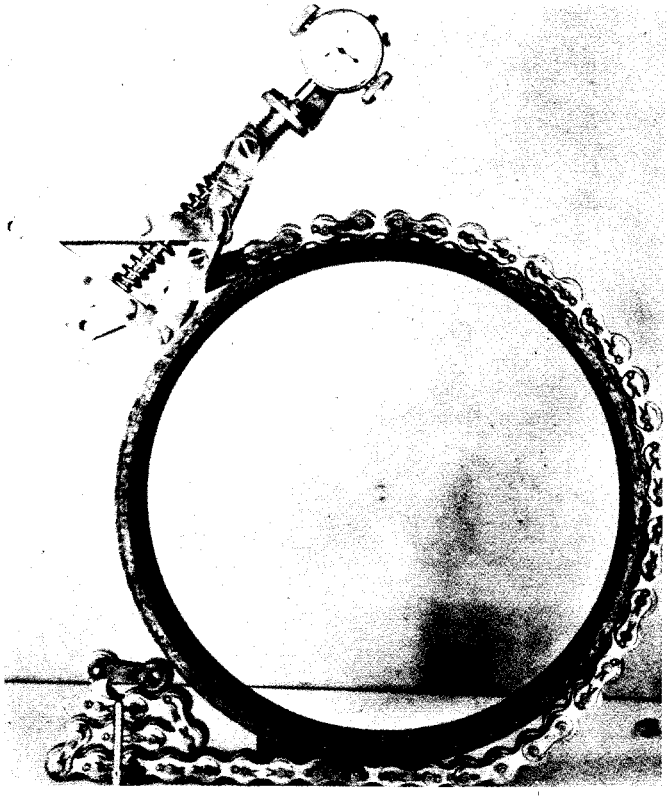


FIG. 23 Roller Chain Type Extensometer, Unclamped

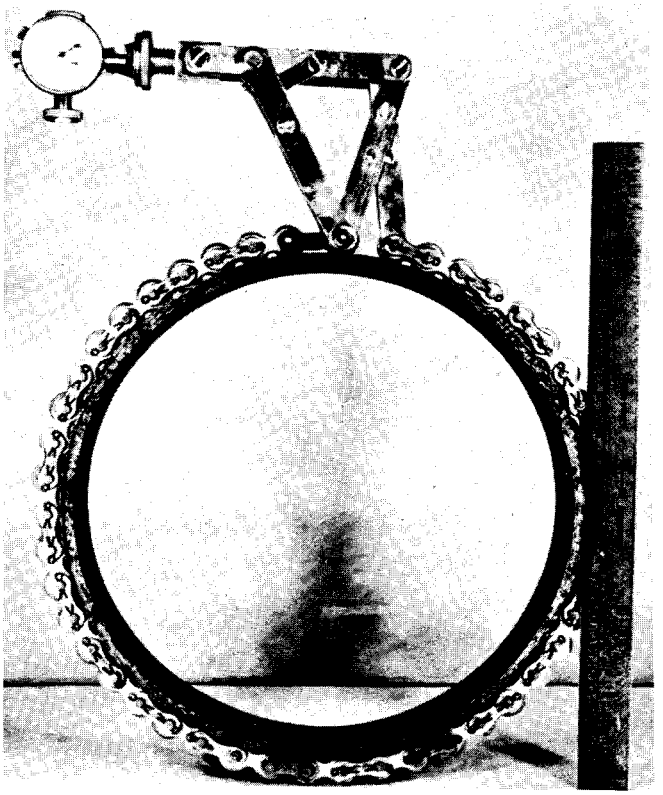


FIG. 24 Roller Chain Type Extensometer, Clamped

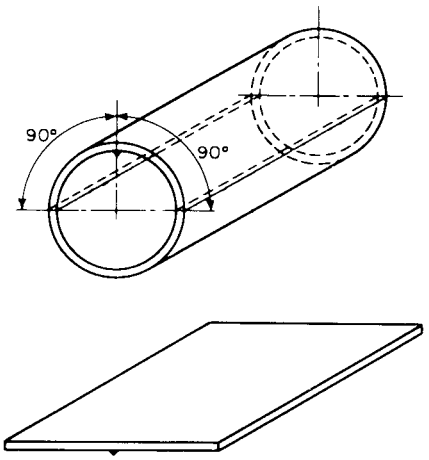
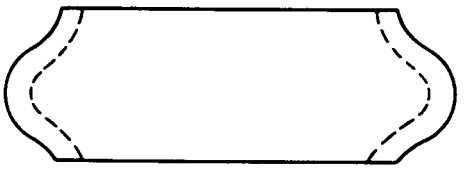


FIG. 25 Reverse Flattening Test



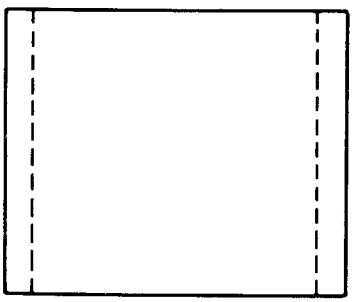
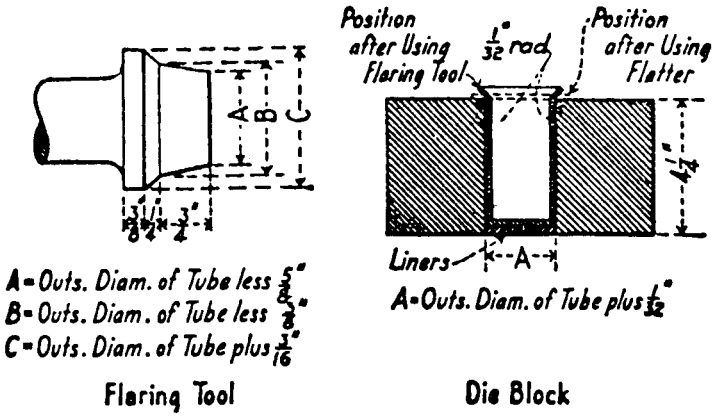


FIG. 26 Crush Test Specimen



NOTE—Metric equivalent: 1 in. = 25.4 mm.

FIG. 27 Flaring Tool and Die Block for Flange Test

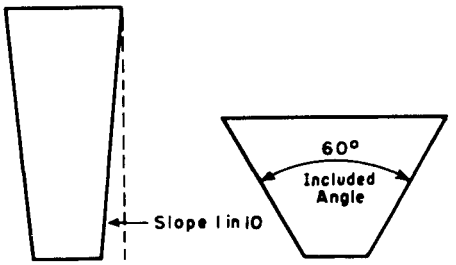
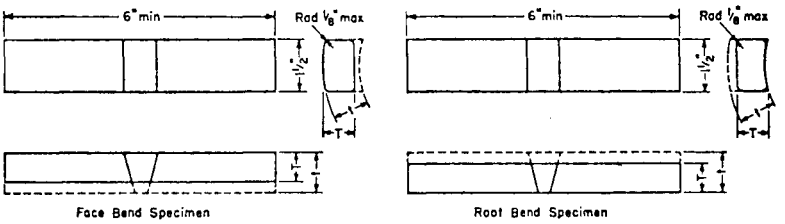


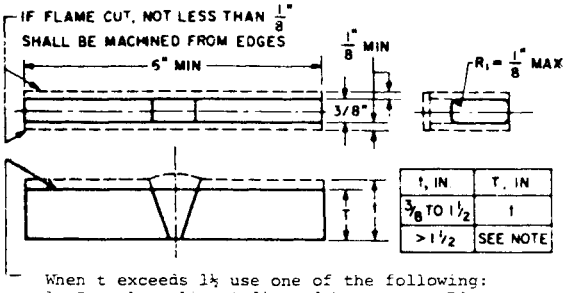
FIG. 28 Tapered Mandrels for Flaring Test



NOTE—Metric equivalent: 1 in. = 25.4 mm.

Pipe Wall Thickness (t), in.	Test Specimen Thickness, in.
Up to 3/8, incl	t
Over 3/8	3/8

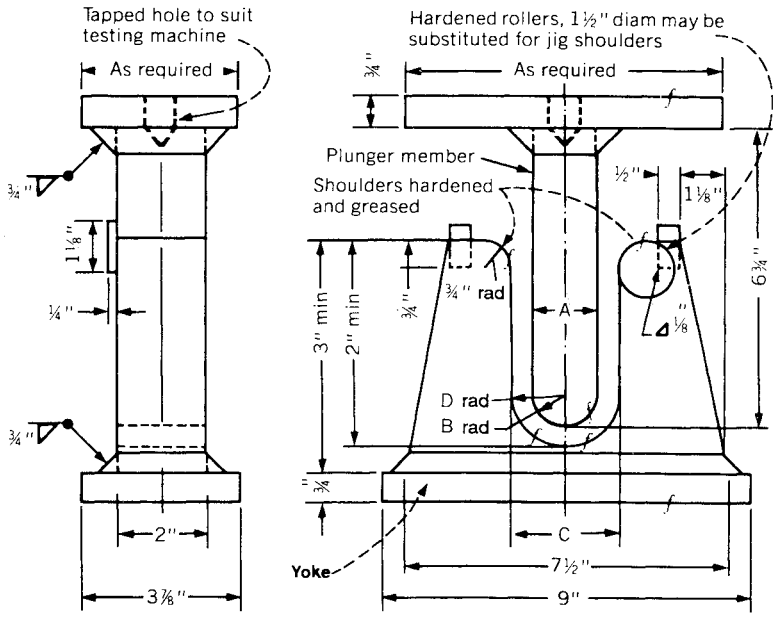
FIG. 29(*a*) Transverse Face- and Root-Bend Test Specimens



When t exceeds 1½ use one of the following:
1. Cut along line indicated by arrow. Edge may be flame cut and may or may not be machined.
2. Specimens may be cut into approximately equal strips between 3/4 in. and 1½ in. wide for testing or the specimens may be bent at full width (see requirements on jig width in Fig. 32.)

NOTE—Metric equivalent: 1 in. = 25.4 mm.

FIG. 29(*b*) Side-Bend Specimen for Ferrous Materials



NOTE: Metric equivalent: 1 in. = 25.4 mm.

Test Specimen Thickness, in.	A	B	C	D	
⅜	1½	¾	2⅜	1 13/16	
t	4*t*	2*t*	6*t* + ⅛	3*t* + 1/16	
					Material
⅜	2½	1¼	3⅜	1 11/16	Materials with a specified minimum tensile strength of 95 ksi or greater.
t	6⅔*t*	3⅓*t*	8⅔*t* + ⅛	4½*t* + 1/16	

FIG. 30 Guided-Bend Test Jig

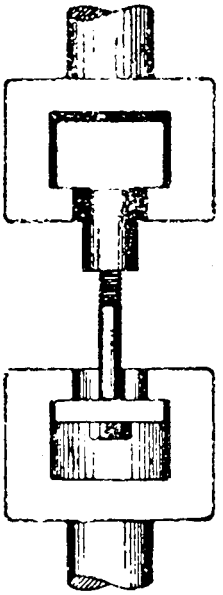
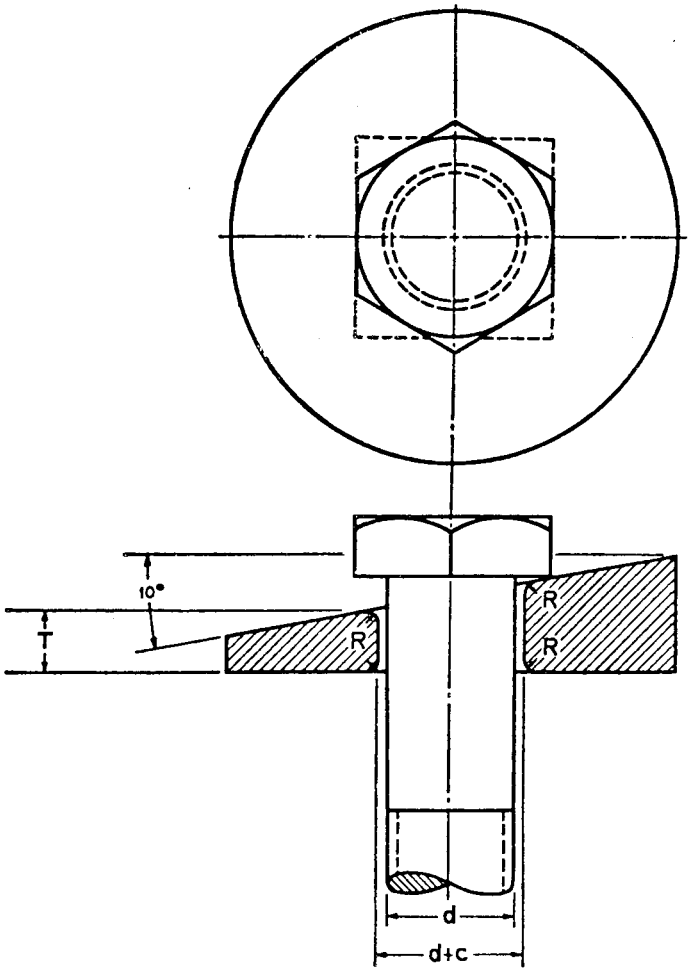
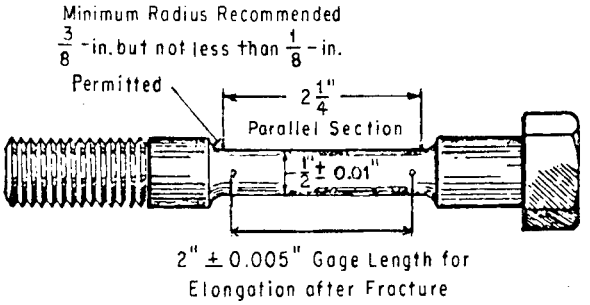


FIG. 31 Tension Testing Full-Size Bolt



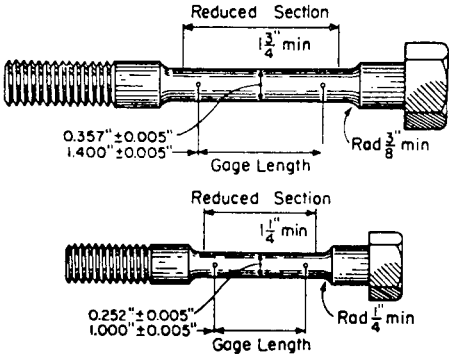
c = Clearance of wedge hole
d = Diameter of bolt
R = Radius
T = Thickness of wedge at short side of hole equal to one-half diameter of bolt

FIG. 32 Wedge Test Detail



NOTE—Metric equivalent: 1 in. = 25.4 mm.

FIG. 33 Tension Test Specimen for Bolt with Turned-Down Shank



NOTE—Metric equivalent: 1 in. = 25.4 mm.

FIG. 34 Examples of Small Size Specimens Proportional to Standard 2-in. Gage Length Specimen

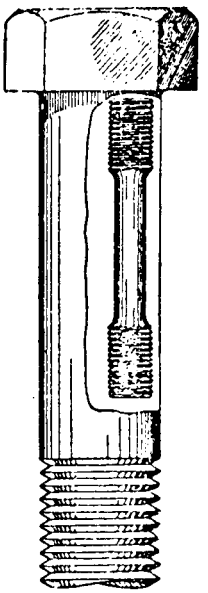
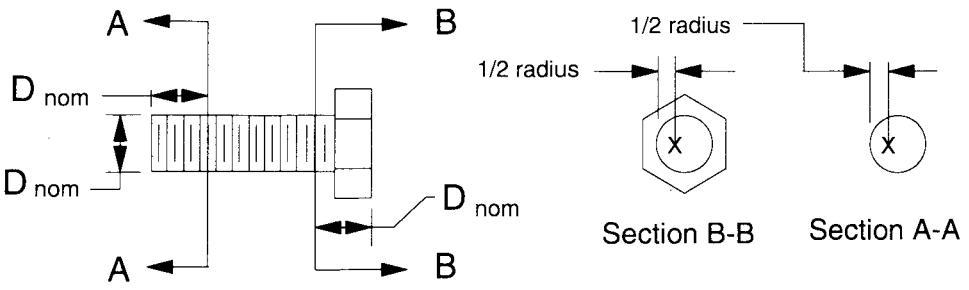


FIG. 35 Location of Standard Round 2-in. Gage Length Tension Test Specimen When Turned from Large Size Bolt



X=Location of Hardness Impressions

FIG. 36 Hardness Test Locations for Bolts in a Dispute

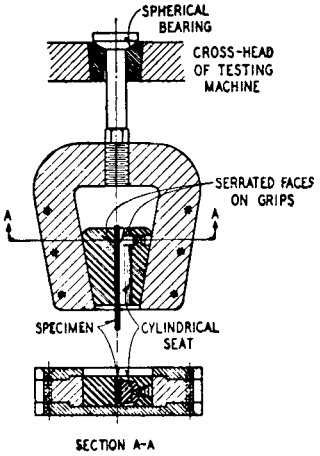


FIG. 37 Wedge-Type Gripping Device

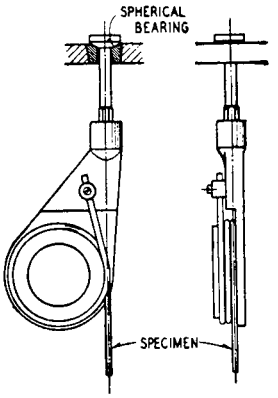


FIG. 38 Snubbing-Type Gripping Device

Designation: A 446/A 446M – 93

This Standard has been discontinued by ASTM and replaced by A 653/A653M and A 924/A924M, effective January 1994

Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Structural (Physical) Quality[1]

This standard is issued under the fixed designation A 446/A 446M; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers steel sheet of structural (physical) quality in coils and cut lengths, zinc-coated (galvanized). Material of this quality is intended primarily where mechanical or structural properties of the base metal are specified or required. Such properties or values include those indicated by tension, hardness, or other commonly accepted mechanical tests. Material of this quality can be produced in six grades, A through F, according to the base metal mechanical requirements (see 6.1). Grade D can be specified with or without a minimum tensile strength required (Classes 1 and 2). Class 1 product will be furnished unless otherwise specified. Structural (physical) quality galvanized sheet is produced with any of the types of coating and coating designations listed in the latest revision of Specifications A 525 or A 525M.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:*

A 525 Specification for General Requirements for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process[2]

A 525M Specification for General Requirements for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process [Metric][2]

A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for[3]

3. General Requirements for Delivery

3.1 Material supplied under this specification shall meet all applicable requirements of the last revision of Specifications A 525 or A 525M unless otherwise specified herein.

4. Ordering Information

4.1 Galvanized sheet in coils and cut lengths is produced to decimal thickness only and thickness tolerances apply. The thickness of the sheet includes both the base metal and the coating.

4.2 Orders for material to this specification shall include the following information, as necessary, to adequately describe the desired product.

4.2.1 Name of material (steel sheet, zinc-coated (galvanized) of structural (physical) quality),

4.2.2 ASTM designation number, year of issue, and grade of product,

4.2.3 Coating designation and type of coating,

4.2.4 Specify whether chemically treated or non-chemically treated,

4.2.5 Specify whether oiled or not oiled,

4.2.6 Extra smooth (if required),

4.2.7 Phosphatized (if required),

4.2.8 Dimensions (show thickness, width, and length, if cut lengths),

4.2.9 Coil-size requirements (specify maximum outside diameter (OD), acceptable inside diameter (ID), and maximum weight),

4.2.10 Application (show part identification and description), and

4.2.11 Special requirements (if required).

4.2.11.1 If required, the product may be ordered to a specified base metal thickness. See Supplementary Requirement S1.

NOTE 1—Typical ordering descriptions are as follows:

Galvanized Sheet, Structural (Physical) Quality, ASTM A 446 – ———, Grade A, Coating Designation G 90, Minimized Spangle, Chemically Treated, Oiled, 0.038 by 36.25 in. by Coil. 24 in. ID, 20 000 lb Maximum for Roof Deck.

Galvanized Sheet, Structural (Physical) Quality, ASTM A 446M – ———, Grade A, Coating Designation Z 275, Minimized Spangle, Chemically Treated, Oiled, 1.00 by 900 mm by Coil. 600 mm ID, 9000 kg Maximum for Roof Deck.

5. Chemical Requirements

5.1 *Cast or Heat Analysis*—The base metal shall conform to the requirements of chemical composition by cast or heat (formerly ladle) analysis prescribed in Table 1.

6. Mechanical Requirements

6.1 The base metal shall conform to the tensile properties prescribed in Table 2.

6.2 Two tension tests for base metal shall be made on random samples of finished material from each cast or heat. When the finished material from said cast or heat is less than

[1] This specification is under the jurisdiction of ASTM Committee A-5 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

Current edition approved March 15, 1993. Published May 1993. Originally published as A 446 – 60 T. Last previous edition A 446 – 91.

[2] *Annual Book of ASTM Standards*, Vol 01.06.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

TABLE 1 Chemical Requirements

	Composition, %					
	Grade					
	A	B	C	D[A]	E	F
Carbon, max	0.20	0.20	0.25	0.40	0.20	0.50
Phosphorus, max	0.04	0.10	0.10	0.20	0.04	0.04
Sulfur, max	0.04	0.04	0.04	0.04	0.04	0.04
Copper, when copper steel is specified, min	0.20	0.20	0.20	0.20	0.20	0.20

[A] Class 1 and 2.

TABLE 2 Mechanical Requirements, Base Metal

Grade	Yield Strength, min, ksi (MPa)	Tensile Strength, min, ksi (MPa)	Elongation in 2 in. (50 mm), min, %
A	33 (230)	45 (310)	20
B	37 (255)	52 (360)	18
C	40 (275)	55 (380)	16
D Class 1	50 (345)	65 (450)	12
D Class 2	50 (345)	. . .	12
E[A]	80 (550)[B]	82 (570)	. . .
F	50 (345)	70 (480)	12

[A] If the Rockwell B result is 85 or higher, no tension test is required.
[B] The yield strength should be taken as the stress at 0.5 % extension under load or 0.2 % offset.

50 tons or 50 Mg, one test for tension will be sufficient. When material rolled from one cast or heat differs 0.050 in. or 1.2 mm or more in thickness, one tension test shall be made from both the thickest and thinnest material rolled regardless of the weight represented. The samples shall be prepared and tested in accordance with the methods specified in Specifications A 525 or A 525M.

6.3 Structural sheet steels are commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a given steel to cold form over a given radius under shop conditions. These factors include thickness, strength level, degree of restraint, relationship to rolling direction, chemistry and microstructure. The appendix lists the suggested minimum inside radius for cold bending. These radii should be used as minima for 90° bends. They presuppose "hard way" bending bend axis parallel to rolling direction and reasonably good shop forming practices. Where possible, the use of larger radii or "easy way" bends are recommended for improved performance.

NOTE 2—Coating thickness/mass equivalence: The coating thickness may be estimated from the coating mass by using the following relationship: 1 g/m^2 total both sides, is equal to 0.14 µm total both sides. 1 oz/ft^2, total both sides, is equal to 0.0017 in. or 1.7 mils total both sides. This relationship is not to be used for calculation of mechanical properties of the base metal, which must be based on actual base metal thickness measurement (see 7.1.2 of Specifications A 525 or A 525M).

NOTE 3—The retest provisions of Specifications A 525 or A 525M are applicable to both base metal and coating tests.

7. Coating Bend Test

7.1 Material of this quality in Grades A, B, and C with coatings designated by the prefix "Z" or "G" shall be capable of being bent through 180° in any direction without flaking of the coating on the outside of the bend only. The coating bend test inside diameter shall have a relation to the thickness as prescribed in Table 4. Flaking of coating within ¼ in. or 6 mm of the edge of the bend specimen shall not be cause for rejection.

7.2 Since the base metal of Grades D (Class 1 and 2), E, and F is not subject to the bend test, there are no coating bend requirements assigned to these grades.

7.3 Coating bend test specimens shall be 2 to 4 in. or 50 to 100 mm wide. The specimen shall be cut not less than 2 in. or 50 mm from the edge of the test sheet.

TABLE 3 Coating Bend Test

NOTE—Since the base metal of Grades D (Class 1 and 2), E, and F is not subject to the bend test, there are no coating bend requirements assigned to these grades.

Coating Designation	Ratio of the Bend Diameter to Thickness of the Specimen		
	Grade A	Grade B	Grade C
Inch-Pound			
G 235	3	3	3
G 210	2	2	2½
G 185	2	2	2½
G 165	2	2	2½
G 140	2	2	2½
G 115	1½	2	2½
G 90	1½	2	2½
G 60	1½	2	2½
G 01	1½	2	2½
SI Units			
Z700	3	3	3
Z600	2	2	2½
Z450	2	2	2½
Z350	1½	2	2½
Z275	1½	2	2½
Z180	1½	2	2½
Z90	1½	2	2½
Z001	1½	2	2½

TABLE 4 Flatness Tolerances (Cut lengths only, not specified to stretcher leveled standard of flatness)

NOTE 1—This table also applies to sheets cut to length from coils by the consumer when adequate flattening measures are performed.

NOTE 2—For Grade D (Class 1 and 2) and F use 1½ times the values given in this table.

NOTE 3—For Grade E, there are no defined flatness standards.

Specified Thickness, in. (mm)	Specified Width, in. (mm)	Flatness Tolerance (Max Deviation From a Horizontal Flat Surface), in. (mm)
Over 0.060 (1.5)	To 60 (1500), incl	½ (12)
	Over 60 (1500) to 72 (1800), incl	¾ (20)
0.060 (1.5) and thinner	To 36 (900), incl	½ (12)†
	Over 36 (900) to 60 (1500), incl	¾ (20)
	Over 60 (1500) to 72 (1800), incl	1 (25)

† SI value editorially corrected.

8. Dimensions and Tolerances

8.1 Except for flatness tolerances, all dimensions and tolerances are subject to the requirements of Specifications A 525 or A 525M. Flatness tolerances of material supplied as structural (physical) quality shall conform to those prescribed in Table 4.

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser. These additional requirements shall apply only when specified on the order.

S1. Base Metal Thickness

S1.1 The specified minimum thickness shall apply to the base metal only.

S1.2 The coating designation shown on the order indicates the coating to be applied to the specified minimum base metal thickness.

S1.3 The applicable tolerances for base metal thickness are shown in Tables 16 and 17, Thickness Tolerance of Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel), of Specification A 568/A 568M.

APPENDIX

(Nonmandatory Information)

X1. BENDING PROPERTIES

TABLE X1. Suggested Minimum Inside Radii for Cold Bending[A]

NOTE X1.1—(*t*) equals a radius equivalent to the steel thickness.

NOTE X1.2—The suggested radii should be used as minimums for 90° bends in actual shop practice.

Grade	Minimum Inside Radius for Cold Bending
A	1½ *t*
B	2 *t*
C	2 *t*
D1	N/A
D2	N/A
E	N/A
F	N/A

[A] Material that does not perform satisfactorily when fabricated in accordance with the above requirements may be subject to rejection pending negotiation with the steel supplier.

Designation: A 529/A 529M – 94

Standard Specification for High-Strength Carbon-Manganese Steel of Structural Quality[1]

This standard is issued under the fixed designation A 529/A 529M; 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 method has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers carbon-manganese steel shapes, plates and bars of structural quality for use in riveted, bolted, or welded construction of buildings and for general structural purposes.

1.2 Material under this specification is available in two grades:

Grade	Yield Strength ksi [MPa]	Thickness
42 [290]	42 [290]	Plates and bar to ½ in. [12.5 mm] Shapes—Group 1
50 [345]	50 [345]	Plates to 1 in. [25 mm] thick to 12 in. [305 mm] width Bars to 1½ in. [38 mm] Shapes—Groups 1 & 2

1.3 When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.4 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Document

2.1 *ASTM Standard:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[2]

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

4. Process

4.1 The steel shall be made by any of the following processes: open-hearth, basic-oxygen, or electric-furnace.

TABLE 1 Chemical Requirements (Heat Analysis)

NOTE—Where "..." appears in this table there is no requirements.

Element	Composition, %	
	Grade 42 [290]	Grade 50 [345]
Carbon, max	0.27	0.27
Manganese, max	1.20	1.35
Phosphorus, max	0.04	0.04
Sulfur, max	0.05	0.05
Silicon, max	...	0.40
Copper, min, when copper is specified	0.20	0.20

TABLE 2 Tensile Requirements[A]

	Grade 42 [290]		Grade 50 [345]	
	ksi	[MPa]	ksi	[MPa]
Tensile strength, min	60	[415]	70	[485]
Tensile strength, max	85	[585]	100	[690]
Yield strength, min	42	[290]	50	[345]
Elongation[B] in 8 in. [200 mm], min, %	19		18	
Elongation[B] in 2 in. [50 mm], min, %	22		21	

[A] See Specimen Orientation in the Tension Tests section of Specification A 6/A 6M.

[B] For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See Elongation Requirement Adjustments in the Tension Tests section of Specification A 6/A 6M.

5. Chemical Requirements

5.1 *Heat Analysis:*

5.1.1 The heat analysis shall conform to the requirements prescribed in Table 1.

5.1.2 Test reports shall include for information the chemical analysis for copper, columbium, chromium, nickel, molybdenum, and vanadium. When the amount of an element present is less than 0.02 %, the analysis may be reported as "equal to or less than 0.02 %."

5.2 *Product Analysis:*

5.2.1 The steel shall conform on product analysis to the requirements of Table 1, subject to the product analysis tolerances in Specification A 6/A 6M, except as specified in 5.2.2.

5.2.2 Product analysis is not required for bar-size shapes or flat bars ½ in. [13 mm] and under in thickness.

6. Mechanical Requirements

6.1 *Tensile Properties:*

6.1.1 The material as represented by the test specimen shall conform to the requirements as to the tensile properties prescribed in Table 2.

7. Keywords

7.1 bars; bolted construction; carbon; frames; metal building systems; plates; riveted construction; shapes; steel; structural steel; trusses; welded construction

[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 A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

Current edition approved June 15, 1994. Published August 1994. Originally published as A 529 – 64. Last previous edition A 529 – 93a.

[2] *Annual Book of ASTM Standards*, Vol 01.04.

SUPPLEMENTARY REQUIREMENTS

Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

S5. Charpy V-Notch Impact Test.

S14. Bend Test.

ADDED SUPPLEMENTARY REQUIREMENTS

In addition, the following optional supplementary requirements are also suitable for use with this specification.

S78. Maximum Carbon Equivalent.

S78.1 This material shall be supplied with a maximum carbon equivalent value of 0.55 or to a lower value specified in the purchase documents. This value will be based on heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported.

S78.2 The carbon equivalent shall be calculated using the following formula:

$$CE = C + (Mn + Si)/6 + (Cu + Ni)/15 + (Cr + Mo + V + Cb)/5$$

S79. Maximum Tensile Strength.

S79.1 The maximum tensile strength for Grade 50 [345] shall be 90 ksi [620 MPa].