ground finished or machine finished shall be free of scale and decarburization.

⁷ The Shepherd Fracture Grain Size Standards may be purchased from Metallurgical Services, Inc., Box 1075, 925 Main St., Niagara Falls, NY 14302.

10. Permissible Variations for Dimensions

10.1 Permissible variations for dimensions shall not exceed the applicable limits stated in Table 6, and Tables 10-22 and Note 1.

NOTE 1—Unmachined tool steel forgings are furnished to size and surface allowances for machining and tolerances over allowances. Experience indicates that the allowances and tolerances in the tabulation below are satisfactory for many applications. When width and thickness differ, each dimension carries its individual allowance and tolerance in accordance with the tabulation; also, the ID and OD take their respective allowances and tolerances. When forgings are ordered, the purchaser should state whether the sizes are the forged or the finished sizes. The minimum sizes ordered for forgings should be the finished sizes plus allowances for machining; and the ordered forged sizes are subject to applicable tolerances

10.2 Out-of-round tolerances for round bars shall be one half the permissible dimensional variations stated in Table 6, Table 10, Table 12, Table 14, Table 15, and Table 17.

11. Workmanship, Finish, and Appearance

11.1 All carbon tool steels shall be free of heavy scale, deep pitting, laps, porosity, injurious segregations, excessive non-metallic inclusions, seams, cracks, checks, slivers, scale marks, dents, soft and hard spots, pipes, or any defects that would detrimentally affect the suitability of the material after removal of the recommended stock allowance.

12. Sampling

12.1 Each particular shipment of a heat of steel by type, size, and shape shall be considered a lot and must conform to the provisions of this specification.

13. Inspection

13.1 When specified in the purchase order, the inspector representing the purchaser shall have access to the material subject to inspection for the purpose of witnessing the selection of samples, preparation of test pieces, and performance of the tests. For such tests, the inspector shall have the right to indicate the pieces from which samples will be selected. Otherwise, the seller shall report to the purchaser, or his representative, the results of the chemical analysis and the physical and mechanical property tests made in accordance with this specification.

14. Rejection and Rehearing

14.1 Unless otherwise specified, any rejections based on tests made in accordance with this specification shall be reported to the seller within 30 days from the date of receipt of the material.

14.2 Material that shows injurious defects subsequent to its acceptance by the purchaser shall be rejected and the seller notified.

14.3 Samples tested in accordance with this specification that represent rejected material shall be preserved for 30 days from the date of the test report. In case of dissatisfaction with the results of the test, the seller may make claim for a rehearing within that time.

15. Packaging, Loading, and Package Marking

15.1 Packaging and Loading:



TABLE 3 Heat-Treating Requirements

Type	Carbon Range, %	Austenitizing Temperature, °F (°C)	Quench Medium	Minimum Hardness, HRC
W1	0.70–0.85	1475 (802)	brine	64
	0.85–0.95	1475 (802)	brine	65
	0.95–1.50	1450 (788)	brine	65
W2	0.85–0.95	1475 (802)	brine	65
	0.95–1.50	1450 (788)	brine	65
W5	1.05–1.15	1475 (802)	brine	65

Hardness Penetration and Fracture Grain Size for Grade A

Specified Depth of Hardening	Quench Temperature, ° F (°C)	W1 (0.70 to 0.95 C)	W2 (0.85 to 0.95 C) ^A	W1 (0.95 to 1.10 C) W2 (0.95 to 1.10 C) ^A	W1 (1.10 to 1.30 C) ^A
		Penetration 64th in.	Grain Size (Shepherd) Not Coarser Than	Penetration 64th in.	Grain Size (Shepherd) Not Coarser Than
Shallow	1450 (788)	10 max	8	8 max	8½
	1550 (843)	not more than 5/64 deeper than at 1450	6½	not more than 5/64 deeper than at 1450	6½
Regular	1450 (788)	9 to 13	8	7 to 11	8½
	1550 (843)	not more than 5/64 deeper than at 1450	6½	not more than 5/64 deeper than at 1450	6½
Deep	1450 (788)	12 min	8	10 to 16	8
	1550 (843)	not more than 10/64 deeper than at 1450	6½	not more than 10/64 deeper than at 1450	6½

^A Applicable to shallow and regular hardening material only.

TABLE 4 Macroetch Standards Maximum Allowable Rating^A

Size Round, in. (mm)	Carbon Tool Steels	
	Porosity	Ingot Pattern
Up to 2 (50.8), incl	4	6
Over 2 to 3 (50.8 to 76.2), incl	4½	6
Over 3 to 4 (76.2 to 101.6), incl	4½	6
Over 4 to 5 (101.6 to 127.0), incl	5	6
Over 5 to 6 (122.0 to 152.4), incl	5	6
Over 6 (152.4)	as negotiated between seller and purchaser.	

^A Refer to macroetch photographs in Practice A 561.

TABLE 5 Maximum Decarburization Limits Rounds, Hexagons and Octagons Maximum Limit Per Side

NOTE—The recommended minimum allowance for machining prior to heat treatment is 25 % greater than the maximum decarburization allowed.

Ordered Size, in. (mm)	Hot Rolled	Forged	Cold Drawn
Up to ½ (12.7), incl	0.013 (0.33)	...	0.013 (0.33)
Over ½ to 1 (12.7 to 25.4), incl	0.025 (0.64)	...	0.025 (0.64)
Over 1 to 2 (25.4 to 50.8), incl	0.038 (0.97)	0.058 (1.47)	0.038 (0.96)
Over 2 to 3 (50.8 to 76), incl	0.050 (1.27)	0.075 (1.91)	0.050 (1.27)
Over 3 to 4 (76 to 102), incl	0.070 (1.78)	0.096 (2.44)	0.070 (1.78)
Over 4 to 5 (102 to 127), incl	0.090 (2.29)	0.116 (2.95)	...
Over 5 to 6 (127 to 152), incl	0.120 (3.05)	0.136 (3.45)	...
Over 6 to 8 (152 to 203), incl	...	0.160 (4.06)	...
Over 8 to 10 (203 to 254), incl	...	0.160 (4.06)	...

15.1.1 Unless otherwise specified, shipments shall be packaged and loaded in accordance with Practices A 700.

15.1.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, when Level A is specified, preservation, packaging, and loading shall be in accordance with the Level A requirements of MIL-STD-163.

15.2 Marking:

15.2.1 Shipments shall be properly marked with the name or brand of manufacturer, purchaser’s name and order number, specification number (ASTM A 686), heat number, grade or type, and where appropriate, the size, length, and weight. Unless otherwise specified, method of marking is at the option of the manufacturer.

15.2.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment, in addition to any requirements specified in the contract or order, shall be in accordance with MIL-STD-163 for military agencies, and in accordance with Fed. Std. No. 123 for civil agencies.

15.2.3 For government procurement by the Defense Supply Agency, steel shall be continuously marked for identification in accordance with Fed. Std. No. 183.



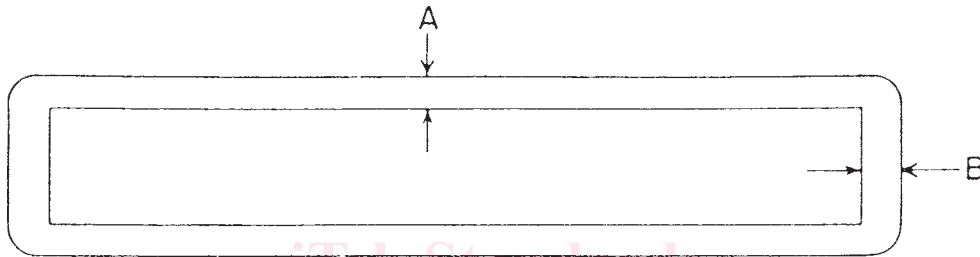
**TABLE 6 Rough-Turned Round Bars
Size Tolerance^A**

Specified Sizes, ^B in. (mm)	Size Tolerance, in. (mm)	
	Under	Over
Over 3/4 to 1 1/2 (19.0 to 38.1), incl	0.00	010 (0.254)
Over 1 1/2 to 3 1/16 (38.1 to 77.8), incl	0.00	015 (0.38)
Over 3 1/16 to 4 1/16 (77.8 to 103.2), incl	0.00	031 (0.79)
Over 4 1/16 to 6 1/16 (103.2 to 154), incl	0.00	062 (1.6)
Over 6 1/16 to 10 1/16 (154 to 255.6), incl	0.00	094 (2.4)
Over 10 1/16 Please consult producer		

^A Out-of-round tolerances to be one half of the total tolerance.
^B Consult producer for oversize allowance and decarburization limits for all sizes.

**TABLE 7 Maximum Decarburization Limits
Hot Rolled Square and Flat Bars
Maximum Limit Per Side**

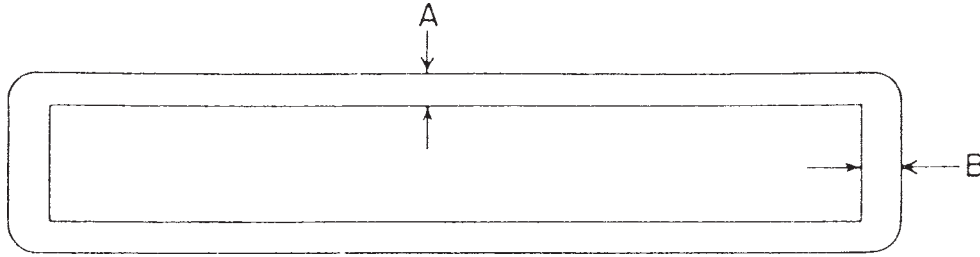
NOTE—The recommended minimum allowance for machining prior to heat treatment is 25 % greater than the maximum decarburization allowed.



Specified Thickness, in. (mm)		Specified Widths, in. (mm)										
		0 to 1/2 (0 to 12.7), incl	Over 1/2 to 1 (12.7 to 25.4), incl	Over 1 to 2 (25.4 to 50.8), incl	Over 2 to 3 (50.8 to 76), incl	Over 3 to 4 (76 to 102), incl	Over 4 to 5 (102 to 127), incl	Over 5 to 6 (127 to 152), incl	Over 6 to 7 (152 to 178), incl	Over 7 to 8 (178 to 203), incl	Over 8 to 9 (203 to 229), incl	Over 9 to 12 (229 to 304), incl
0 to 1/2 (0 to 12.7), incl	A	0.020 (0.51)	0.020 (0.51)	0.024 (0.61)	0.028 (0.71)	0.032 (0.81)	0.036 (0.91)	0.040 (1.02)	0.044 (1.12)	0.048 (1.22)	0.048 (1.22)	0.048 (1.22)
	B	0.020 (0.51)	0.026 (0.66)	0.032 (0.81)	0.038 (0.97)	0.044 (1.12)	0.054 (1.37)	0.062 (1.57)	0.066 (1.68)	0.078 (1.98)	0.082 (2.08)	0.096 (2.44)
Over 1/2 to 1 (12.7 to 25.4), incl	A	...	0.036 (0.91)	0.036 (0.91)	0.036 (0.91)	0.040 (1.02)	0.044 (1.12)	0.052 (1.32)	0.056 (1.42)	0.060 (1.52)	0.060 (1.52)	0.060 (1.52)
	B	...	0.036 (0.91)	0.042 (1.07)	0.046 (1.17)	0.056 (1.42)	0.064 (1.63)	0.082 (2.08)	0.090 (2.29)	0.098 (2.49)	0.102 (2.59)	0.108 (2.74)
Over 1 to 2 (25.4 to 50.8), incl	A	...	...	0.052 (1.32)	0.052 (1.32)	0.056 (1.42)	0.056 (1.42)	0.060 (1.52)	0.060 (1.52)	0.064 (1.63)	0.068 (1.73)	0.072 (1.83)
	B	...	...	0.052 (1.32)	0.056 (1.42)	0.060 (1.52)	0.072 (1.83)	0.086 (2.18)	0.098 (2.49)	0.112 (2.84)	0.118 (3.00)	0.122 (3.10)
Over 2 to 3 (50.8 to 76), incl	A	...	...	...	0.064 (1.63)	0.064 (1.63)	0.068 (1.73)	0.068 (1.73)	0.072 (1.83)	0.072 (1.83)	0.080 (2.03)	0.080 (2.03)
	B	...	...	...	0.064 (1.63)	0.072 (1.83)	0.082 (2.08)	0.094 (2.39)	0.110 (2.79)	0.122 (3.10)	0.130 (3.30)	0.136 (3.45)
Over 3 to 4 (76 to 102), incl	A	...	...	...	...	0.080 (2.03)	0.080 (2.03)	0.086 (2.18)	0.092 (2.34)	0.094 (2.39)	0.100 (2.54)	0.100 (2.54)
	B	...	...	...	...	0.080 (2.03)	0.090 (2.29)	0.100 (2.54)	0.120 (3.05)	0.132 (3.35)	0.132 (3.35)	0.150 (3.81)

**TABLE 8 Maximum Decarburization Limits
Cold Drawn Square and Flat Bars
Maximum Limits Per Side**

NOTE—The recommended minimum allowance for machining prior to heat treatment is 25 % greater than the maximum decarburization allowed.



Specified Thickness, in. (mm)	Specified Width, in. (mm)						
		0 to ½ (0 to 12.7), incl	Over ½ to 1 (12.7 to 25.4), incl	Over 1 to 2 (25.4 to 50.8), incl	Over 2 to 3 (50.8 to 76), incl	Over 3 to 4 (76 to 102), incl	Over 4 to 5 (102 to 127), incl
0 to ½ (0 to 12.7), incl	A	0.020 (0.51)	0.020 (0.51)	0.024 (0.61)	0.028 (0.71)	0.032 (0.81)	0.036 (0.91)
	B	0.020 (0.51)	0.026 (0.66)	0.032 (0.81)	0.038 (0.97)	0.044 (1.12)	0.054 (1.37)
Over ½ to 1 (12.7 to 25.4), incl	A	...	0.036 (0.91)	0.036 (0.91)	0.036 (0.91)	0.040 (1.02)	0.044 (1.12)
	B	...	0.036 (0.91)	0.042 (1.07)	0.046 (1.17)	0.056 (1.42)	0.064 (1.63)
Over 1 to 2 (25.4 to 50.8), incl	A	0.052 (1.32)	0.052 (1.32)	0.056 (1.42)	...
	B	0.052 (1.32)	0.056 (1.42)	0.060 (1.52)	...

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[ASTM A686-92\(1999\)](https://standards.itih.ai/catalog/standards/sist/4e1f0fd8-6dab-40b5-ba36-bceb7ad5590c/astm-a686-921999)

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