EXHIBIT 152
PART 1

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A36: Standard Specification for Carbon Structural Steel

CFR Section(s): 24 CFR Part 200

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 36 – 77a**[ε]

American Association State Highway and Transportation Officials Standard AASHTO No.: M 183

Standard Specification for STRUCTURAL STEEL[1]

This standard is issued under the fixed designation A 36; 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.

[ε]NOTE—Supplementary Requirement S5 was added editorially in August 1979.

This specification has been approved for use by agencies of the Department of Defense for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification[2] covers carbon steel shapes, plates, and bars of structural quality for use in riveted, bolted, or welded construction of bridges and buildings, and for general structural purposes. When the steel is used in welded construction, welding procedure shall be suitable for the steel and the intended service.

1.2 Supplemental requirements are provided where improved notch toughness is important. These shall apply only when specified by the purchaser in the order.

NOTE—The values stated in inch-pound units are to regarded as the standard.

2. Appurtenant Materials

2.1 Unless otherwise provided in the order, the current edition of the specifications of the American Society for Testing and Materials listed in Table 1 shall govern the delivery of otherwise unspecified appurtenant materials when included with material purchased under this specification. Unless otherwise specified, all plain and threaded bars used for anchorage purposes shall be subjected to mechanical tests and shall conform to the tensile requirements of Section 7; headed bolts used for anchorage purposes, and all nuts, shall conform to the requirements of Specification A 307, for Carbon Steel Externally and Internally Threaded Standard Fasteners.[3]

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 6, for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use.[3]

4. Bearing Plates

4.1 Unless otherwise specified, plates used as bearing plates for bridges shall be subjected to mechanical tests and shall conform to the tensile requirements of Section 7.

4.2 Unless otherwise specified, mechanical tests shall not be required for plates over 1½ in. (38 mm) in thickness used as bearing plates in structures other than bridges, subject to the requirement that they shall contain 0.20 to 0.33% carbon by heat analysis, that the chemical composition shall conform to the requirements of Table 2 in phosphorus and sulfur content, and that a sufficient discard shall be made from each ingot to secure sound plates.

5. Process

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

5.2 No rimmed or capped steel shall be used

---

[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.

Current edition approved Aug. 29 and Sept. 30, 1977. Published November 1977. Originally published as A 36 – 60 T. Last previous edition A 36 – 75.

[2] For ASME Boiler and Pressure Vessel Code Applications see related Specifications SA-36 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Part 4.

for plates and bars over ½ in. (13 mm) thick or for shapes other than Group 1.

6. Chemical Requirements

6.1 The heat analysis shall conform to the requirements prescribed in Table 2, except as specified in 4.2.

6.2 The steel shall conform on product analysis to the requirements prescribed in Table 2, subject to the product analysis tolerances in Specification A 6, except as specified in 6.3.

6.3 Product analysis is not applicable for bar-size shapes or flat bars ½ in. (13 mm) and under in thickness.

6.4 When tension tests are waived in accordance with 7.2, chemistry consistent with the requirements in Table 2, and with the mechanical properties desired must be applied.

7. Tensile Requirements

7.1 The material as represented by the test specimen, except as specified in 4.2 and 7.2, shall conform to the requirements as to the tensile properties prescribed in Table 3.

7.2 Shapes less than 1 in.^{2} (645 mm^2) in cross section and bars, other than flats, less than ½ in. (13 mm) in thickness or diameter need not be subjected to tension tests by the manufacturer.

7.3 For material under 5/16 in. (8 mm) in thickness or diameter, a deduction from the percentage of elongation in 8 in. (203 mm), specified in Table 3, of 1.25% shall be made for each decrease of 1/32 in. (0.8 mm) of the specified thickness or diameter below 5/16 in.

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order.

Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6. Those which are considered suitable for use with this specification are listed below 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.

S1. The material supplied shall be other than rimmed or capped steel.

S2. The material to be supplied shall be silicon-killed fine-grain practice.

ASTM Logo Removed

TABLE 1 Material Specifications

Material	ASTM Designation[a]
Plate to be bent or formed cold	A 283, Grade C[b]
Steel rivets	A 502, Grade 1[b]
Bolts and nuts	A 307[b], A 325
Cast steel	A 27, Grade 65–35[b]
Forgings (carbon steel)	A 668, Class D
Hot-rolled sheets	A 570, Grade D
Hot-rolled strip	A 570, Grade D
Cold-formed tubing	A 500, Grade B
Hot-formed tubing	A 501

[a] These designations refer to the following specifications of the American Society for Testing and Materials:

A 283, Low and Intermediate Tensile Strength Carbon Steel Plates of Structural Quality,[3]
A 502, Steel Structural Rivets,[3]
A 307, Carbon Steel Externally and Internally Threaded Standard Fasteners,[3]
A 325, High-Strength Bolts for Structural Steel Joints Including Suitable Nuts and Plain Hardened Washers,[3]
A 27, Mild- to Medium-Strength Carbon-Steel Castings for General Application,[4]
A 668, Steel Forgings, Carbon and Alloy, for General Industrial Use,[5]
A 570, Hot-Rolled Carbon Steel Sheet and Strip, Structural Quality,[3]
A 500, Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes,[3] and
A 501, Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.[3]

[b] These have lower yield point than A 36 steel.

[4] *Annual Book of ASTM Standards,* Part 2.
[5] *Annual Book of ASTM Standards,* Part 5.

TABLE 2 Chemical Requirements

Product	Shapes[a]	Plates					Bars			
Thickness, in. (mm)	All	To ¾ (19), incl.	Over ¾ to 1½ (19 to 38), incl.	Over 1½ to 2½ (38 to 64), incl.	Over 2½ to 4 (64 to 102), incl.	Over 4 (102)	To ¾ (19), incl.	Over ¾ to 1½ (19 to 38), incl.	Over 1½ to 4 (102), incl.	Over 4 (102)
Carbon, max, %	0.26	0.25	0.25	0.26	0.27	0.29	0.26	0.27	0.28	0.29
Manganese, %	...	...	0.80–1.20	0.80–1.20	0.85–1.20	0.85–1.20	...	0.60–0.90	0.60–0.90	0.60–0.90
Phosphorus, max, %	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max, %	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Silicon, %	...	...	...	0.15–0.40	0.15–0.40	0.15–0.40	...	...	...	...
Copper, min, % when copper steel is specified	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

[a] Manganese content of 0.85–1.35 % and silicon content of 0.15–0.40 % is required for shapes over 426 lb/ft.

TABLE 3 Tensile Requirements[a]

Plates, Shapes,[b] and Bars:	
Tensile strength, psi (MPa)	58 000–80 000 (400–550)
Yield point, min, psi (MPa)	36 000 (250)[c]
Plates and Bars[e,f]:	
Elongation in 8 in. or 200 mm, min, %	20[d]
Elongation in 2 in. or 50 mm, min, %	23
Shapes:	
Elongation in 8 in. or 200 mm, min, %	20[d]
Elongation in 2 in. or 50 mm, min, %	21[b]

[a] For plates wider than 24 in. (610 mm), the test specimen is taken in the transverse direction. See 11.2 of Specification A 6.

[b] For wide flange shapes over 426 lb/ft tensile strength minimum of 58 000 psi (400 MPa) only and elongation in 2 in. of 19 % minimum applies.

[c] Yield point 32 000 psi (220 MPa) for plates over 8 in. in thickness.

[d] See 7.3.

[e] Elongation not required to be determined for floor plate.

[f] For plates wider than 24 in. (610 mm), the elongation requirement is reduced two percentage points.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A36: Standard Specification for Carbon Structural Steel

CFR Section(s): 46 CFR 160.035-3(b)(2)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: A 36/A 36M – 97a$^{\epsilon 1}$

Standard Specification for Carbon Structural Steel[1]

This standard is issued under the fixed designation A 36/A 36M; 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.

ϵ^1 NOTE—Table 2 was editorially corrected in September 1999.

1. Scope

1.1 This specification[2] covers carbon steel shapes, plates, and bars of structural quality for use in riveted, bolted, or welded construction of bridges and buildings, and for general structural purposes.

1.2 Supplementary requirements are provided for use where additional testing or additional restrictions are required by the purchaser. Such requirements apply only when specified in the purchase order.

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

1.4 For Group 4 and 5 wide flange shapes for use in tension, it is recommended that the purchaser consider specifying supplementary requirements, such as fine austenitic grain size and Charpy V-Notch Impact testing.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately 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 is to be used independently of the other, without combining values in any way.

1.6 The text of this specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

1.7 For plates cut from coiled product, the additional requirements, including additional testing requirements and the reporting of additional test results, of A 6/A 6M apply.

2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[3]
A 27/A 27M Specification for Steel Castings, Carbon, for General Application[4]
A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength[5]
A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength[5]
A 325M Specification for High-Strength Bolts for Structural Steel Joints [Metric][5]
A 500 Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes[6]
A 501 Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing[6]
A 502 Specification for Steel Structural Rivets[5]
A 563 Specification for Carbon and Alloy Steel Nuts[5]
A 563M Specification for Carbon and Alloy Steel Nuts [Metric][5]
A 570/A 570M Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality[7]
A 668 Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use[8]
F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners[5]

3. Appurtenant Materials

3.1 When components of a steel structure are identified with this ASTM designation but the product form is not listed in the scope of this specification, the material shall conform to one of the standards listed in Table 1 unless otherwise specified by the purchaser.

4. General Requirements for Delivery

4.1 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

[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 Nov. 10, 1997. Published April 1998. Originally published as A 36 – 60 T. Last previous edition A 36/A 36M – 97.

[2] For ASME Boiler and Pressure Vessel Code Applications, see related Specifications SA-36 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.
[4] *Annual Book of ASTM Standards*, Vol 01.02.
[5] *Annual Book of ASTM Standards*, Vol 15.08.
[6] *Annual Book of ASTM Standards*, Vol 01.01.
[7] *Annual Book of ASTM Standards*, Vol 01.03.
[8] *Annual Book of ASTM Standards*, Vol 01.05.

Copyright © ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, United States.

ASTM Logo Removed

TABLE 1 Appurtenant Material Specifications

NOTE 1—The specifier should be satisfied of the suitability of these materials for the intended application. Composition and/or mechanical properties may be different than specified in A 36/A 36M.

Material	ASTM Designation
Steel rivets	A 502, Grade 1
Bolts	A 307, Grade A or F 568M, Class 4.6
High-strength bolts	A 325 or A 325M
Steel nuts	A 563 or A 563M
Cast steel	A 27/A 27M, Grade 65–35 [450–240]
Forgings (carbon steel)	A 668, Class D
Hot-rolled sheets and strip	A 570/A 570M, Grade 36
Cold-formed tubing	A 500, Grade B
Hot-formed tubing	A 501
Anchor bolts	F 1554

which case this specification shall prevail.

4.1.1 Coiled product is excluded from qualification to this specification until levelled and cut to length. Plates produced from coil means plates that have been cut to individual lengths from a coiled product and are furnished without heat treatment. The processor decoils, levels, cuts to length and marks the product. The processor is responsible for performing and certifying all tests, examinations, repairs, inspections or operations not intended to affect the properties of the material. For plates produced from coils, two test results shall be reported for each qualifying coil. See Note 1.

NOTE 1—Additional requirements regarding plate from coil are described in Specification A 6/A 6M.

5. Bearing Plates

5.1 Unless otherwise specified, plates used as bearing plates for bridges shall be subjected to mechanical tests and shall conform to the tensile requirements of Section 8.

5.2 Unless otherwise specified, mechanical tests shall not be required for plates over 1½ in. [40 mm] in thickness used as bearing plates in structures other than bridges, subject to the requirement that they shall contain 0.20 to 0.33 % carbon by heat analysis, that the chemical composition shall conform to the requirements of Table 2 in phosphorus and sulfur content, and that a sufficient discard shall be made to secure sound plates.

6. Process

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

6.2 No rimmed or capped steel shall be used for plates and bars over ½ in. [12.5 mm] thick or for shapes other than Group 1.

7. Chemical Requirements

7.1 The heat analysis shall conform to the requirements prescribed in Table 2, except as specified in 5.2.

7.2 The steel shall conform on product analysis to the requirements prescribed in Table 2, subject to the product analysis tolerances in Specification A 6/A 6M.

8. Tensile Requirements

8.1 The material as represented by the test specimen, except as specified in 5.2 and 8.2, shall conform to the requirements as to the tensile properties prescribed in Table 3.

8.2 Shapes less than 1 in.^{2}[645 mm ^{2}] in cross section and bars, other than flats, less than ½ in. [12.5 mm] in thickness or diameter need not be subjected to tension tests by the manufacturer, provided that the chemical composition used is appropriate for obtaining the tensile properties in Table 3.

TABLE 2 Chemical Requirements

NOTE 1— Where "..." appears in this table there is no requirement. The heat analysis for manganese shall be determined and reported as described in the heat analysis section of Specification A 6/A 6M.

Product	Shapes^A	Plates^B					Bars			
Thickness, in. [mm]	All	To ¾ [20], incl	Over ¾ to 1½ [20 to 40], incl	Over 1½ to 2 ½ [40 to 65], incl	Over 2½ to 4 [65 to 100], incl	Over 4 [100]	To ¾ [20], incl	Over ¾ to 1½ [20 to 40], incl	Over 1½ to 4 [100], incl	Over 4 [100]
Carbon, max, %	0.26	0.25	0.25	0.26	0.27	0.29	0.26	0.27	0.28	0.29
Manganese, %	...	...	0.80–1.20	0.80–1.20	0.85–1.20	0.85–1.20	...	0.60–0.90	0.60–0.90	0.60–0.90
Phosphorus, max, %	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max, %	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Silicon, %	0.40 max	0.40 max	0.40 max	0.15–0.40	0.15–0.40	0.15–0.40	0.40 max	0.40 max	0.40 max	0.40 max
Copper, min, % when copper steel is specified	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

^A Manganese content of 0.85–1.35 % and silicon content of 0.15–0.40 % is required for shapes over 426 lb/ft [634 kg/m].

^B For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to the maximum of 1.35 %.

ASTM Logo Removed [redacted] **A 36/A 36M**

TABLE 3 Tensile Requirements[A]

Plates, Shapes,[B] and Bars:	
Tensile strength, ksi [MPa]	58–80 [400–550]
Yield point, min, ksi [MPa]	36 [250][C]
Plates and Bars[D,E]:	
Elongation in 8 in. [200 mm], min, %	20
Elongation in 2 in. [50 mm], min, %	23
Shapes:	
Elongation in 8 in. [200 mm], min, %	20
Elongation in 2 in. [50 mm], min, %	21[B]

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

[B] For wide flange shapes over 426 lb/ft [634 kg/m], the 80 ksi [550 MPa] maximum tensile strength does not apply and a minimum elongation in 2 in. [50 mm] of 19 %, applies.

[C] Yield point 32 ksi [220 MPa] for plates over 8 in. [200 mm] in thickness.

[D] Elongation not required to be determined for floor plate.

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

9. Keywords

9.1 bars; bolted construction; bridges; buildings; carbon; plates; riveted construction; shapes; steel; structural steel; welded construction

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order.

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.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

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

S91. Fine Austenitic Grain Size

S91.1 The steel shall be killed and have a fine austenitic grain size.

S97. Limitation on Rimmed or Capped Steel

S97.1 The steel shall be other than rimmed or capped.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

This standard is copyrighted by ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (http://www.astm.org).

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A82: Cold-Drawn Steel Wire for Concrete Reinforcement

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 82 – 79**

American Association State Highway and Transportation Officials Standard AASHTO No.: M 32

Standard Specification for COLD-DRAWN STEEL WIRE FOR CONCRETE REINFORCEMENT[1]

This standard is issued under the fixed designation A 82; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers cold-drawn steel wire to be used as such, or in fabricated form, for the reinforcement of concrete, in sizes not less than 0.080 in. (2.03 mm) in diameter.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards*:

A 370 Methods and Definitions for Mechanical Testing of Steel Products[2]

A 700 Recommended Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[3]

2.2 *Military Standards*:

MIL-STD-129 Marking for Shipment and Storage[4]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[4]

2.3 *Federal Standard*:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[4]

3. General Requirements

3.1 When wire for concrete reinforcement is ordered by size number, the following relation between size number, diameter, and area shall apply, unless otherwise specified:

Size Number	Nominal Diameter, in. (mm)	Nominal Area, in.^{2} (mm^2)
W 31	0.628 (15.95)	0.310 (200.00)
W 30	0.618 (15.70)	0.300 (193.50)
W 28	0.597 (15.16)	0.280 (180.60)
W 26	0.575 (14.61)	0.260 (167.70)
W 24	0.553 (14.05)	0.240 (154.80)
W 22	0.529 (13.44)	0.220 (141.90)
W 20	0.505 (12.83)	0.200 (129.03)
W 18	0.479 (12.17)	0.180 (116.13)
W 16	0.451 (11.46)	0.160 (103.25)
W 14	0.422 (10.72)	0.140 (90.32)
W 12	0.391 (9.93)	0.120 (77.42)
W 10	0.357 (9.07)	0.100 (64.52)
W 8	0.319 (8.10)	0.080 (51.61)
W 7	0.299 (7.59)	0.070 (45.16)
W 6	0.276 (7.01)	0.060 (38.71)
W 5.5	0.265 (6.73)	0.055 (35.48)
W 5	0.252 (6.40)	0.050 (32.26)
W 4.5	0.239 (6.07)	0.045 (29.03)
W 4	0.226 (5.74)	0.040 (25.81)
W 3.5	0.211 (5.36)	0.035 (22.58)
W 3	0.195 (4.95)	0.030 (19.38)
W 2.5	0.178 (4.52)	0.025 (16.13)
W 2	0.160 (4.06)	0.020 (12.90)
W 1.5	0.138 (3.51)	0.015 (9.68)
W 1.2	0.124 (3.15)	0.012 (7.74)
W 1	0.113 (2.87)	0.010 (6.48)
W 0.5	0.080 (2.03)	0.005 (3.23)

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 Quantity (weight),

4.1.2 Name of material (cold-drawn steel wire for concrete reinforcement),

4.1.3 Wire size number,

---

[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 A01.05 on Steel Reinforcement.

Current edition approved July 27, 1979. Published September 1979. Originally published as A 82 – 21 T. Last previous edition A 82 – 76.

[2] *Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, 5, and 10.

[3] *Annual Book of ASTM Standards*, Parts 1, 3, 4, and 5.

[4] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120.

4.1.4 Packaging (see Section 11), and

4.1.5 ASTM designation and date of issue.

NOTE 2—A typical ordering description is as follows: 100 000 lb, cold-drawn steel wire for concrete reinforcement, size No. W 5, in 500-lb secured coils, in accordance with ASTM A 82 dated ______.

5. Process

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

5.2 The wire shall be cold drawn from rods that have been hot rolled from billets.

5.3 Unless otherwise specified, the wire shall be "as cold drawn," except wire smaller than size number W 1.2 for welded wire fabric, which shall be galvanized at finish size.

6. Physical Requirements

6.1 *Tension Tests*:

6.1.1 The material, except as specified in 6.1.2 shall conform to the tensile property requirements in Table 1, based on nominal area of wire.

6.1.2 For material to be used in the fabrication of welded fabric, the tensile and yield strength properties shall conform to the requirements given in Table 2, based on nominal area of the wire.

6.1.3 The yield strength shall be determined at an extension of 0.005 in./in. of gage length. The manufacturer is not required to test for yield strength, but is responsible for supplying a product that will meet the stipulated limit when tested in accordance with the provisions of 12.3.

6.1.4 The material shall not exhibit a definite yield point as evidenced by a distinct drop of the beam or halt in the gage of the testing machine prior to reaching ultimate tensile load. The purchaser may, at his option, accept this feature as sufficient evidence of compliance with the specified minimum yield strength to forego conducting the yield strength tests covered in 12.3.

6.2 *Bend Tests*—The bend test specimen shall stand being bent cold through 180° without cracking on the outside of the bent portion, as given in Table 3.

7. Test Specimens

7.1 Tension and bend test specimens shall be of the full section of the wire as drawn, or in the case of galvanized wire, as galvanized.

8. Number of Tests

8.1 One tension test and one bend test shall be made from each 10 tons (9072 kg) or less of each size of wire.

8.2 If any test specimen shows imperfections or develops flaws, it may be discarded and another specimen substituted.

9. Permissible Variation in Wire Diameter

9.1 The permissible variation in the diameter of the wire shall conform to the requirements given in Table 4.

9.2 The difference between the maximum and minimum diameters, as measured on any given cross section of the wire, shall be no more than the tolerances listed in Table 4 for the given wire size.

10. Finish

10.1 The wire shall be free of injurious imperfections and shall have a workmanlike finish.

10.2 Galvanized wire shall be completely covered in a workmanlike manner with a zinc coating, which is recognized in the industry as a "regular" coating.

10.3 Rust, surface seams, or surface irregularities on wire not intended for manufacture of fabric shall not be a cause for rejection provided the minimum dimensions and physical properties of a hand wire-brushed test specimen are not less than the requirements of this specification.

11. Packaging, Marking, and Shipping

11.1 The size of the wire, ASTM specification, and name or mark of the manufacturer shall be marked on a tag securely attached to each coil of wire.

11.2 When specified in the purchase order, packaging shall be in accordance with the procedures in Recommended Practices A 700.

11.3 *For Government Procurement Only*—When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

12. Inspection

12.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification.

12.2 Except for yield strength, all tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified. Such tests shall be so conducted as not to interfere unnecessarily with the operation of the works.

12.3 If the purchaser considers it desirable to determine compliance with the yield strength requirements in 6.1, he may have yield strength tests made in a recognized laboratory, or his representative may make the test at the mill if such tests do not interfere unnecessarily with the mill operations.

12.4 *For Government Procurement Only*—Except as otherwise specified in the contract, the contractor is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at the time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

13. Rejection

13.1 Material that shows injurious imperfections subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

TABLE 1 Tension Test Requirements

Tensile strength, min, ksi (MPa)	80 (550)
Yield strength, min, ksi (MPa)	70 (485)
Reduction of area, min, percent	30[A]

[A] For material testing over 100 ksi tensile strength, the reduction of area shall be not less than 25 percent.

TABLE 2 Tension Test Requirements (Material for Welded Fabric)

	Size W1.2 and Larger	Smaller than Size W1.2
Tensile strength, min, ksi (MPa)	75 (517)	70 (483)
Yield strength, min, ksi (MPa)	65 (448)	56 (386)

TABLE 3 Bend Test Requirements

Size Number of Wire	Bend Test
W7 and smaller	Bend around a pin the diameter of which is equal to the diameter of the specimen
Larger than W7	Bend around a pin the diameter of which is equal to twice the diameter of the specimen

TABLE 4 Permissible Variation in Wire Diameter

Size Number	Nominal Diameter, in. (mm)	Permissible Variation plus and minus, in. (mm)
Smaller than W5	Under 0.252 (6.40)	0.003 (0.08)
W5 to W12, incl	0.252 (6.40) to 0.391 (9.93), incl	0.004 (0.10)
Over W12 to W20 incl	Over 0.391 (9.93) to 0.505 (12.83) incl	0.006 (0.15)
Over W20	Over 0.505 (12.83)	0.008 (0.20)

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A184: Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 184 – 79**

American Association State Highway and Transportation Officials Standard AASHTO No.: M 54

Standard Specification for FABRICATED DEFORMED STEEL BAR MATS FOR CONCRETE REINFORCEMENT[1]

This standard is issued under the fixed designation A 184; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers material in mat (or sheet) form fabricated from hot-rolled deformed steel bars to be used for the reinforcement of concrete. The mats shall consist of two layers of bars which are assembled at right angles to each other. Mats may be assembled by clipping or welding at the intersections.

NOTE 1—The values stated in U. S. customary units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards*:

A 615 Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement[2]

A 616 Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement[2]

A 617 Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement[2]

2.2 *Military Standard*[3]:

MIL-STD-129 Marking for Shipment and Storage.

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage.

2.3 *Federal Standard*[2]:

Fed Std No. 123 Marking for Shipments, Civil Agencies

3. Ordering Information

3.1 The purchaser shall specify:

3.1.1 Quantity,

3.1.2 Size and spacing of members in each direction,

3.1.3 Grade required (Grade 40, 50, or 60),

3.1.4 Type of steel as appropriate (see Section 4),

3.1.5 Clipped or welded mats, and

3.1.6 ASTM designation A 184 and date of issue.

NOTE 2—A typical ordering description is as follows: 1000 welded bar mats; Grade 40; to ASTM A 184 dated ——; 6 by 6 in.; No. 4 by 120 in. longitudinal tip to tip, outer bars spaced 54 in.; No. 3 by 60 in. transverse, outer bars spaced 114 in.

4. Materials

4.1 Deformed steel bars of Grades 40, 50, and 60 only used in the manufacture of clipped mats shall conform to one of the following specifications: A 615, A 616, or A 617.

4.2 Deformed steel bars of Grades 40 and 60 only used in the manufacture of welded mats shall conform to specification.

5. Fabrication

5.1 Fabricated mats shall be composed of two layers of bars substantially parallel and perpendicular to each other. Mats shall be fabricated in a manner that assures against appreciable dislodgement of the members during handling, shipping, placing, and concreting.

---

[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 A01.05 on Steel Reinforcement.

Current edition approved April 27, 1979. Published September 1979. Originally published as A 184 – 36 T. Last previous edition A 184 – 74.

[2] *Annual Book of ASTM Standards*, Part 4.

[3] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120.

ASTM Logo Removed

5.2 *Assembly*—Mats shall be assembled by means of welding or clipping to provide attachment at intersections.

5.2.1 *Welds*:

5.2.1.1 Welds at intersections shall be made in a workmanlike manner and shall provide attachment at all exterior intersections and at not less than alternate interior intersections.

5.2.1.2 The separation of 5 % or less of all welded intersections of any mat shall not be cause for rejection provided that no more than half of the welds on any one bar are separated.

5.2.1.3 Welding shall be done in such a manner that the minimum tensile strength, yield strength, and elongation requirements in Section 4 shall be met when a specimen is tested across a point of weld.

5.2.2 *Clips*—Clips for clipped mats shall be formed mechanically prior to or during the fabrication and assembly of the mats. They shall engage and attach both bars at any intersection in such manner that separation in normal handling is prevented and the assembly conforms to the requirements hereinafter specified for physical tests of attachment at intersections.

6. Mechanical Requirements

6.1 *Strength of Connections in Welded or Clipped Deformed Bar Mats*—It shall be considered satisfactory compliance with this specification if connections made by clipping shall be capable of withstanding a static load of 75 lbf (334 N) exerted in the direction of either bar, with not more than ½ in. (12.7 mm) slip; and, on either clipped or welded mats, a static load of 150 lbf (667 N) exerted perpendicular to the plane of the mat tending to separate the bars, with no apparent loosening when applied to one intersection of connected bars.

6.2 *Number of Tests*:

6.2.1 For clipped mats, one bar of each size (diameter) or grade to be used in the fabrication of the mat shall be tested for conformance with the provisions of 6.1 for each 75 000 ft^2 (7000 m^2) of mats or fraction thereof.

6.2.2 For welded mats, one sample consisting of not less than two connections on the same transverse member shall be tested for conformance with the provisions of paragraphs 5.2.1.3 and 6.1 from each 75 000 ft^2 (7000 m^2) of mats or fraction thereof.

6.3 *Test Methods*:

6.3.1 Tension test specimens for determining conformance with 5.2.1.3 shall have a welded joint located approximately at the center of the bar being tested, and the cross bar shall extend approximately 1 in. (25 mm) beyond each side. All unit stress determinations shall be based on the nominal area calculated using the nominal diameter specified.

6.3.2 Tests of connections against slipping may be performed on clipped intersections in an assembled mat by means of a spring balance (6.1).

6.3.3 Tests of connections against separation may be performed on an assembled mat by placing blocks under a welded or clipped deformed bar in the upper layer and applying the prescribed load upon the bar in the lower layer.

7. Size, Dimensions, and Tolerances

7.1 *Size and Spacing Dimensions*—The sizes, spacings, dimensions, and arrangement of the bar mats shall conform to the design specified by the purchaser. Bars shall extend beyond exterior intersections a distance of not less than 1 in. (25 mm). The spacing of bars shall average that specified in the design, and the space between individual bars shall not vary more than ¼ in. (6.35 mm) from that specified.

7.2 *Width and Length Tolerances*—The overall length or width of the mats shall not be more than 1 in. (25 mm) greater or less than the specified dimension.

8. Finish and Surface Condition

8.1 The finished mats shall be free of injurious defects in material or workmanship.

8.2 Rust, surface seams, surface irregularities, or mill scale shall not be cause for rejection provided the weight, dimensions including height of deformation, cross-sectional area, and tensile properties of a hand wire-brushed test specimen are not less than the requirements of this specification.

9. Marking

9.1 Each bundle of mats shall be marked with a suitable tag showing the name of the manufacturer and other marking to identify it with the order.

9.2 *For Government Procurement Only*—When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163.

The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

10. Inspection and Test Reports

10.1 *Inspection*—The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's plant which concern the fabrication of the mats ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the mats are being furnished in accordance with this specification. All tests and inspection shall be made at the place of fabrication prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with fabricating operations. Inspection as to general workmanship shall be visual.

10.2 *Test Reports on Bar Material*—The manufacturer shall supply test reports showing that the material used in the fabrication of the mats as delivered has fulfilled the tension and bend test requirements of the specified type and grade described in Section 4, which reports shall show the manufacturer's test identification numbers, including the identity of the material.

10.3 *For Government Procurement Only*—Except as otherwise specified in the contract, the contractor is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at the time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

11. Rejection and Retests

11.1 Fabricated mats that do not meet the requirements of this specification shall be rejected and reported to the supplier within 5 working days from the receipt of samples by the purchaser.

11.2 In case a test specimen fails to meet the provisions of 6.1, two additional samples shall be selected and tested. All retest specimens shall meet the requirements of this specification.

11.3 In case a test specimen fails to meet the provisions of 5.2.1.3, all of the remaining bars on the transverse member shall be tested and the average of all tests (including the original test) shall meet the requirements specified in 5.2.1.3.

12. Rehearing

12.1 Samples tested in accordance with this specification that represent rejected material shall be preserved for 2 weeks from the date rejection is reported to the manufacturer. In case of dissatisfaction with the results of the tests, the supplier may make claim for a hearing within that time.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A185: Steel Wire Fabric for Concrete Reinforcement

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD ANSI/ASTM A 185 – 79

American Association State Highway and Transportation Officials Standard AASHTO No: M 55

Standard Specification for
WELDED STEEL WIRE FABRIC FOR CONCRETE REINFORCEMENT[1]

This standard is issued under the fixed designation A 185; 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.

1. Scope

1.1 This specification covers welded wire fabric to be used for the reinforcement of concrete.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards*:

A 82 Specification for Cold-Drawn Steel Wire for Concrete Reinforcement[2]

A 700 Recommended Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[2]

2.2 *Military Standard*[3]:

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.3 *Federal Standard*[3]:

Fed Std No. 123 Marking for Shipments, Civil Agencies

3. Description of Term

3.1 *Welded Wire Fabric*, as used in this specification, designates a material composed of cold-drawn steel wires, "as drawn" or galvanized, fabricated into sheet (or so-called "mesh") formed by the process of electric welding. The finished material shall consist essentially of a series of longitudinally and transverse wires arranged substantially at right angles to each other and welded together at all points of intersection.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 Quantity (weight or square area),

4.1.2 Name of material (welded steel wire fabric for concrete reinforcement),

4.1.3 Wire spacing and sizes,

4.1.4 Length and width of sheets or rolls,

4.1.5 Packaging (see Section 18), and

4.1.6 ASTM designation and date of issue

NOTE 2—A typical ordering description is as follows: 10 000 ft^2 welded steel wire fabric for concrete reinforcement, 4 x 12-W20 x W6, in flat sheets 96 in. wide x 240 in. long, in secured lifts, to ASTM A 185 dated ——.

5. Grade of Wire

5.1 The wire used in the manufacture of welded wire fabrics shall conform to Specification A 82.

6. Fabrication

6.1 The wires shall be assembled by automatic machines or by other suitable mechanical means which will assure accurate spacing and alignment of all members of the finished fabric.

6.2 Longitudinal and transverse members shall be securely connected at every intersection by a process of electrical-resistance welding which employs the principle of fusion combined with pressure.

---

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloy and is the direct responsibility of Subcommittee A01.05 on Steel Reinforcement.

Current edition approved April 27, 1979. Published June 1979. Originally published as A 185 – 36 T. Last previous edition A 185 – 73.

[2] *Annual Book of ASTM Standards*, Part 4.

[3] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120.

6.3 Wire of proper grade and quality when fabricated in the manner herein required shall result in a strong, serviceable mesh-type product having substantially square or rectangular openings. It shall be fabricated and finished in a workmanlike manner, shall be free from injurious defects, and shall conform to this specification.

7. Mechanical Requirements

7.1 All wire of the finished fabric shall meet the minimum requirements for tensile properties and shall also withstand the bend test as prescribed for the wire before fabrication in Specification A 82.

7.2 In order to assure adequate weld-shear strength between longitudinal and transverse wires, weld-shear tests as described in 8.3 shall be made. The minimum average shear value in pounds-force shall not be less than 35,000 multiplied by the nominal area of the larger wire in square inches (or in newtons shall not be less than 241 multiplied by the nominal area in square millimetres) where the smaller wire is not less than size W1.2 and has an area of 40 percent or more of the area of the larger wire. Typical examples of the 40 percent or more wire size differential are as follows:

Larger	Smaller
Size No. W20	Size No. W8
Size No. W15	Size No. W6
Size No. W10	Size No. W4

7.3 Fabric having a relationship of longitudinal and transverse wires other than those covered in 7.2 shall not be subject to the weld shear requirement.

8. Tension Tests and Weld Shear Tests

8.1 Tests for determination of conformance to the requirements of 7.1 may be made on the welded wire fabric after fabrication either across or between the welds. Not less than 50 percent of the samples tested shall be across a weld.

8.2 Reduction of area may be determined by measuring the ruptured section of a specimen which has been tested either across or between the welds. However, in the case of a specimen which has been tested across a weld, the measurement shall be made only when rupture has occurred at a sufficient distance from the center of the weld to permit an accurate measurement of the fractured section.

8.3 Weld-shear tests for determination of conformance to the requirements of 7.2 shall be conducted using a fixture as described in Section 11.

8.3.1 Four welds selected at random from a specimen representing the entire width of the fabric shall be tested for weld shear strength. The material shall be deemed to conform to the requirements for weld shear strength if the average of the four samples complies with the values stipulated in 7.2. If this average fails to meet the prescribed minimum value, all the welds across the specimen shall then be tested. The fabric will be acceptable if the average of all weld shear test values across the specimen meets the prescribed minimum value.

9. Bend Tests

9.1 The bend test shall be made on a specimen between the welds.

10. Test Specimens

10.1 Test specimens for testing tensile properties shall be obtained by cutting from the finished fabric, units of suitable size to enable proper performance of the intended tests.

10.2 Specimens used for testing tensile properties across a weld shall have the welded joint located approximately at the center of the wire being tested, and the cross wire forming the welded joint shall extend approximately 1 in. (25 mm) beyond each side of the welded joint.

10.3 Test specimens for determining weld-shear properties shall be obtained by cutting from the finished fabric a section, including one transverse wire, across the entire width of the sheet or roll. From this specimen four welds shall be selected at random for testing. The transverse wire of each test specimen shall extend approximately 1 in. (25 mm) on each side of the longitudinal wire. The longitudinal wire of each test specimen shall be of such length below the transverse wire so as to be adequately engaged by the grips of the testing machine and of such length above the transverse wire that its end shall be above the center line of the upper bearing of the testing device.

10.4 Tests for conformance to dimensional characteristics shall be made on full sheets or rolls.

10.5 If any test specimen shows defects or develops flaws it may be discarded and another substituted.

11. Weld Shear Test Apparatus and Methods

11.1 As the welds in welded wire fabric contribute to the bonding and anchorage value of the wires in concrete, it is imperative that the weld acceptance tests be made in a jig which will stress the weld in a manner similar to which it is stressed in concrete. In order to accomplish this the longitudinal wire in the jig must be stressed in an axis close to its center line. Also the transverse wire must be held closely to the longitudinal wire, and in the same relative position, so as to prevent rotation of the transverse wire.

11.2 Figure 1[4] shows the details of a typical testing jig together with two anvils which make it possible to test welds for wire up to ⅝ in. (15.88 mm) in diameter. This testing jig can be used in most tension testing machines and should be hung in a ball and socket arrangement at the center of the machine. This, or a similarly effective fixture designed on the same principle, is acceptable.

11.3 Test specimens should be inserted through the notch in the anvil using the smallest notch available in which the longitudinal wire will fit loosely. The longitudinal wire shall be in contact with the surface of the free rotating rollers while the transverse wire shall be supported by the anvil on each side of the slot. The bottom jaws of the testing machine shall grip the lower end of the longitudinal wire and the load shall be applied at a rate of stressing not to exceed 100,000 psi/min (689 MPa/min).

12. Number of Tests

12.1 One test for conformance with the provisions of 6.1 shall be made for each 75,000 ft^2 (6968 m^2) of fabric or remaining fraction thereof.

12.2 One specimen for each 300,000 ft^2 (27,870 m^2) of fabric or remaining fraction thereof, and as defined in 10.3 shall be tested for conformance to the requirements of 7.2.

13. Gages, Spacing, and Dimensions

13.1 Gages, spacing, and arrangement of wires, and dimensions of units in flat sheet form or rolls shall conform to the requirements specified by the purchaser.

14. Width of Fabric

14.1 The width of fabric shall be considered to be the center-to-center distance between outside longitudinal wires. The permissible variation shall not exceed ½ in. (13 mm) greater or less than the specified width.

14.2 Transverse wires shall not project beyond the centerline of each longitudinal edge wire more than a distance of 1 in., unless otherwise specified.

14.3 When transverse wires are specified to project a specific length beyond the center line of a longitudinal edge wire, the permissible variation shall not exceed ½ in. (13 mm) greater or less than the specified length; however, the over-all width (total of projection one side plus width plus projection other side) shall not exceed 1 in. (25 mm) greater or less than specified.

15. Permissible Variations in Wire Diameter

15.1 The permissible variation in diameter of any wire in the finished fabric shall conform to the tolerances prescribed for the wire before fabrication in the Specification A 82 with the exception of out-of-round requirements.

16. Spacings

16.1 The average spacing of wires shall be such that the total number of wires contained in a sheet or roll is equal to or greater than that determined by the specific spacing, but the center-to-center distance between individual members may vary not more than ¼ in. (6.35 mm) from the specified spacing. It is understood that sheets of fabric of the same specified length may not always contain an identical number of transverse wires and, therefore, may have various lengths of longitudinal overhand.

17. Overall Dimensions

17.1 The overall length of flat sheets, measured on any wire, may vary ±1 in. (25.4 mm) or 1 percent, whichever is greater.

17.2 In case the width of flat sheets or rolls is specified as the overall width (tip-to-tip length of cross wires), the width shall not be more than ±1 in. (25.4 mm) of the specified width.

18. Rolls or Sheets

18.1 Welded wire fabric shall be furnished

[4] A detailed drawing showing complete dimensions of the testing jig may be obtained at a nominal cost from ASTM Headquarters, 1916 Race St., Philadelphia, Pa. 19103. Request Adjunct No. 12-101850-00.

either in flat sheets or in rolls as specified by the purchaser.

19. Packaging

19.1 When fabric is furnished in flat sheets, it shall be assembled in bundles of convenient size containing not more than 150 sheets and securely fastened together.

19.2 When fabric is furnished in rolls, each roll shall be secured so as to prevent unwinding during shipping and handling.

19.3 When specified in the purchase order, packaging shall be in accordance with the procedures in Recommended Practices A 700.

20. Marking

20.1 Each bundle of flat sheets and each roll shall have attached thereto a suitable tag bearing the name of the manufacturer, description of the material and such other information as may be specified by the purchaser.

20.2 *For Government Procurement Only*—When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

21. Inspection

21.1 The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification.

21.2 Except for yield strength, all tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified. Such tests shall be so conducted as not to interfere unnecessarily with the operation of the works.

21.3 If the purchaser considers it desirable to determine compliance with the yield strength requirements of Specification A 82, he may have yield strength tests made in a recognized laboratory, or his representative may make the test at the mill if such tests do not interfere unnecessarily with the mill operations.

21.4 *For Government Procurement Only*—Except as otherwise specified in the contract, contractor is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at the time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

22. Rejection and Retests

22.1 Material that does not meet the requirements of this specification may be rejected. Unless otherwise specified, any rejection shall be reported to the manufacturer within 5 days from the time of selection of test specimens.

22.2 In case a specimen fails to meet the tension or bend test, the material shall not be rejected until two additional specimens taken from other wires in the same sheet or roll, have been tested. The material shall be considered as meeting this specification in respect to any prescribed tensile property, provided the tested average for the three specimens, including the specimen originally tested, is at least equal to the required minimum for the particular property in question and provided further that none of the three specimens develops less than 80 percent of the required minimum for the tensile property in question. The material shall be considered as meeting this specification in respect to bend test requirements, provided both additional specimens satisfactorily pass the prescribed bend test.

22.3 Any material that shows injurious defects subsequent to its acceptance at the manufacturer's works may be rejected and the manufacturer shall be promptly notified.

22.4 Welded joints shall withstand normal shipping and handling without becoming broken, but the presence of broken welds, regardless of cause, shall not constitute cause for rejection unless the number of broken welds per sheet exceeds 1 percent of the total number of joints in a sheet, or if the material is furnished in rolls, 1 percent of the total number of joints in 150 ft^2 (14 m^2) of fabric and, furthermore, provided not more than one half the permissible maximum number of broken welds are located on any one wire.

22.5 In case rejection is justified, by reason of failure to meet the weld shear requirements, four additional specimens shall be taken from four different sheets or rolls and tested in accordance with 8.3. If the average of all the weld shear tests does not meet the requirement, the material shall be rejected.

22.5.1 In case rejection is justified by reason of failure to meet the requirements for dimensions, the amount of material rejected shall be limited to those individual sheets or rolls which fail to meet this specification. If, however, the total number of sheets or rolls thus rejected exceeds 25 percent of the total number in the shipment, the entire shipment may be rejected.

22.6 Rust, surface seams, or surface irregularities will not be cause for rejection provided the minimum dimensions, cross-sectional area and tensile properties of a hand wirebrushed test specimen are not less than the requirements of this specification.

23. Rehearing

23.1 Rejected materials shall be preserved for a period of at least two weeks from the date of inspection, during which time the manufacturer may make claim for a rehearing and retesting.

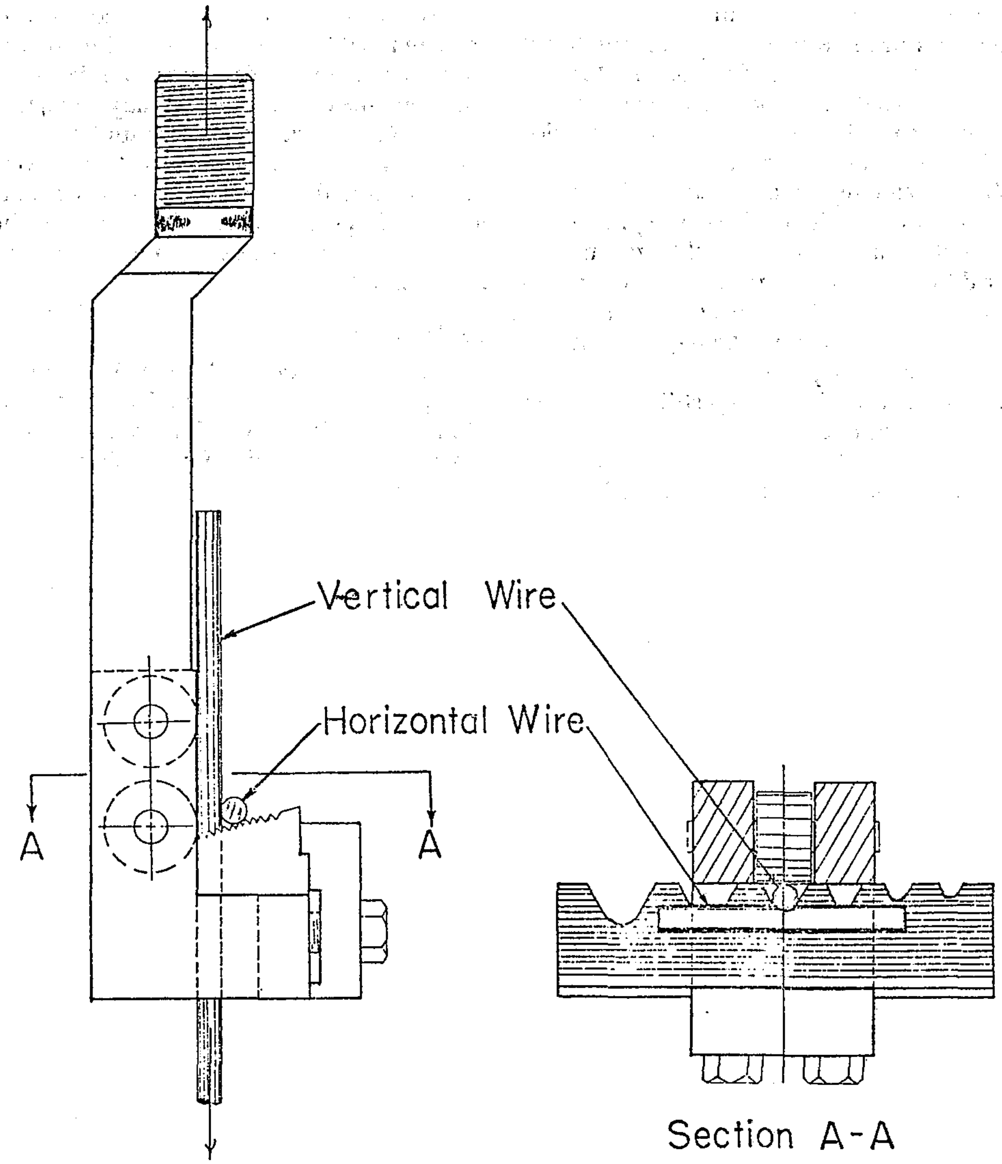


FIG. 1 Welded Wire Fabric Weld Tester.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A203: Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel

CFR Section(s): 46 CFR 54.05-20(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: A 203/A 203M – 97

Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel[1]

This standard is issued under the fixed designation A 203/A 203M; 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.

1. Scope

1.1 This specification[2] covers nickel-alloy steel plates intended primarily for welded pressure vessels.

1.2 Plates under this specification are available with four strength levels and two nickel compositions as follows:

Grade	Nominal Nickel Content %	Yield Strength, min, ksi [MPa]	Tensile Strength, min, ksi [MPa]
A	2.25	37 [255]	65 [450]
B	2.25	40 [275]	70 [485]
D	3.50	37 [255]	65 [450]
E	3.50	40 [275]	70 [485]
F	3.50		
2 in. [50 mm] and under		55 [380]	80 [550]
Over 2 in. [50 mm]		50 [345]	75 [515]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements. However, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade	Maximum Thickness, in. [mm]
A	6 [150]
B	6 [150]
D	4 [100]
E	4 [100]
F	4 [100]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately 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 this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of imperfections, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the basis of purchase that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be thermally treated as follows:

5.1.1 All plates of Grades A, B, D, and E shall be normalized except as permitted by 5.1.1.1.

5.1.1.1 If approved by the purchaser for Grades A, B, D, and E, cooling rates faster than air cooling are permissible for

[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 A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved March 10, 1997. Published November 1997. Originally published as A 203–37 T. Last previous edition A 203/A 203M–93.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-203/SA-203M in Section II of that Code.

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

Copyright © ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, United States.

improvement of the toughness, provided the plates are subsequently tempered at not less than 1100°F [595°C] for not less than ½ h.

5.1.2 All plates of Grade F shall be heat treated by heating into the austenitic range, quenching in water, and tempering at not less than 1100°F [595°C] for not less than ½ h.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Properties

7.1 *Tension Test Requirements*—The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

7.1.1 For plates that have been heat treated in accordance with 5.1.1.1 or 5.1.2 and have a nominal thickness of ¾ in. [20 mm] and under, the 1½-in. (40-mm) wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation. When this specimen is used, the elongation shall be not less than 23 %.

7.2 *Impact Test Requirements*:

7.2.1 Plates of Grades A, B, D, and E that have been heat treated in accordance with 5.1.1.1 shall be Charpy V-notch impact tested. The impact test shall meet 20 ft · lbf [27 J]. The test temperature and orientation shall be a matter of agreement between the purchaser and supplier.

7.2.2 Grade F plates shall be impact tested in accordance with Supplementary Requirement S5 in Specification A 20/A 20M.

TABLE 1 Chemical Requirements

Elements	Composition, %			
	Grade A	Grade B	Grade D	Grades E and F
Carbon, max[A]:				
Up to 2 in. [50 mm] in thickness	0.17	0.21	0.17	0.20
Over 2 in. to 4 in. [100 mm] incl. in thickness	0.20	0.24	0.20	0.23
Over 4 in. [100 mm] in thickness	0.23	0.25	...	...
Manganese, max:				
Heat analysis:				
2 in. [50 mm] and under	0.70	0.70	0.70	0.70
Over 2 in. [50 mm]	0.80	0.80	0.80	0.80
Product analysis:				
2 in. [50 mm] and under	0.78	0.78	0.78	0.78
Over 2 in. [50 mm]	0.88	0.88	0.88	0.88
Phosphorus, max[A]	0.035	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45
Nickel:				
Heat analysis	2.10–2.50	2.10–2.50	3.25–3.75	3.25–3.75
Product analysis	2.03–2.57	2.03–2.57	3.18–3.82	3.18–3.82

[A] Applies to both heat and product analyses.

TABLE 2 Tensile Requirements

	Grades A and D		Grades B and E		Grade F	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength						
2 in. [50 mm] and under	65–85	[450–585]	70–90	[485–620]	80–100	[550–690]
Over 2 in. [50 mm]	65–85	[450–585]	70–90	[485–620]	75–95	[515–655]
Yield strength, min						
2 in. [50 mm] and under	37	[255]	40	[275]	55	[380]
Over 2 in. [50 mm]	37	[255]	40	[275]	50	[345]
Elongation in 8 in. [200 mm] min, %[A]	19		17		...	
Elongation in 2 in. [50 mm] min, %[A,B]	23		21		20	

[A] See Specification A 20/A 20M for elongation adjustments.

[B] See 7.1.1.

8. Keywords

8.1 alloy steel plate; nickel alloy steel; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A242: Standard Specification for High-Strength Low-Alloy Structural Steel

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 242 – 79**

American Association State Highway and Transportation Officials Standard AASHTO No.: M 161

Standard Specification for
HIGH-STRENGTH LOW-ALLOY STRUCTURAL STEEL[1]

This standard is issued under the fixed designation A 242; 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.

1. Scope

1.1 This specification covers high-strength low-alloy structural steel shapes, plates and bars for welded, riveted, or bolted construction intended primarily for use as structural members where savings in weight or added durability are important. These steels have enhanced atmospheric corrosion resistance of approximately two times that of carbon structural steels with copper (Note 1). Welding technique is of fundamental importance, and it is presupposed that welding procedure will be in accordance with approved methods. This specification is limited to material up to 4 in. (101.6 mm), inclusive, in thickness.

NOTE 1—Two times carbon structural steel with copper is equivalent to four times carbon structural steel without copper (copper 0.02 max).

NOTE 2—The values stated in U.S. customary units are to be regarded as the standard.

2. General Requirements for Delivery

2.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of ASTM Specification A 6, General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use.[2]

3. Process

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

4. Chemical Requirements

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

4.2 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6.

4.3 Choice and use of alloying elements, combined with carbon, manganese, phosphorus, sulfur, and copper within the limits prescribed in 4.1 to give the mechanical properties prescribed in Section 5 and to provide the atmospheric corrosion resistance of 1.1, shall be made by the manufacturer and included and reported in the heat analysis to identify the type of steel applied. Elements commonly added include: chromium, nickel, silicon, vanadium, titanium, and zirconium.

4.4 When required, the manufacturer shall supply evidence of corrosion resistance satisfactory to the purchaser.

5. Tensile Requirements

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

5.2 For material under $\frac{5}{16}$ in. (7.9 mm) in thickness or diameter, as represented by the test specimen, a deduction of 1.25 percentage points from the percentage of elongation in 8 in. (203.2 mm) specified in Table 2 shall be made for each decrease of $\frac{1}{32}$ in. (0.8 mm) of the specified thickness or diameter flow below $\frac{5}{16}$ in.

---

[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.

Current edition approved July 27, 1979. Published September 1979. Originally published as A 242 – 41 T. Last previous edition A 242 – 75.

[2] *Annual Book of ASTM Standards*, Part 4.

SUPPLEMENTARY REQUIREMENTS

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

S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S5. Charpy V-Notch Impact Test,
S6. Drop Weight Test,
S8. Ultrasonic Examination,
S14. Bend Test, and
S15. Reduction of Area Measurement.

TABLE 1 Chemical Requirements (Heat Analysis)

Element	Composition, %	
	Type 1	Type 2
Carbon, max	0.15	0.20
Manganese, max	1.00	1.35
Phosphorous, max	0.15	0.04
Sulfur, max	0.05	0.05
Copper, min	0.20	0.20[a]

[a] If chromium and silicon contents are each 0.50 min, then the copper 0.20 min requirement does not apply.

TABLE 2 Tensile Requirements

	Plates and Bars[a]			Structural Shapes		
	For Thicknesses ¾ in. (19.1 mm), and under	For Thicknesses over ¾ to 1½ in. (19.1 to 38.1 mm), incl.	For Thicknesses over 1½ to 4 in. (38.1 to 101.6 mm), incl.	Groups 1 and 2	Group 3	Groups 4 and 5
Tensile strength, min, psi (MPa)	70 000 (480)	67 000 (460)	63 000 (435)	70 000 (480)	67 000 (460)	63 000 (435)
Yield point, min, psi (MPa)	50 000 (345)	46 000 (315)	42 000 (290)	50 000 (345)	46 000 (315)	42 000 (290)
Elongation in 8 in. or 200 mm, min, %	18[b, d, e]	18[d, e]	18[d, e]	18[b]	18	18
Elongation in 2 in. or 50 mm, min, %	...	21[e]	21[e]	...	...	21[c]

[a] For plates wider than 24 in. (610 mm), the test specimen is taken in the transverse direction. See 11.2 of Specification A 6.
[b] See 5.2.
[c] For wide flange shapes over 426 lb/ft elongation in 2 in. or 50 mm of 18% minimum applies.
[d] Elongation not required to be determined for floor plate.
[e] For plates wider than 24 in. (610 mm) the elongation requirement is reduced two percentage points.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A285: Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength

CFR Section(s): 49 CFR 179.300-7(a)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 285 - 78**

Standard Specification for
PRESSURE VESSEL PLATES, CARBON STEEL, LOW- AND INTERMEDIATE-TENSILE STRENGTH[1]

This Standard is issued under the fixed designation A 285; 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.

This specification has been approved for use by agencies of the Department of Defense for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification[2] covers carbon steel plates of low- and intermediate-tensile strengths which may be made by killed, semi-killed, capped, or rimmed steel practices at the producer's option. These plates are intended for fusion-welded pressure vessels.

1.2 Plates under this specification are available in three grades having different strength levels as follows:

Grade	Tensile Strength, ksi (MPa)
A	45–65 (310–450)
B	50–70 (345–485)
C	55–75 (380–515)

1.3 The maximum thickness of plates under this specification, for reasons of internal soundness, is limited to a maximum thickness of 2 in. (50 mm) for all grades.

1.4 Plates to a maximum thickness of ½ in. (13 mm) may be processed as coils. All such plates must be furnished by the producer in cut lengths only. When processed in this manner, an additional tension test per coil is required.

NOTE 1—For killed carbon steels only refer to the following ASTM specifications:[3]

A 299 Pressure Vessel Plates, Carbon Steel, Manganese-Silicon.
A 455 Pressure Vessel Plates, Carbon Steel, High Strength Manganese.
A 515 Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service.
A 516 Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service.

NOTE 2—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standard:*

A 20 Specification for General Requirements for Steel Plates for Pressure Vessels.[3]

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to the current issue of Specification A 20. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20 also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control testing or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A 20, the requirements of this specification shall prevail.

---

[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 A01.11 on Steel for Boilers and Pressure Vessels.

Current edition approved April 28, 1978. Published June 1978. Originally published as A 285 - 46. Last previous edition A 285 - 77.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-285 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Part 4.

4. Heat Treatment

4.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5. Chemical Requirements

5.1 The steel shall conform to the requirements as to chemical composition as shown in Table 1.

6. Mechanical Requirements

6.1 *Tension Tests:*

6.1.1 *Requirements:*

6.1.1.1 The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

6.1.2 *Number and Location of Tension Tests:*

6.1.2.1 When plates are processed as coils, one tension-test specimen shall be taken from the approximate center lap and one tension-test specimen shall be taken from the outer lap of the coil as rolled.

6.1.2.2 When plates are processed other than as coils, one tension test shall be taken from each plate as rolled as specified in Specification A 20.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20. Those which are considered suitable for use with this specification are listed below by title.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4. Additional Tension Test, and

S14. Bend Test.

Also listed below are additional optional supplementary requirements suitable for this specification:

S57. Copper-Bearing

S57.1 The copper content, by heat analysis shall be 0.20–0.35 % and by product analysis 0.18–0.37 %.

S58. Restricted Copper

S58.1 The maximum incidental copper content by heat analysis shall not exceed 0.25 %.

TABLE 1 Chemical Requirements

Elements	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max[a]	0.17	0.22	0.28
Manganese, max			
Heat analysis	0.90	0.90	0.90
Product analysis	0.98	0.98	0.98
Phosphorus, max[a]	0.035	0.035	0.035
Sulfur, max[a]	0.040	0.040	0.040

[a] Applies to both heat and product analyses.

ASTM Logo Removed **A 285**

TABLE 2 Tensile Requirements

	Grade A		Grade B		Grade C	
	ksi	MPa	ksi	MPa	ksi	MPa
Tensile strength	45–65	310–450	50–70	345–485	55–75	380–515
Yield strength, min[a]	24	165	27	185	30	205
Elongation in 8 in. or 200 mm, min, %[b]	27		25		23	
Elongation in 2 in. or 50 mm, min, %	30		28		27	

[a] Determined by either the 0.2% offset method or the 0.5% extension-under-load method.
[b] See Specification A 20.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A307: Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength

CFR Section(s): 46 CFR 56.25-20(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 307 – 78ε**

Standard Specification for
CARBON STEEL EXTERNALLY THREADED STANDARD FASTENERS[1]

This standard is issued under the fixed designation A 307; 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.

ε Note—Table 3, which was incorrectly retained at last revision, was editorially deleted and Table 4 renumbered to Table 3 in November 1979.

1. Scope

1.1 This specification[2] covers the chemical and mechanical requirements of two grades of carbon steel externally threaded standard fasteners, in sizes 1/4 in. (6.35 mm) through 4 in. (104 mm). This specification does not cover requirements for externally threaded fasteners having heads with slotted or recessed drives or for mechanical expansion anchors. The fasteners covered by this specification are frequently used for the following applications:

1.1.1 *Grade A Bolts,* for general applications, and

1.1.2 *Grade B Bolts,* for flanged joints in piping systems where one or both flanges are cast iron.

1.2 If no grade is specified in the inquiry, contract, or order, Grade A bolts shall be furnished.

1.3 Nonheaded anchor bolts, either straight or bent, to be used for structural anchorage purposes, shall conform to the requirements of Specification A 36 with tension tests to be made on the bolt body or on the bar stock used for making the anchor bolts.

1.4 Suitable nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut for each grade of fastener, of all surface finishes, shall be as follows:

Fastener Grade and Size	Nut Grade and Style[A]
A, 1/4 to 1 1/2 in.	A, hex
A, over 1 1/2 to 4 in.	A, heavy hex
B, 1/4 to 4 in.	A, heavy hex

[A] Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are also suitable.

Note—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards:*

A 36 Specification for Structural Steel[3]

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware[4]

A 370 Methods and Definitions for Mechanical Testing of Steel Products[7]

A 563 Specification for Carbon and Alloy Steel Nuts[5]

B 454 Specification for Mechanically Deposited Coatings of Cadmium and Zinc on Ferrous Metals[6]

2.2 *American National Standards:*[8]

ANSI B1.1 Unified Screw Threads

ANSI B18.2.1 Square and Hex Bolts and Screws

3. Materials and Manufacture

3.1 Steel for bolts shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

[1] This specification is under the jurisdiction of ASTM Committee F-16 on Fasteners, and is the direct responsibility of Subcommittee F 16.02 on Steel Bolting.

Current edition approved Oct. 27, 1978. Published December 1978. Originally published as A 307 – 47 T. Last previous edition A 307 – 76 b.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-307 in Section II of that Code.

[3] *Annual Book of ASTM Standards,* Part 4.

[4] *Annual Book of ASTM Standards,* Part 3.

[5] *Annual Book of ASTM Standards,* Parts 1 and 4.

[6] *Annual Book of ASTM Standards,* Parts 4 and 9.

[7] *Annual Book of ASTM Standards,* Parts 1, 2, 3, 4, 5, and 10.

[8] May be obtained from American National Standards Institute, Inc., 1430 Broadway, New York, N. Y. 10018.

3.2 Bolts may be produced by hot or cold forging of the heads or machining from bar stock.

3.3 Bolt threads may be rolled or cut.

3.4 When specified, galvanized bolts shall be hot-dip zinc coated in accordance with the requirements of Class C of Specification A 153. When specified by the purchaser to be mechanically galvanized, bolts covered by this specification shall be mechanically zinc coated and the coating and coated fasteners shall conform to the requirements for Class 50 of Specification B 454, or to the coating thickness, adherence, and quality requirements for Class C of Specification A 153.

4. Chemical Requirements

4.1 Steel shall conform to the following chemical requirements:

	Grade A Bolts	Grade B Bolts
Phosphorus, max, %	0.06	0.04
Sulfur, max, %	0.15	0.05

4.2 Resulfurized material is not subject to rejection based on product analysis for sulfur.

4.3 Bolts are customarily furnished from stock, in which case individual heats of steel cannot be identified.

4.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for Grade B bolts.

5. Mechanical Requirements

5.1 Bolts shall not exceed the maximum hardness required in Table 1. Bolts less than three diameters in length, or bolts with drilled or undersize heads shall have hardness values not less than the minimum nor more than the maximum hardness limits required in Table 1, as hardness is the only requirement.

5.2 Bolts 1³/₈ in. in diameter or less, other than those excepted in 4.1, shall be tested full size and shall conform to the requirements for tensile strength specified in Table 2.

5.3 Bolts larger than 1³/₈ in. in diameter, other than those excepted in 4.1, shall preferably be tested full size and when so tested, shall conform to the requirements for tensile strength specified in Table 2. When equipment of sufficient capacity for full-size bolt testing is not available, or when the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements shown below:

	Tensile Strength, ksi (MPa)	Elongation in 2 in. or 50 mm, %
Grade A and Grade B bolts	60 (415) min	18 min
Grade B bolts only	100 (690) max	. . .

In the event that bolts are tested by both full size and by machine test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

5.4 For bolts on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

6. Dimensions

6.1 Unless otherwise specified, threads shall be the Coarse Thread Series as specified in the latest issue of ANSI B1.1, having a Class 2A tolerance.

6.2 Unless otherwise specified, Grade A bolts shall be hex bolts with dimensions as given in the latest issue of ANSI B 18.2.1. Unless otherwise specified, Grade B bolts shall be heavy hex bolts with dimensions as given in the latest issue of ANSI B 18.2.1.

6.3 Unless otherwise specified, bolts to be used with nuts or tapped holes which have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot dip or mechanical galvanizing. After galvanizing, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

Diameter, in.	Oversize Limit, in. (mm)[A]
Up to 7/16, incl	0.016 (0.41)
Over 7/16 to 1, incl	0.021 (0.53)
Over 1	0.031 (0.79)

[A] These values are the same as the minimum overtapping required for galvanized nuts in Specification A 563.

6.4 The gaging limit for bolts shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown above. In case of dispute, a calibrated thread ring gage of that same size (Class X tolerance, gage tolerance plus) shall be used. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, shall be performed at the frequency and quality described in Table 3.

7. Test Methods

7.1 The material shall be tested in accordance with Supplement III of Methods and A 370.

7.2 Standard square and hexagon bolts only shall be tested by the wedge tension method. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body. Other headed bolts shall be tested by the axial tension method.

7.3 Speed of testing as determined with a free running crosshead shall be a maximum of 1 in. (25.4 mm)/min for the tensile strength tests of bolts.

8. Number of Tests and Retests

8.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

8.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

8.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time that has the following common characteristics:

8.3.1 One type of item.

8.3.2 One nominal size, and

8.3.3 One nominal length of bolts.

8.4 From each lot, the number of tests for each requirement shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and under	1
801 to 8 000	2
8 001 to 22 000	3
Over 22 000	5

8.5 If any machined test specimen shows defective machining it may be discarded and another specimen substituted.

8.6 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be tested, in which case all of the additional samples shall meet the specification.

9. Marking

9.1 Bolt heads shall be marked (by raised or depressed mark at the option of the manufacturer) to identify the manufacturer. The manufacturer may use additional marking for his own use.

10. Inspection

10.1 If the inspection described in 10.2 is required by the purchaser it shall be specified in the inquiry, order, or contract.

10.2 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

11. Rejection

11.1 Unless otherwise specified, any rejection based on tests specified herein shall be reported to the manufacturer within 30 working days from the receipt of samples by the purchaser.

TABLE 1 Hardness Requirements for Bolts

Bolt Size, in.	Grade	Hardness: Brinell min	Hardness: Brinell max	Hardness: Rockwell B min	Hardness: Rockwell B max
All	A	121	241[A]	69	100[A]
	B	121	212	69	95

[A] Except when tested by wedge tension test.

TABLE 2 Tensile Requirements for Full-Size Bolts

Bolt Size, in.	Threads per inch	Stress Area[A] in.²	Tensile Strength, lbf[B]: Grades A and B, min[C]	Tensile Strength, lbf[B]: Grade B only, max[D]
1/4	20	0.0318	1 900	3 180
5/16	18	0.0524	3 100	5 240
3/8	16	0.0775	4 650	7 750
7/16	14	0.1063	6 350	10 630
1/2	13	0.1419	8 500	14 190
9/16	12	0.182	11 000	18 200
5/8	11	0.226	13 550	22 600
3/4	10	0.334	20 050	33 400
7/8	9	0.462	27 700	46 200
1	8	0.606	36 350	60 600
1 1/8	7	0.763	45 800	76 300
1 1/4	7	0.969	58 150	96 900
1 3/8	6	1.155	69 300	115 500
1 1/2	6	1.405	84 300	140 500
1 3/4	5	1.90	114 000	190 000
2	4 1/2	2.50	150 000	250 000
2 1/4	4 1/2	3.25	195 000	325 000
2 1/2	4	4.00	240 000	400 000
2 3/4	4	4.93	295 800	493 000
3	4	5.97	358 200	597 000
3 1/4	4	7.10	426 000	710 000
3 1/2	4	8.33	499 800	833 000
3 3/4	4	9.66	579 600	966 000
4	4	11.08	664 800	1 108 000

[A] Area calculated from the formula:

$$A_s = 0.7854\,[D - (0.9743/n)]^2$$

where:
A_s = stress area,
D = nominal diameter of bolt, and
n = threads per inch.
[B] 1 lbf = 4.448 N.
[C] Based on 60 ksi (414 MPa).
[D] Based on 100 ksi (689 MPa).

TABLE 3 Sample Sizes and Acceptance Numbers for Inspection of Hot Dip or Mechanically Galvanized Threads

Lot Size	Sample Size[A, B]	Acceptance Number[A]
2 to 90	13	1
91 to 150	20	2
151 to 280	32	3
281 to 500	50	5
501 to 1 200	80	7
1 201 to 3 200	125	10
3 201 to 10 000	200	14
10 001 and over	315	21

[A] Sample sizes of acceptance numbers are extracted from "Single Sampling Plan for Normal Inspection" Table IIA, MIL-STD-105D.
[B] Inspect all bolts in the lot if the lot size is less than the sample size.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A325: High-Strength Bolts for Structural Steel Joists

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 325 – 79**

American Association
State Highway and
Transportation Officials
Standard AASHTO No.: M 164

Standard Specification for
HIGH-STRENGTH BOLTS FOR STRUCTURAL STEEL JOINTS[1]

This standard is issued under the fixed designation A 325; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This specification[2] covers the chemical and mechanical requirements of various types of quenched and tempered steel bolts commonly known as "high-strength structural bolts," intended for use in structural joints that are covered under requirements of the Specifications for Structural Joints Using ASTM A 325 or A 490 Bolts,[3] issued by the Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation. The various types of bolts covered in this specification are:

1.1.1 *Type 1*—Bolts made of medium-carbon steel, supplied in sizes 1/2 to 1 1/2 in., inclusive, in diameter.

1.1.2 *Type 2*—Bolts made from what is generally described as low-carbon martensite steel, supplied in sizes 1/2 to 1 1/2 in., inclusive, in diameter.

1.1.3 *Type 3*—Bolts, 1/2 to 1 1/2 in., inclusive, in diameter having atmospheric corrosion resistance and weathering characteristics comparable to that of the steels covered in Specification A 588, Specification A 242, and Specification A 709 (these steels have atmospheric corrosion resistance approximately two times that of carbon structural steel with copper).

1.2 When the bolt type is not specified, either Type 1 or Type 2 may be supplied at the option of the manufacturer. Type 3 bolts may be supplied by the manufacturer if agreed by the purchaser. Where elevated temperature applications are involved, Type 1 bolts shall be specified by the purchaser on the order.

1.3 When atmospheric corrosion resistance is required, Type 3 bolts shall be specified by the purchaser in any inquiry or order.

NOTE 1—Bolts for general applications, including anchor bolts, are covered by ASTM Specification A 449, for Quenched and Tempered Steel Bolts and Studs.[4] Also refer to Specification A 449 for quenched and tempered steel bolts and studs with diameters greater than 1 1/2 in., but with similar mechanical properties.

1.4 This specification provides that heavy hex structural bolts shall be furnished unless other dimensional requirements are stipulated in the purchase inquiry and order.

1.5 When galvanized high-strength structural bolts are specified, the bolts shall be either Type 1 or 2, at the manufacturer's option, unless otherwise ordered by the purchaser. Bolts shall be hot-dip galvanized, or, with the approval of the purchaser, bolts may be mechanically galvanized. Galvanized bolts and nuts shall be shipped in the same container.

1.6 Suitable nuts are covered in Specification A 563. Unless otherwise specified, nuts shall be heavy hex, and the grade and surface finish of nut for each type of bolt shall be as follows:

---

[1] This specification is under the jurisdiction of ASTM Committee F-16 on Fasteners, and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.

Current edition approved May 25, 1979. Published September 1979. Originally published as A 325 – 49 T. Last previous edition A 325 – 78a.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-325 in Section II of that Code.

[3] Published by American Institute of Steel Construction, New York, N. Y.

[4] *Annual Book of ASTM Standards,* Part 4.

Bolt Type	Nut Grade and Finish
1 and 2, plain (noncoated)	C, plain
1 and 2, galvanized	DH, galvanized
3	C3

1.6.1 Grades 2 and 2H nuts, as specified in Specification A 194, and Grades D and DH nuts, as specified in Specification A 563, are acceptable alternatives for Grade C nuts. Grade 2H nuts, as specified in Specification A 194, are acceptable alternatives for Grade DH nuts. Type DH3 nuts are acceptable alternatives for C3 nuts.

1.7 Suitable hardened washers are covered in Specification F 436. Unless otherwise specified, galvanized washers shall be furnished when galvanized bolts are specified, and Type 3 weathering steel washers shall be furnished when Type 3 bolts are specified.

NOTE 2—A complete metric companion to Specification A 325 has been developed—Specification A 325M; therefore no metric equivalents are presented in this specification.

2. Applicable Documents

2.1 *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware[5]

A 194 Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service[6]

A 242 Specification for High-Strength Low-Alloy Structural Steel[4]

A 370 Methods and Definitions for Mechanical Testing of Steel Products[7]

A 490 Specification for Quenched and Tempered Alloy Steel Bolts for Structural Steel Joints[4]

A 563 Specification for Carbon and Alloy Steel Nuts[4,6]

A 588 Specification for High-Strength Low-Alloy Structural Steel with 50,000 psi Minimum Yield Point to 4 in. Thick[4]

A 709 Specification for Structural Steel for Bridges[4]

B 454 Specification for Mechanically Deposited Coatings of Cadmium and Zinc on Ferrous Metals[8]

F 436 Specification for Hardened Steel Washers for Use with High-Strength Bolts[4]

2.2 *American National Standards:*[9]

ANSI B1.1 Unified Screw Threads

ANSI B18.2.1 Square and Hex Bolts and Screws

2.3 *Military Standard:*[10]

MIL-STD-105D Sampling Procedure and Tables for Inspection by Attributes

3. Ordering Information

3.1 Orders for products under this specification shall include the following:

3.1.1 Quantity (number of pieces of bolts and accessories),

3.1.2 Name of products, including accessories such as nuts and washers when desired,

3.1.3 Coating if required (that is, hot dip galvanized, or mechanical galvanized),

3.1.4 Dimensions including nominal bolt diameter and length. For bolts of dimensional requirements other than heavy hex structural bolts (see 1.4) it is normally necessary to specify grip length,

3.1.5 Type of bolt (that is, Type 1, 2 or 3). Note that Type 1 and 2 bolts may be shipped at the manufacturer's option if type has not been specified by the purchaser.

3.1.6 ASTM designation and date of issue, and

3.1.7 Any special requirements.

NOTE 3—Two examples of ordering descriptions follow: (*1*) 1000 pieces, heavy hex structural bolts, each with one hardened washer, ASTM F 436 and one heavy hex nut, ASTM 563 Grade C, hot dip galvanized, 1 by 4, ASTM A 325 dated ____. (*2*) 1000 pieces, heavy hex structural bolts, no nuts or washers, $^7/_8$ by $2^1/_4$ Type 1, ASTM A 325 dated ____, for hot-dip galvanizing.

4. Materials and Manufacture

4.1 Steel for bolts shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 Bolts shall be heat treated by quenching in a liquid medium from above the austenitizing temperature and then tempering by reheating to a temperature of at least 800°F.

4.3 Threads of bolts may be cut or rolled.

4.4 Unless otherwise specified, galvanized bolts shall be hot-dip zinc coated in accordance with the requirements for Class C of Specification A 153. When specified by the purchaser to be mechanically galvanized,

[5] *Annual Book of ASTM Standards,* Part 3.
[6] *Annual Book of ASTM Standards,* Part 1.
[7] *Annual Book of ASTM Standards,* Parts 1, 2, 3, 4, 5, and 10.
[8] *Annual Book of ASTM Standards,* Parts 4 and 9.
[9] May be obtained from American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.
[10] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120.

bolts shall be mechanically zinc coated and the coating and coated products shall conform to the requirements for Class 50 of Specification B 454, or to the coating thickness, adherence, and quality requirements for Class C of Specification A 153.

4.5 If heat treatment is performed by a subcontractor the heat-treated material shall be returned to the manufacturer for testing.

5. Chemical Requirements

5.1 Type 1 and 2 bolts shall conform to the requirements as to chemical composition prescribed in Table 1.

5.2 Type 3 bolts shall conform to one of the chemical compositions prescribed in Table 2. The selection of the chemical composition, A, B, C, D, E, or F, shall be at the option of the bolt manufacturer.

5.3 Product analyses may be made by the purchaser from finished material representing each lot of bolts. The chemical composition thus determined shall conform to the requirements prescribed in 4.1 or 4.2.

5.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for bolts.

6. Mechanical Requirements

6.1 Bolts shall not exceed the maximum hardness specified in Table 3. Bolts less than three diameters in length shall have hardness values not less than the minimum nor more than the maximum in hardness limits required in Table 3, as hardness is the only requirement.

6.2 Bolts $1^1/_4$ in. in diameter or less, other than those excepted in 6.1, shall be tested full size and shall conform to the tensile strength and either the proof load or alternative proof load requirements specified in Table 4.

6.3 Bolts larger than $1^1/_4$ in. in diameter, other than those excepted in 6.1, shall preferably be tested full size and when so tested shall conform to the tensile strength and either the proof load or alternative proof load requirements specified in Table 4. When equipment of sufficient capacity for full-size testing is not available, or when the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements of Table 5. In the event that bolts are tested by both full-size and by the machined test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

6.4 For bolts on which hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

6.5 In addition, when galvanized bolts and nuts are supplied, the bolt/nut assembly shall be tested full size in an assembled joint as specified in 8.5. After the tightening test, the assembly shall show no signs of failure.

6.6 When hot-dip galvanized Type 2 bolts are supplied, they shall be tension tested after galvanizing in accordance with 6.2 or 6.3 depending on the diameter. The number of tests from each lot shall be in accordance with 9.2.4 or 9.3.4.

7. Dimensions

7.1 Bolts with hex heads shall be full-body bolts conforming to the dimensions for heavy hex structural bolts specified in the American National Standard for Square and Hex Bolts and Screws (ANSI B18.2.1).

7.2 Threads shall be the Unified Coarse Thread Series as specified in the American National Standard for Unified Screw Threads (ANSI B1.1), and shall have Class 2A tolerances. When specified, 8 pitch thread series may be used on bolts over 1 in. in diameter.

7.3 Unless otherwise specified, bolts to be used with nuts or tapped holes which have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot dip or mechanical galvanizing. After galvanizing, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

Diameter, in.[A]	Oversize Limit, in.[A]
Up to $^7/_{16}$, incl	0.016
Over $^7/_{16}$ to 1, incl	0.021
Over 1	0.031

[A] These values are the same as the minimum overtapping required for galvanized nuts in Specification A 563.

7.4 The gaging limit for bolts shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown above. In case of dispute, a calibrated thread ring gage of that same size (Class X tolerance, gage tolerance plus) is to be used. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, are to be performed at the frequency and quality described in Table 6.

8. Test Methods

8.1 Tests shall be conducted in accordance with Supplement III of Methods and Definitions A 370.

8.2 For tension tests a proof load determination is preferred conducted in accordance with Method 1, Length Measurement, of Supplement III of Methods A 370.

8.3 Bolts tested in full size shall be tested in accordance with the wedge test method described in S11.1.5, Supplement III of Methods A 370. Fracture shall be in the body or threads of the bolt, without any fracture at the junction of the head and body.

8.4 The speed of testing as determined with a free-running cross head shall be a **maximum of ⅛ in./min for the bolt proof-load determination, and a maximum of 1 in./min for the bolt tensile-strength determination.**

8.5 The galvanized bolt shall be placed in a steel joint and assembled with a galvanized washer and a galvanized nut. The joint shall be one or more flat structural steel plates with a total thickness, including the washer, such that 3 to 5 full threads of the bolt are located between the bearing surfaces of the bolt head and nut. The hole in the joint shall have the same nominal diameter as the hole in the washer. The initial tightening of the nut shall produce a load in the bolt not less than 10 % of the specified proof load.[11] After initial tightening, the nut position shall be marked relative to the bolt, and the rotation shown in Table 8 shall be applied. During rotation, the bolt head shall be restrained from turning.

9. Quality Assurance of Mechanical Requirements

9.1 The manufacturer shall make sample inspections of every lot of bolts to ensure that properties of bolts are in conformance with the requirements of this specification. All bolts shall be inspection tested prior to shipment in accordance with one of the two quality assurance procedures described in 9.2 and 9.3, respectively. The manufacturer shall have the option of which procedure will be followed when furnishing bolts to any single purchase order.

9.1.1 The purpose of a lot inspection testing program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that following delivery the purchaser continue to maintain the identification and integrity of each lot until the product is installed in its service application.

9.2 *Production Lot Method:*

9.2.1 All bolts shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer shall identify and maintain the integrity of each production lot of bolts from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.2.2 A production lot, for purposes of assigning an identification number and from which test samples shall be selected, shall consist of all bolts processed essentially together through all operations to the shipping container that are of the same nominal size, the same nominal length, and produced from the same mill heat of steel.

9.2.3 The manufacturer shall make tests for proof load, tensile strength (wedge test), and hardness of each lot of bolts. Alternatively, in accordance with 6.3, tests may be tensile strength, yield strength, reduction of area, elongation, and hardness.

9.2.4 From each production lot, the minimum number of tests of each required property shall be as follows:

Number of Pieces in Production Lot	Number of Specimens
800 and less	1
801 to 8,000	2
8,001 to 35,000	3
35,001 to 150,000	8
150,001 and over	13

[11] Use of the torque value obtained in a Skidmore-Wilhelm or equivalent calibrator may be used in meeting this requirement.

9.2.5 If any test specimen shows defective machining it may be discarded and another specimen substituted.

9.2.6 Bolts shall be packed in shipping containers as soon as practicable following final processing. Shipping containers shall be marked with the lot identification number.

9.2.7 A copy of the inspection test report for each production lot from which bolts are supplied to fill the requirements of a shipment shall be furnished to the purchaser when specified in the order. Individual heats of steel need not be identified on the test report.

9.3 *Shipping Lot Method:*

9.3.1 In-process inspection during all manufacturing operations and treatments and storage of manufactured bolts shall be in accordance with the practices of the individual manufacturer.

9.3.2 Before packing bolts for shipment, the manufacturer shall make tests of sample bolts taken at random from each shipping lot. A shipping lot, for purposes of selecting test samples, is defined as that quantity of bolts of the same nominal size and same nominal length necessary to fill the requirements of a single purchase order.

9.3.3 The manufacturer shall make tests for proof load, tensile strength (wedge test), and hardness of each lot of bolts. Alternatively, in accordance with 6.3, tests may be tensile strength, yield strength, reduction of area, elongation, and hardness.

9.3.4 From each shipping lot, the minimum number of tests of each required property shall be as follows:

Number of Pieces in Shipping Lot	Number of Specimens
150 and less	1
151 to 280	2
281 to 500	3
501 to 1,200	5
1,201 to 3,200	8
3,201 to 10,000	13
10,001 and over	20

9.3.5 If any test specimen shows defective machining it may be discarded and another specimen substituted.

9.3.6 A copy of the inspection test report for each shipping lot shall be furnished to the purchaser when specified in the order. Individual heats of steel are not identified in the finished product.

10. Marking

10.1 All bolts, Types 1, 2 and 3, shall be marked A 325 and shall also be marked with a symbol identifying the manufacturer.

10.2 In addition Type 1 bolts may, at the option of the manufacturer be marked with three radial lines 120 deg apart.

10.3 In addition Type 2 bolts shall be marked with three radial lines 60 deg apart.

10.4 In addition Type 3 bolts shall have the A 325 *underlined*, and the manufacturer may add other distinguishing marks indicating that the bolt is atmospheric corrosion resistant and of a weathering type.

10.5 All markings shall be located on the top of the bolt head and may be either raised or depressed, at the option of the manufacturer.

11. Visual Inspection for Head Bursts

11.1 A burst is an open break in the metal (material). Bursts can occur on the flats or corners of the heads of bolts.

11.2 A defective bolt, for the purposes of the visual inspection for bursts, shall be any bolt that contains a burst in the flat of the head which extends into the top crown surface of the head (chamfer circle) or the underhead bearing surface. In addition, bursts occurring at the intersection of two wrenching flats shall not reduce the width across corners below the specified minimum.

11.3 A lot, for the purposes of visual inspection, shall consist of all bolts of one type having the same nominal diameter and length offered for inspection at one time. No lot shall contain more than 10 000 pieces.

11.4 From each lot of bolts, a representative sample shall be picked at random and visually inspected for bursts. The sample size shall be as shown in Table 7. If the number of defective bolts found during inspection by the manufacturer is greater than the acceptance number given in Table 7 for the sample size, all bolts in the lot shall be visually inspected and all defective bolts shall be removed and destroyed. If the number of defective bolts found during inspection by the purchaser is greater than the acceptance number given in Table 7 for the sample size, the lot shall be subject to rejection.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection

13.1 Unless otherwise specified, any rejection based on tests specified herein shall be reported to the manufacturer within 30 working days from the receipt of samples by the purchaser.

14. Certification

14.1 *Bolts*—When specified on the order the manufacturer shall furnish the test reports described in 9.2.7 or 9.3.6, depending on whether the bolts are furnished by the production lot or shipping lot method.

TABLE 1 Chemical Requirements for Types 1 and 2 Bolts

Element	Composition, %	
	Type 1 Bolts	Type 2 Bolts[A]
Carbon:		
Heat analysis	0.30 min	0.15–0.23
Product analysis	0.27 min	0.13–0.25
Manganese, min:		
Heat analysis	0.50	0.70
Product analysis	0.47	0.67
Phosphorus, max:		
Heat analysis	0.040	0.040
Product analysis	0.048	0.048
Sulfur, max:		
Heat analysis	0.050	0.050
Product analysis	0.058	0.058
Boron, min:		
Heat analysis	...	0.0005
Product analysis	...	0.0005

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

TABLE 2 Chemical Requirements for Type 3 Bolts

Element	Composition, %					
	Type 3 Bolts[A]					
	A	B	C	D	E	F
Carbon:						
Heat analysis	0.33–0.40	0.38–0.48	0.15–0.25	0.15–0.25	0.20–0.25	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	0.19–0.26
Manganese:						
Heat analysis	0.90–1.20	0.70–0.90	0.80–1.35	0.40–1.20	0.60–1.00	0.90–1.20
Product analysis	0.86–1.24	0.67–0.93	0.76–1.39	0.36–1.24	0.56–1.04	0.86–1.24
Phosphorus:						
Heat analysis	0.040 max	0.06–0.12	0.035 max	0.040 max	0.040 max	0.040 max
Product analysis	0.045 max	0.06–0.125	0.040 max	0.045 max	0.045 max	0.045 max
Sulfur:						
Heat analysis	0.050 max	0.050 max	0.040 max	0.050 max	0.040 max	0.040 max
Product analysis	0.055 max	0.055 max	0.045 max	0.055 max	0.045 max	0.045 max
Silicon:						
Heat analysis	0.15–0.30	0.30–0.50	0.15–0.30	0.25–0.50	0.15–0.30	0.15–0.30
Product analysis	0.13–0.32	0.25–0.55	0.13–0.32	0.20–0.55	0.13–0.32	0.13–0.32
Copper:						
Heat analysis	0.25–0.45	0.20–0.40	0.20–0.50	0.30–0.50	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.17–0.43	0.17–0.53	0.27–0.53	0.27–0.63	0.17–0.43
Nickel:						
Heat analysis	0.25–0.45	0.50–0.80	0.25–0.50	0.50–0.80	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.47–0.83	0.22–0.53	0.47–0.83	0.27–0.63	0.17–0.43
Chromium:						
Heat analysis	0.45–0.65	0.50–0.75	0.30–0.50	0.50–1.00	0.60–0.90	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	0.42–0.68
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	. . .	0.11max	. . .	. . .
Titanium:						
Heat analysis	. . .	. . .	. . .	0.05 max	. . .	. . .
Product analysis	. . .	. . .	. . .	. . .	. . .	. . .

[A] A, B, C, D, E and F are classes of material used for Type 3 bolts. Selection of a class shall be at the option of the bolt manufacturer.

TABLE 3 Hardness Requirements for Bolts

Bolt Size, in.	Hardness Number			
	Brinell		Rockwell C	
	Min	Max	Min	Max
1/2 to 1, incl	248	331	24	35
1 1/8 to 1 1/2, incl	223	293	19	31

ASTM Logo Removed

A 325

TABLE 4 Tensile Requirements for Full Size Bolts

Bolt Size, Threads per Inch and Series Designation	Stress Area,[A] in.^{2}	Tensile Strength[B] min, lbf	Proof Load,[B] Length Measurement Method	Alternative Proof Load,[B] Yield Strength Method, min
Column 1	Column 2	Column 3	Column 4	Column 5
½-13 UNC	0.142	17 050	12 050	13 050
⅝-11 UNC	0.226	27 100	19 200	20 800
¾-10 UNC	0.334	40 100	28 400	30 700
⅞-9 UNC	0.462	55 450	39 250	42 500
1-8 UNC	0.606	72 700	51 500	55 750
1⅛-7 UNC	0.763	80 100	56 450	61 800
1⅛-8 UN	0.790	82 950	58 450	64 000
1¼-7 UNC	0.969	101 700	71 700	78 500
1¼-8 UN	1.000	105 000	74 000	81 000
1⅜-6 UNC	1.155	121 300	85 450	93 550
1⅜-8 UN	1.233	129 500	91 250	99 870
1½-6 UNC	1.405	147 500	104 000	113 800
1½-8 UN	1.492	156 700	110 400	120 850

[A] The stress area is calculated as follows:

$$A_s = 0.7854\,[D - (0.9743/n)]^2$$

where:

A_s = stress area, in.^{2},
D = nominal bolt size, and
n = threads per inch.

[B] Loads tabulated are based on the following:

Bolt Size	Column 3	Column 4	Column 5
½, to 1 incl	120 000 psi	85 000 psi	92 000 psi
1⅛ to 1½, incl	105 000 psi	74 000 psi	81 000 psi

TABLE 5 Tensile Requirements for Specimens Machined from Bolts

Bolt Size, in.	Tensile Strength, min, psi	Yield Strength (0.2 % Offset) min, psi	Elongation in 2 in., min, %	Reduction of Area, min, %
1¼, 1⅜ and 1½	105 000	81 000	14	35

TABLE 6 Sample Sizes and Acceptance Numbers for Inspection of Hot Dip or Mechanically Galvanized Threads

Lot Size	Sample Size[A B]	Acceptance Number[A]
2 to 90	13	1
91 to 150	20	2
151 to 280	32	3
281 to 500	50	5
501 to 1 200	80	7
1 201 to 3 200	125	10
3 201 to 10 000	200	14
10 001 and over	315	21

[A] Sample sizes of acceptance numbers are extracted from "Single Sampling Plan for Normal Inspection" Table IIA, MIL-STD-105D.

[B] Inspect all bolts in the lot if the lot size is less than the sample size.

ASTM Logo Removed

TABLE 7 Sample Sizes and Acceptance Numbers for Inspection of Bursts

Lot Size	Sample Size[A, B]	Acceptance Number[A]
1 to 150	5	0
151 to 500	20	1
501 to 1 200	32	2
1 201 to 3 200	50	3
3 201 to 10 000	80	5

[A] Sample sizes and acceptance numbers are extracted from "Single Sampling Plan for Normal Inspection" Table 11A, MIL-STD-105D.

[B] Inspect all bolts in the lot if the lot size is less than the sample size.

TABLE 8 Test for Galvanized Bolts

Bolt Length Diameter, in.	Nominal Nut Rotation, deg (turn)
Up to and including 4	300 ($^5/_6$)
Over 4, but not exceeding 8	360 (1)
Over 8	420 ($1^1/_{16}$)

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A370: Standard Test Method and Definitions for Mechanical Testing of Steel Products

CFR Section(s): 49 CFR 179.102-1(a)(1)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: A 370 – 77$^{\epsilon 2}$

An American National Standard
American Association State Highway and Transportation Officials Standard
AASHTO No.: T 244

Standard Methods and Definitions for
MECHANICAL TESTING OF STEEL PRODUCTS[1]

This standard is issued under the fixed designation A 370; 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.

These methods have been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

$^{\epsilon 1}$ NOTE—Paragraph 18.2 was editorially changed in May 1979.
$^{\epsilon 2}$ NOTE—Fig. 21 was editorially corrected in October 1980.

1. Scope

1.1 These methods[2] cover procedures and definitions for the mechanical testing of wrought and cast steel products. The various mechanical tests herein described are used to determine properties required in the product specifications. Variations in testing methods are to be avoided and standard methods of testing are to be followed to obtain reproducible and comparable results. In those cases where the testing requirements for certain products are unique or at variance with these general procedures, the product specification testing requirements shall control.

1.2 The following mechanical tests are described:

	Sections
Tension	5 to 13
Bend	14
Hardness:	15
Brinell	16 and 17
Rockwell	18
Impact	19 to 23

1.3 Supplements covering details peculiar to certain products are appended to these methods as follows:

	Sections
Bar Products (Supplement I)	S 1 to S 4
Tubular Products (Supplement II)	S 5 to S 9
Fasteners (Supplement III)	S 10 to S 15
Round Wire Products (Supplement IV)	S 16 to S 22
Significance of Notched Bar Impact Testing (Supplement V)	S 23 to S 28
Converting Percentage Elongation of Round Specimens to Equivalents for Flat Specimens (Supplement VI)	S 29 to S 31
Testing Seven Wire Stress-Relieved Strand (Supplement VII)	S 32 to S 36
Rounding Test Data (Supplement VIII)	

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards:*

A 416 Specification for Uncoated Seven-Wire Stress-Relieved Steel Strand for Prestressed Concrete[3]

E 4 Practices for Load Verification of Testing Machines[4]

E 6 Definitions of Terms Relating to Methods of Mechanical Testing[4]

E 8 Methods of Tension Testing of Metallic Materials[4]

E 10 Test Method for Brinell Hardness of Metallic Materials[4]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[4]

E 23 Methods for Notched Bar Impact Testing of Metallic Materials[4]

E 83 Method of Verification and Classification of Extensometers[4]

E 110 Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers[4]

E 208 Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels[4]

---

[1] These methods are under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys and are the direct responsibility of Subcommittee A01.13 on Mechanical Testing.

Current edition approved June 24, 1977. Published August 1977. Originally published as A 370 – 53 T. Last previous edition A 370 – 76.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-370 in Section II of that Code.

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

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

3. General Precautions

3.1 Certain methods of fabrication such as bending, forming, and welding, or operations involving heating, may affect the properties of the material under test. Therefore, the product specifications cover the stage of manufacture at which mechanical testing is to be performed. The properties shown by testing prior to fabrication may not necessarily be representative of the product after it has been completely fabricated.

3.2 Improper machining or preparation of test specimens may give erroneous results. Care should be exercised to assure good workmanship in machining. Improperly machined specimens should be discarded and other specimens substituted.

3.3 Flaws in the specimen may also affect results. If any test specimen develops flaws, the retest provision of the applicable product specification shall govern.

3.4 If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

4. Orientation of Test Specimens

4.1 The terms "longitudinal test" and "transverse test" are used only in material specifications for wrought products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.1.1 *Longitudinal Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is parallel to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a longitudinal tension test specimen is in the direction of the greatest extension, and the axis of the fold of a longitudinal bend test specimen is at right angles to the direction of greatest extension (Figs. 1, 2(*a*), and 2(*b*)).

4.1.2 *Transverse Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is at right angles to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a transverse tension test specimen is at right angles to the greatest extension, and the axis of the fold of a transverse bend test specimen is parallel to the greatest extension (Fig. 1).

4.2 The terms "radial test" and "tangential test" are used in material specifications for some wrought circular products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.2.1 *Radial Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to the axis of the product and coincident with one of the radii of a circle drawn with a point on the axis of the product as a center (Fig. 2(*a*)).

4.2.2 *Tangential Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a center (Figs. 2(*a*), 2(*b*), 2(*c*), and 2(*d*)).

TENSION TEST

5. Description

5.1 The tension test related to the mechanical testing of steel products subjects a machined or full-section specimen of the material under examination to a measured load sufficient to cause rupture. The resulting properties sought are defined in Definitions E 6.

5.2 In general the testing equipment and methods are given in Methods E 8. However, there are certain exceptions to Methods E 8 practices in the testing of steel, and these are covered in these methods.

6. Test Specimen Parameters

6.1 *Selection*—Test coupons shall be selected in accordance with the applicable product specifications.

6.1.1 *Wrought Steels*—Wrought steel products are usually tested in the longitudinal direction, but in some cases, where size permits and the service justifies it, testing is in the transverse, radial, or tangential directions (see Figs. 1 and 2).

6.1.2 *Forged Steels*—For open die forgings, the metal for tension testing is usually provided by allowing extensions or prolongations on one or both ends of the forgings, either on all or a representative number as provided by the applicable product specifications. Test specimens are normally taken at mid-radius. Certain product specifications permit the use of a representative bar or the destruction of a production part for test purposes. For ring or disk-like forgings test metal is provided by increasing the diameter, thickness, or length of the forging. Upset disk or ring forgings, which are worked or extended by forging in a direction perpendicular to the axis of the forging, usually have their principal extension along concentric circles and for such forgings tangential tension specimens are obtained from extra metal on the periphery or end of the forging. For some forgings, such as rotors, radial tension tests are required. In such cases the specimens are cut or trepanned from specified locations.

6.1.3 *Cast Steels*—Test coupons for castings from which tension test specimens are prepared shall be attached to the castings where practicable. If the design of the casting is such that test coupons should not be attached thereon, test coupons shall be cast attached to separate cast blocks (Fig. 3 and Table 1).

6.2 *Size and Tolerances*—Test specimens shall be the full thickness or section of material as-rolled, or may be machined to the form and dimensions shown in Figs. 4 to 7, inclusive. The selection of size and type of specimen is prescribed by the applicable product specification. Full section specimens shall be tested in 8-in. (200-mm) gage length unless otherwise specified in the product specification.

6.3 *Procurement of Test Specimens*—Specimens shall be sheared, blanked, sawed, trepanned, or oxygen-cut from portions of the material. They are usually machined so as to have a reduced cross section at mid-length in order to obtain uniform distribution of the stress over the cross section and to localize the zone of fracture. When test coupons are sheared, blanked, sawed, or oxygen-cut, care shall be taken to remove by machining all distorted, cold-worked, or heat-affected areas from the edges of the section used in evaluating the test.

6.4 *Aging of Test Specimens*—Unless otherwise specified, it shall be permissible to age tension test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water, heating in oil or in an oven.

6.5 *Measurement of Dimensions of Test Specimens:*

6.5.1 *Standard Rectangular Tension Test Specimens*—These forms of specimens are shown in Fig. 4. To determine the cross-sectional area, the center width dimension shall be measured to the nearest 0.005 in. (0.13 mm) for the 8-in. (200-mm) gage length specimen and 0.001 in. (0.025 mm) for the 2-in. (50-mm) gage length specimen in Fig. 4. The center thickness dimension shall be measured to the nearest 0.001 in. for both specimens.

6.5.2 *Standard Round Tension Test Specimens*—These forms of specimens are shown in Figs. 5 and 6. To determine the cross-sectional area, the diameter shall be measured at the center of the gage length to the nearest 0.001 in.

6.6 *General*—Test specimens shall be either substantially full size or machined, as prescribed in the product specifications for the material being tested.

6.6.1 Improperly prepared test specimens often cause unsatisfactory test results. It is important, therefore, that care be exercised in the preparation of specimens, particularly in the machining, to assure good workmanship.

6.6.2 It is desirable to have the cross-sectional area of the specimen smallest at the center of the gage length to ensure fracture within the gage length. This is provided for by the taper in the gage length permitted for each of the specimens described in the following sections.

6.6.3 For brittle materials it is desirable to have fillets of large radius at the ends of the gage length.

7. Plate-Type Specimen

7.1 The standard plate-type test specimen is shown in Fig. 4. This specimen is used for testing metallic materials in the form of plate, structural and bar-size shapes, and flat material having a nominal thickness of $^3/_{16}$ in. (5 mm) or over. When product specifications so permit, other types of specimens may be used.

NOTE 1—When called for in the product specification, the 8-in. gage length specimen of Fig. 4 may be used for sheet and strip material.

8. Sheet-Type Specimen

8.1 The standard sheet-type test specimen is shown in Fig. 4. This specimen is used for testing metallic materials in the form of sheet, plate, flat wire, strip, band, and hoop ranging in nominal thickness from 0.005 to ¾ in. (0.13 to 19 mm). When product specifications so permit, other types of specimens may be used, as provided in Section 7.

9. Round Specimens

9.1 The standard 0.500-in. (12.5-mm) diameter round test specimen shown in Fig. 5 is used quite generally for testing metallic materials, both cast and wrought.

9.2 Figure 5 also shows small size specimens proportional to the standard specimen. These may be used when it is necessary to test material from which the standard specimen or specimens shown in Fig. 4 cannot be prepared. Other sizes of small round specimens may be used. In any such small size specimen it is important that the gage length for measurement of elongation be four times the diameter of the specimen (see Note 4, Fig. 5).

9.3 The shape of the ends of the specimens outside of the gage length shall be suitable to the material and of a shape to fit the holders or grips of the testing machine so that the loads are applied axially. Figure 6 shows specimens with various types of ends that have given satisfactory results.

10. Gage Marks

10.1 The specimens shown in Figs. 4, 5, and 7 shall be gage marked with a center punch, scribe marks, multiple device, or drawn with ink. The purpose of these gage marks is to determine the percent elongation. Punch marks shall be light, sharp, and accurately spaced. The localization of stress at the marks makes a hard specimen susceptible to starting fracture at the punch marks. The gage marks for measuring elongation after fracture shall be made on the flat or on the edge of the flat tension test specimen and within the parallel section; for the 8-in. gage length specimen, Fig. 4, one or more sets of 8-in. gage marks may be used, intermediate marks within the gage length being optional. Rectangular 2-in. gage length specimens, Fig. 4, and round specimens, Fig. 5, are gage marked with a double-pointed center punch or scribe marks. In both cases the gage points shall be approximately equidistant from the center of the length of the reduced section. These same precautions shall be observed when the test specimen is full section.

11. Testing Apparatus and Operations

11.1 *Loading Systems*—There are two general types of loading systems, mechanical (screw power) and hydraulic. These differ chiefly in the variability of the rate of load application. The older screw power machines are limited to a small number of fixed free running crosshead speeds. Some modern screw power machines and all hydraulic machines permit stepless variation throughout the range of speeds.

11.2 The tension testing machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision of Practices E 4.

NOTE 2—Many machines are equipped with stress-strain recorders for autographic plotting of stress-strain curves. It should be noted that some recorders have a load measuring component entirely separate from the load indicator of the testing machine. Such recorders are calibrated separately.

11.3 *Loading*—It is the function of the gripping or holding device of the testing machine to transmit the load from the heads of the machine to the specimen under test. The essential requirement is that the load shall be transmitted axially. This implies that the centers of the action of the grips shall be in alignment, insofar as practicable, with the axis of the specimen at the beginning and during the test, and that bending or twisting be held to a minimum. Gripping of the specimen shall be restricted to the section outside the gage length. In the case of certain sections tested in full size, nonaxial loading is unavoidable and in such cases shall be permissible.

11.4 *Speed of Testing*—The speed of testing shall not be greater than that at which load and strain readings can be made accurately. In production testing, speed of testing is commonly expressed (*1*) in terms of free running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), or (*2*) in terms of rate of separation of the two heads of the testing machine under load, or (*3*) in terms of rate of stressing the specimen. Speed of testing may also be expressed in terms of rate of straining the specimen. However, it is not practicable to control the rate of straining on machines currently used in production testing. The following limitations on the speed of testing are recommended as adequate for most steel products:

11.4.1 Any convenient speed of testing may be used up to one half the specified yield point or yield strength. When this point is reached, the rate of separation of the crossheads under load shall be adjusted so as not to exceed $^1/_{16}$ in. per min per inch of gage length, or the distance between the grips for test specimens not having reduced sections. This speed shall be maintained through the yield point or yield strength. In determining the tensile strength, the rate of separation of the heads under load shall not exceed $^1/_2$ in. per min per inch of gage length. In any event the minimum speed of testing shall not be less than $^1/_{10}$ of the specified maximum rates for determining yield point or yield strength and tensile strength.

11.4.2 It shall be permissible to set the speed of the testing machine by adjusting the free running crosshead speed to the above specified values, inasmuch as the rate of separation of heads under load at these machine settings is less than the specified values of free running crosshead speed.

11.4.3 As an alternative, if the machine is equipped with a device to indicate the rate of loading, the speed of the machine from half the specified yield point or yield strength through the yield point or yield strength may be adjusted so that the rate of stressing does not exceed 100,000 psi (690 MPa)/min. However, the minimum rate of stressing shall not be less than 10,000 psi (70 MPa)/min.

12. Definitions

12.1 For definitions of terms pertaining to tension testing, including tensile strength, yield point, yield strength, elongation, and reduction of area, reference should be made to Definitions E 6.

13. Determination of Tensile Properties

13.1 *Yield Point*—Yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. Yield point is intended for application only for materials that may exhibit the unique characteristic of showing an increase in strain without an increase in stress. The stress-strain diagram is characterized by a sharp knee or discontinuity. Determine yield point by one of the following methods:

13.1.1 *Drop of the Beam or Halt of the Pointer Method*—In this method apply an increasing load to the specimen at a uniform rate. When a lever and poise machine is used, keep the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of the load will stop, but run the poise a trifle beyond the balance position, and the beam of the machine will drop for a brief but appreciable interval of time. When a machine equipped with a load-indicating dial is used there is a halt or hesitation of the load-indicating pointer corresponding to the drop of the beam. Note the load at the "drop of the beam" or the "halt of the pointer" and record the corresponding stress as the yield point.

13.1.2 *Autographic Diagram Method*—When a sharp-kneed stress-strain diagram is obtained by an autographic recording device, take the stress corresponding to the top of the knee (Fig. 8), or the stress at which the curve drops as the yield point (Fig. 8).

13.1.3 *Total Extension Under Load Method*—When testing material for yield point and the test specimens may not exhibit a well-defined disproportionate deformation that characterizes a yield point as measured by the drop of the beam, halt of the pointer, or autographic diagram methods described in 13.1.1 and 13.1.2, a value equivalent to the yield point in its practical significance may be determined by the following method and may be recorded as yield point: Attach a Class C or better extensometer (Notes 3 and 4) to the specimen. When the load producing a specified extension (Note 5) is reached record the stress corresponding to the load as the yield point, and remove the extensometer (Fig. 9).

NOTE 3—Automatic devices are available that determine the load at the specified total extension without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated. Multiplying calipers and other such devices are acceptable for use provided their accuracy has been demonstrated as equivalent to a Class C extensometer.

NOTE 4—Reference should be made to Method E 83.

NOTE 5—For steel with a yield point specified not over 80 000 psi (550 MPa), an appropriate value is 0.005 in./in. of gage length. For values above 80 000 psi, this method is not valid unless the limiting total extension is increased.

13.2 *Yield Strength*—Yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. The deviation is expressed in terms of strain, percent offset, total extension under load, etc. Determine yield strength by one of the following methods:

13.2.1 *Offset Method*—To determine the yield strength by the "offset method," it is necessary to secure data (autographic or numerical) from which a stress-strain diagram may be drawn. Then on the stress-strain diagram (Fig. 10) lay off *Om* equal to the specified value of the offset, draw *mn* parallel to *OA*, and thus locate *r*, the intersection of *mn* with the stress-strain curve corresponding to load *R* which is the yield strength load. In reporting values of yield strength obtained by this method, the specified value of "offset" used should be stated in parentheses after the term yield strength, thus:

Yield strength (0.2% offset)
= 52 000 psi (360 MPa)

In using this method, a minimum extensometer magnification of 250 to 1 is required. A Class B1 extensometer meets this requirement (see Note 5). See also Note 7 for automatic devices.

13.2.2 *Extension Under Load Method*—For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified offset (see Note 7) occurs will be known within satisfactory limits. The stress on the specimen, when this total strain is reached, is the value of the yield strength. The total strain can be obtained satisfactorily by use of a Class B1 extensometer (Notes 3 and 4).

NOTE 6—Automatic devices are available that determine offset yield strength without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated.

NOTE 7—The appropriate magnitude of the extension under load will obviously vary with the strength range of the particular steel under test. In general, the value of extension under load applicable to steel at any strength level may be determined from the sum of the proportional strain and the plastic strain expected at the specified yield strength. The following equation is used:

Extension under load, in./in. of gage length
$= (YS/E) + r$

where:

YS = specified yield strength, psi or MPa,
E = modulus of elasticity, psi or MPa, and
r = limiting plastic strain, in./in.

13.3 *Tensile Strength*—Calculate the tensile strength by dividing the maximum load the specimen sustains during a tension test by the original cross-sectional area of the specimen.

13.4 *Elongation:*

13.4.1 Fit the ends of the fractured specimen together carefully and measure the distance between the gage marks to the nearest 0.01 in. (0.25 mm) for gage lengths of 2 in. and under, and to the nearest 0.5 percent of the gage length for gage lengths over 2 in. A percentage scale reading to 0.5 percent of the gage length may be used. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In reporting elongation values, give both the percentage increase and the original gage length.

13.4.2 If any part of the fracture takes place outside of the middle half of the gage length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is indicated, but if the elongation is less than the minimum requirements, discard the test and retest.

13.5 *Reduction of Area*—Fit the ends of the fractured specimen together and measure the mean diameter or the width and thickness at the smallest cross section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area, is the reduction of area.

Bend Test

14. Description

14.1 The bend test is one method for evaluating ductility, but it cannot be considered as a quantitative means of predicting service performance in bending operations. The severity of the bend test is primarily a function of the angle of bend and inside diameter to which the specimen is bent, and of the cross section of the specimen. These conditions are varied according to location and orientation of the test specimen and the chemical composition, tensile properties, hardness, type, and quality of the steel specified.

14.2 Unless otherwise specified, it shall be permissible to age bend test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water, heating in oil, or in an oven.

14.3 Bend the test specimen at room temperature to an inside diameter, as designated by the applicable product specifications, to the extent specified without major cracking on the outside of the bent portion. The speed of bending is ordinarily not an important factor.

Hardness Test

15. General

15.1 A hardness test is a means of determining resistance to penetration and is occasionally employed to obtain a quick approximation of tensile strength. Tables 3A, 3B, 3C, and 3D are for the conversion of hardness measurements from one scale to another or to approximate tensile stength. These conversion values have been obtained from computer-generated curves and are presented to the nearest 0.1 point to permit accurate reproduction of those curves. Since all converted hardness values must be considered approximate, however, all converted Rockwell hardness numbers shall be rounded to the nearest whole number.

16. Brinell Test

16.1 *Description:*

16.1.1 A specified load is applied to a flat surface of the specimen to be tested, through a hard ball of specified diameter. The average diameter of the indentation is used as a basis for calculation of the Brinell hardness number. The quotient of the applied load divided by the area of the surface of the indentation, which is assumed to be spherical, is termed the Brinell hardness number (HB) in accordance with the following equation:

$$HB = P/[(\pi D/2)(D - \sqrt{D^2 - d^2})]$$

where:

HB = Brinell hardness number,
P = applied load, kgf,
D = diameter of the steel ball, mm, and
d = average diameter of the indentation, mm.

NOTE 8—The Brinell hardness number is more conveniently secured from standard tables which show numbers corresponding to the various indentation diameters, usually in increments of 0.05 mm.

16.1.2 The standard Brinell test using a 10-mm ball employs a 3000-kgf load for hard materials and a 1500 or 500-kgf load for thin sections or soft materials (see Supplement II on Steel Tubular Products, Section S 8). Other loads and different size indentors may be used when specified. In reporting hardness values, the diameter of the ball and the load must be stated except when a 10-mm ball and 3000-kgf load are used.

16.1.3 A range of hardness can properly be specified only for quenched and tempered or normalized and tempered material. For annealed material a maximum figure only should be specified. For normalized material a minimum or a maximum hardness may be specified by agreement. In general, no hardness requirements should be applied to untreated material.

16.1.4 Brinell hardness may be required when tensile properties are not specified. When agreed upon, hardness tests can be substituted for tension tests in order to expedite testing of a large number of duplicate pieces from the same lot.

16.2 *Apparatus*—Equipment shall meet the following requirements:

16.2.1 *Testing Machine*—A Brinell hardness testing machine is acceptable for use over a loading range within which its load measuring device is accurate within 3 percent.

16.2.2 *Micrometer Microscope*—The micrometer microscope or equivalent device for measuring diameter or depth of indentation is adjusted so that throughout the range covered the error of reading does not exceed 0.02 mm.

16.2.3 *Standard Ball*—The standard ball for Brinell hardness testing is 10 mm (0.3937 in.) in diameter with a deviation from this value of not more than 0.01 mm (0.0004 in.) in any diameter. A ball suitable for use must not show a permanent change in diameter greater than 0.01 mm (0.0004 in.) when pressed with a force of 3000 kgf against the test specimen.

16.3 *Test Specimen*—Brinell hardness tests are made on prepared areas and sufficient metal must be removed from the surface to eliminate decarburized metal and other surface irregularities. The thickness of the piece tested must be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the indentation.

16.4 *Procedure:*

16.4.1 It is essential that the applicable product specifications state clearly the position at which Brinell hardness indentations are to be made and the number of such indentations required. The distance of the center of the indentation from the edge of the specimen or edge of another indentation must be at least three times the diameter of the indentation.

16.4.2 Apply the load for a minimum of 10 s.

16.4.3 Measure two diameters of the indentation at right angles to the nearest 0.1 mm, estimate to the nearest 0.05 mm, and average to the nearest 0.05 mm. If the two diameters differ by more than 0.1 mm, discard the readings and make a new indentation.

16.4.4 Do not use a steel ball on steels having a hardness over 444 HB nor a carbide ball over 627 HB. The Brinell test is not recommended for materials having a HB over 627.

16.5 *Detailed Procedure*—For detailed requirements of this test, reference shall be made to the latest revision of Method E 10.

17. Portable Hardness Test

17.1 *Portable Testers*—Under certain circumstances, it may be desirable to substitute a portable Brinell testing instrument, which is calibrated to give equivalent results to those of a standard Brinell machine on a comparison test bar of approximately the same hardness as the material to be tested.

17.2 *Detailed Procedure*—For detailed requirements of the portable test, reference shall be made to the latest revision of Method E 110.

18. Rockwell Test

18.1 *Description:*

18.1.1 In this test a hardness value is obtained by using a direct-reading testing machine which measures hardness by determining the depth of penetration of a diamond point or a steel ball into the specimen under certain arbitrarily fixed conditions. A minor load of 10 kgf is first applied which causes an initial penetration, sets the penetrator on the material and holds it in position. A major load which depends on the scale being used is applied increasing the depth of indentation. The major load is removed and, with the minor load still acting, the Rockwell number, which is proportional to the difference in penetration between the major and minor loads, is read directly on the dial gage. This is an arbitrary number which increases with increasing hardness. The scales most frequently used are as follows:

Scale Symbol	Penetrator	Major Load, kgf	Minor Load, kgf
B	1/16-in. steel ball	100	10
C	Diamond brale	150	10

18.1.2 Rockwell superficial hardness machines are used for the testing of very thin steel or thin surface layers. Loads of 15, 30, or 45 kgf are applied on a hardened steel ball or diamond penetrator, to cover the same range of hardness values as for the heavier loads. The superficial hardness scales are as follows:

Scale Symbol	Penetrator	Major Load, kgf	Minor Load, kgf
15T	1/16-in. steel ball	15	3
30T	1/16-in. steel ball	30	3
45T	1/16-in. steel ball	45	3
15N	Diamond brale	15	3
30N	Diamond brale	30	3
45N	Diamond brale	45	3

18.2 *Reporting Hardness*—In reporting hardness values, the hardness number should always precede the scale symbol, 96 HRB, 40 HRC, 75 HR15N, or 77 HR30T.

18.3 *Test Blocks*—Machines should be checked to make certain they are in good order by means of standardized Rockwell test blocks.

18.4 *Detailed Procedure*—For detailed requirements of this test, reference shall be made to the latest revision of Methods E 18.

CHARPY IMPACT TESTING

18. Description

19.1 A Charpy impact test is a dynamic test in which a selected specimen, machined or surface ground and notched, is struck and broken by a single blow in a specially designed testing machine and the energy absorbed in breaking the specimen is measured. The energy values determined are qualitative comparisons on a selected specimen and although frequently specified as an acceptance criterion, they cannot be converted into energy figures that would serve for engineering calculations. Percentage shear fracture and mils of lateral expansion opposite the notch are other frequently used criteria of acceptance for Charpy V-notch impact test specimens.

19.2 Testing temperatures other than ambient temperature are often specified in the individual product specifications. Although the testing temperature is sometimes governed by the service temperature, the two may not be identical.

19.3 Further information on the significance of impact testing appears in Supplement V.

20. Test Specimens

20.1 *Selection and Number of Tests:*

20.1.1 Unless otherwise specified, longitudinal test specimens shall be used with the notch perpendicular to the surface of the object being tested.

20.1.2 An impact test shall consist of three specimens taken from a single test coupon or test location.

20.2 *Size and Type:*

20.2.1 The type of specimen desired, Charpy V-notch Type A or Charpy keyhole notch Type B, shown in Fig. 11, should be specified.

20.2.2 For material less than 7/16 in. (11 mm) thick, subsize test specimens shall be used. They shall be made to the following dimensions and to the tolerances shown in Fig. 11:

10 by 7.5 mm
10 by 6.7 mm
10 by 5 mm
10 by 3.3 mm
10 by 2.5 mm

The base of the notch shall be perpendicular to the 10-mm-wide face.

20.2.3 When subsize specimens are required, the specified energy level or test temperature, or both, shall be reduced as agreed upon by purchaser and supplier.

NOTE 9—The Charpy U-notch specimen may be substituted for the keyhold specimen. A sketch of the U-notch specimen may be found as Fig. 4 (Specimen Type C) in Methods E 23.

20.3 *Notch Preparation:*

20.3.1 Particular attention must be paid to the machining of V-notches as it has been demonstrated that extremely minor variations in notch radius may result in very erratic test data. Tool marks at the bottom of the notch must be carefully avoided.

20.3.2 Keyhole notches shall be made by drilling the round hole and then cutting the slot by any feasible means. The drilling must be done carefully with a slow feed. Care must also be exercised in cutting the slot to see that the surface of the drilled hole is not damaged.

21. Testing Apparatus and Conditions

21.1 *General Characteristics:*

21.1.1 A Charpy impact machine is one in which a notched specimen is broken by a single blow of a freely swinging pendulum. The pendulum is released from a fixed height, so that the energy of the blow is fixed and known. The height to which the pendulum rises in its swing after breaking the specimen is measured and used to determine the residual energy of the pendulum. The specimen is supported horizontally as a simple beam with the axis of the notch vertical. It is struck in the middle of the face opposite the notch.

21.1.2 Charpy machines used for testing steel generally strike the specimen with an energy of from 220 to 265 ft·lbf (298 to 359 J) and a linear velocity at the point of impact of 16 to 19 ft (4.88 to 5.80 m)/s. Sometimes machines of lighter capacity are used.

21.2 *Calibration (Accuracy and Sensitivity):*

21.2.1 Charpy impact machines shall be calibrated and adjusted in accordance with the requirements of the latest revision of Methods E 23.

21.2.2 The indicator should have an error not greater than 1 ft·lbf (1.4 J) as calibrated by the prescribed procedure.

21.2.3 The dimensions of the pendulum should be such that the center of percussion is at the point of impact with an error not greater than 1 percent of the distance from the axis of rotation to the point of impact.

21.2.4 The dimensions of the specimen supports and striking edge shall conform to Fig. 12.

21.3 *Temperature:*

21.3.1 The effect of variations in temperature on Charpy test results is sometimes very great and this variable shall be closely controlled. The actual temperature at which each specimen is broken shall be reported.

21.3.2 Tests are often specified to be run at low temperatures. These low temperatures can be obtained readily in the laboratory by the use of chilled liquids such as: water, ice plus water, dry ice plus organic solvents, liquid nitrogen, or chilled gases. Specimens to be tested at low temperatures shall be held at the specified temperature for at least 5 min in liquid coolants and 60 min in gaseous environments.

21.3.3 For elevated-temperature tests, the specimens shall preferably be immersed in an agitated oil, or other suitable liquid bath and held at temperature for at least 10 min; if samples are heated in an oven they must be held in the oven for at least 60 min.

21.3.4 When tested at temperatures other than ambient, specimens shall be inserted in the machine and broken within 5 s so as to minimize the change of temperature prior to breaking.

21.3.5 Tongs for handling the test specimens, and centering devices used to ensure proper location of the test on the anvil of the impact tester, shall be at the same relative temperature as the test specimen prior to each test so as not to affect the temperature of the test specimen at the notch.

22. Test Results

22.1 The result of an impact test shall be the average (arithmetic mean) of the results of the three specimens.

22.2 When the acceptance criteria are based on absorbed energy, not more than one specimen may exhibit a value below the specified minimum average, and in no case shall an individual value be below either two thirds of the specified minimum average or 5 ft·lbf (6.8 J), whichever is greater, subject to the retest provisions of 22.2.1.

22.2.1 If more than one specimen is below the specified minimum average, or if one value is below two thirds of the specified minimum average, a retest of three additional specimens shall be made, each of which shall have a value equal to or exceeding the specified minimum average value.

22.3 When the acceptance criteria are based on lateral expansion, the value for each of the specimens must equal or exceed the specified minimum value subject to the retest provision of 22.3.1.

22.3.1 If the value on one specimen falls below the specified minimum value, and not below two thirds of the specified minimum value, and if the average of the three specimens equals or exceeds the specified minimum value, a retest of three additional specimens shall be made. The value for each of the three retest specimens must equal or exceed the specified minimum value.

23. Acceptance Criteria

23.1 *Impact Strength*—In some applications, impact tests are specified to determine the behavior of the metal when subjected to a single application of a load that produces multiaxial stresses associated with a notch with high rates of loading, in some cases at high or low temperature. Data are reported in terms of foot-pounds of absorbed energy at the test temperature.

23.2 *Ductile-to-Brittle Transition Temperature*—Body-centered-cubic or ferritic alloys exhibit a significant change in behavior when impact tested over a range of temperatures. At elevated temperatures, impact specimens fracture by a shear mechanism absorbing large amounts of energy; at low temperatures they fracture brittlely by a cleavage mechanism absorbing little energy. The transition from one type of behavior to the other has been defined in various ways for specification purposes: (*1*) the temperature corresponding to a specific energy level; (*2*) the temperature at which Charpy V-notch specimens exhibit some specific value of cleavage (shiny, facetted appearance, often termed brittle or crystalline) and shear (often termed ductile or fibrous) fractures. This temperature is commonly called the fracture appearance transition temperature or $FATT_n$ where "n" is the percentage of shear fracture. $FATT_{50}$ is most frequently specified; (*3*) the temperature at which the lateral expansion (increase in specimen width on the compression side, opposite the notch, of the fractured Charpy V-notch specimen, Fig. 13) is some specified amount measured in thousandths of an inch (mils).

23.2.1 *Energy Level*—Energy level as determined on the Charpy V-notch impact test has been shown to have fairly good correlation with service failures and also with the nil-ductility transition temperature determined by the drop-weight test (Method E 208). Specific requirements should be based on material capability and either service experience or correlations with the drop weight test or other valid tests for fracture toughness. The test temperature must be specified.

23.2.2 *Fracture Appearance Transition Temperature, $FATT_n$:*

23.2.2.1 *Determination of Percent Shear Fracture*—The percentage of shear fracture may be determined by any of the following methods: (*1*) Measure the length and width of the cleavage portion of the fracture surface, as shown in Fig. 14, and determine the percent shear from either Table 4 or Table 5 depending on the units of measurement; (*2*) compare the appearance of the fracture of the specimen with a fracture appearance chart such as that shown in Fig. 15; (*3*) magnify the fracture surface and compare it to a precalibrated overlay chart or measure the percent shear fracture by means of a planimeter; or (*4*) photograph the fracture surface at a suitable magnification and measure the percent shear fracture by means of a planimeter.

23.2.2.2 *Determination of Transition Temperature*—For determining the transition temperature, break at least four specimens that have been taken from comparable locations. Break each specimen at a different temperature, but in a range of temperature that will produce fractures within the range of ±25 percent of the specified value, *n*, of shear. Plot the percent shear fracture against the test temperature and determine the transition by graphic interpolation (extrapolation is not permitted).

23.2.3 *Mils of Lateral Expansion:*

23.2.3.1 *Determination of Lateral Expansion*—The method for measuring lateral expansion must take into account the fact that the fracture path seldom bisects the point of maximum expansion on both sides of a specimen. One half of a broken specimen may include the maximum expansion for both sides, one side only, or neither. The technique used must therefore provide an expansion value equal to the sum of the higher of the two values obtained for each side by measuring the two halves separately. The amount of expansion on each side of each half must be measured relative to the plane defined by the undeformed portion of the side of the specimen. Expansion may be measured by using a gage similar to that shown in Figs. 16 and 17. Measure the two broken halves individually. First, though, check the sides perpendicular to the notch to ensure that no burrs were formed on these sides during impact testing; if such burrs exist, they must be removed, for example, by rubbing on emery cloth, making sure that the protrusions being measured are not rubbed during the removal of the burr. Next, place the halves together so that the compression sides are facing one another. Take one half and press it firmly against the reference supports, with the protrusion against the gage anvil. Note the reading, then repeat this step with the other broken half, ensuring that the same side of the specimen is measured. The larger of the two values is the expansion of that side of the specimen. Next, repeat this procedure to measure the protrusions on the opposite side, then add the larger values obtained for each side. Measure each specimen.

NOTE 10—Examine each fracture surface to ascertain that the protrusions have not been damaged by contacting the anvil, machine mounting surface, etc. Such samples should be discarded since this may cause erroneous readings.

23.2.3.2 *Determination of Transition Temperature*—For determining the transition temperature, break a sufficient number of specimens over a range of temperatures such that the temperature producing the specified lateral expansion may be determined by graphic interpolation (extrapolation is not permitted).

23.3 *Report*—Test reports shall include the test temperature and energy value (foot-pounds) for each test specimen broken. When specified in the product specification the percent shear fracture or mils of lateral expansion, or both, shall also be reported for each test specimen broken.

SUPPLEMENTS

I. STEEL BAR PRODUCTS

S1. Scope

S1.1 This supplement delineates only those details which are peculiar to hot-rolled and cold-finished steel bars and are not covered in the general section of these methods.

S2. Orientation of Test Specimens

S2.1 Carbon steel bars and bar-size shapes, due to their relatively small cross-sectional dimensions, are customarily tested in the longitudinal direction.

S2.2 Alloy steel bars and bar-size shapes are usually tested in the longitudinal direction. In special cases where size permits and the fabrication or service of a part justifies testing in a transverse direction, the selection and location of test or tests are a matter of agreement between the manufacturer and the purchaser.

S3. Tension Test

S3.1 *Carbon Steel Bars*—Carbon steel bars are not commonly specified to tensile requirements in the as-rolled condition for sizes of rounds, squares, hexagons, and octagons under $^1/_2$ in. (13 mm) in diameter or distance between parallel faces nor for other bar-size sections, other than flats, less than 1 in.^{2} (645 mm^2) in cross-sectional area.

S3.2 *Alloy Steel Bars*—Alloy steel bars are usually not tested in the as-rolled condition.

S3.3 When tension tests are specified, the recommended practice for selecting test specimens for hot-rolled and cold-finished steel bars of various sizes shall be in accordance with Table 7, unless otherwise specified.

S4. Bend Test

S4.1 When bend tests are specified, the recommended practice for hot-rolled and cold-finished steel bars shall be in accordance with Table 6.

II. STEEL TUBULAR PRODUCTS

S5. Scope

S5.1 This supplement covers definitions and methods of testing peculiar to tubular products which are not covered in the general section of these methods.

S6. Tension Test

S6.1 *Longitudinal Test Specimens:*

S6.1.1 It is standard practice to use tension test specimens of full-size tubular sections within the limit of the testing equipment (Fig. 20 (*d*)). Snug-fitting metal plugs should be inserted far enough in the end of such tubular specimens to permit the testing machine jaws to grip the specimens properly without crushing. A design that may be used for such plugs is shown in Fig. 18. The plugs shall not extend into that part of the specimen on which the elongation is measured (Fig. 18). Care should be exercised to see that insofar as practicable, the load in such cases is applied axially. The length of the full-section specimen depends on the gage length prescribed for measuring the elongation.

S6.1.2 Unless otherwise required by the individual product specification, the gage length for furnace-welded pipe is normally 8 in. (200 mm), except that for nominal sizes ¾ in. and smaller, the gage length shall be as follows:

Nominal Size, in.	Gage Length, in. (mm)
$^3/_4$ and $^1/_2$	6 (150)
$^3/_8$ and $^1/_4$	4 (100)
$^1/_8$	2 (50)

S6.1.3 For seamless and electric-welded pipe and tubes the gage length is 2 in. However, for tubing having an outside diameter of $^3/_8$ in. (10 mm) or less, it is customary to use a gage length equal to four times the outside diameter when elongation values comparable to larger specimens are required.

S6.1.4 To determine the cross-sectional area of the full-section specimen, measurements shall be recorded as the average or mean between the greatest and least measurements of the outside diameter and the average or mean wall thickness, to the nearest 0.001 in. (0.025 mm) and the cross-sectional area is determined by the following equation:

$$A = 3.1416t(D - t)$$

where:

A = sectional area, in.^{2}
D = outside diameter, in., and
t = thickness of tube wall, in.

NOTE 11—There exist other methods of cross-sectional area determination, such as by weighing of the specimens, which are equally accurate or appropriate for the purpose.

S6.2 *Longitudinal Strip Test Specimens:*

S6.2.1 For larger sizes of tubular products which cannot be tested in full-section, longitudinal test specimens are obtained from strips cut from the tube or pipe as indicated in Fig. 19. For furnace-welded tubes or pipe the 8-in. gage length specimen as shown in Fig. 20 (*b*), or with both edges parallel as in Fig. 20 (*a*) is standard, the specimen being located at approximately 90 deg from the weld. For seamless and electric-welded tubes or pipe, the 2-in. gage length specimen as shown in Fig. 20 (*c*) is standard, the specimen being located approximately 90 deg from the weld in the case of electric-welded tubes. The specimen shown in Fig. 20 (*a*) may be used as an alternate for seamless and electric-welded tubes or pipe. Specimens of the type shown in Fig. 20 (*a*), (*b*), (*c*), may be tested with grips having a surface contour corresponding to the curvature of the tubes. When grips with curved faces are not available, the ends of the specimens may be flattened without heating. Standard tension test specimens, as shown in specimen No. 4 of Fig. 21, are nominally $1^1/_2$ in. (38 mm) wide in the gage length section. When sub-size specimens are necessary due to the dimensions and character of the material to be tested, specimens 1, 2, or 3 shown in Fig. 21 where applicable, are considered standard. For tubes ¾ in. (19 mm) and over in wall thickness, the test specimen shown in Fig. 5 (Note 12) may be used.

NOTE 12—Standard round tension test specimen with 2-in. gage length.

S6.2.2 The width should be measured at each end of the gage length to determine parallelism and also at the center. The thickness should be measured at the center and used with the center measurement of the width to determine the cross-sectional area. The center width dimension should be recorded to the nearest 0.005 in. (0.127 mm), and the thickness measurement to the nearest 0.001 in. When the specimen shown in Fig. 5 (Note 12) is used, the diameter is measured at the center of the specimen to the nearest 0.001 in. (0.025 mm).

S6.3 *Transverse Test Specimens.*

S6.3.1 In general, transverse tension tests are not recommended for tubular products, in sizes smaller than 8 in. in nominal diameter. When required, transverse tension test specimens may be taken from rings cut from ends of tubes or pipe as shown in Fig. 22. Flattening of the specimen may be done either after separating it from the tube as in Fig. 22 (*a*), or before separating it as in Fig. 22 (*b*), and may be done hot or cold; but if the flattening is done cold, the specimen may subsequently be normalized. Specimens from tubes or pipe for which heat treatment is specified, after being flattened either hot or cold, shall be given the same treatment as the tubes or pipe. For tubes or pipe having a wall thickness of less than ¾ in. (19 mm), the transverse test specimen shall be of the form and dimensions shown in Fig. 23 and either or both surfaces may be machined to secure uniform thickness. For tubes having a sufficiently heavy wall thickness the test specimen shown in Fig. 5 (Note 12) may be used. The elongation requirements for the 2-in. gage length in the product specification shall apply to the gage length as specified in Fig. 5. Specimens for transverse tension tests on welded steel tubes or pipe to determine strength of welds, shall be located perpendicular to the welded seams with the weld at about the middle of their length.

S6.3.2 The width should be measured at each end of the gage length to determine parallelism and also at the center. The thickness should be measured at the center and used with the center measurement of the width to determine the cross-sectional area. The center width dimension should be recorded to the nearest 0.005 in. (0.127 mm), and the thickness measurement to the nearest 0.001 in. (0.025 mm). When the specimen shown in Fig. 5 (Note 12) is used, the diameter is measured at the center of the specimen to the nearest 0.001 in.

S7. Determination of Transverse Yield Strength, Hydraulic Ring-Expansion Method

S7.1 Until recently, the transverse yield strength, when required on tubular products, has been determined, as described in the general section of these methods, from standard tension test coupons cut transversely from the tubular sections. Due to the curvature on such coupons it is necessary to cold straighten them. It has long been recognized that the cold work introduced by straightening changes the mechanical properties so that the yield strength obtained is not truly representative of the yield strength in the original tubular section. The transverse yield strength is highly important on some classes of tubular products, such as line pipe, and a method for determining the true yield strength has been desirable for some time.

S7.2 A testing machine and method for determining the transverse yield strength from an annular ring specimen, have been developed and described in S7.3 through S7.5.

S7.3 A diagrammatic vertical cross-sectional sketch of the testing machine is shown in Fig. 24.

S7.4 In determining the transverse yield strength on this machine, a short ring (commonly 3 in. (76 mm) in length) test specimen is used. After the large circular nut is removed from the machine, the wall thickness of the ring specimen is determined and the specimen is telescoped over the oil resistant rubber gasket. The nut is then replaced, but is not turned down tight against the specimen. A slight clearance is left between the nut and specimen for the purpose of permitting free radial movement of the specimen as it is being tested. Oil under pressure is then admitted to the interior of the rubber gasket through the pressure line under the control of a suitable valve. An accurately calibrated pressure gage serves to measure oil pressure. Any air in the system is removed through the bleeder line. As the oil pressure is increased, the rubber gasket expands which in turn stresses the specimen circumferentially. As the pressure builds up, the lips of the rubber gasket act as a seal to prevent oil leakage. With continued increase in pressure, the ring specimen is subjected to a tension stress and elongates accordingly. The entire outside circumference of the ring specimen is considered as the gage length and the strain is measured with a suitable extensometer which will be described later. When the desired total strain or extension under load is reached on the extensometer, the oil pressure in pounds per square inch is read and by employing Barlow's formula, the unit yield strength is calculated. The yield strength, thus determined, is a true result since the test specimen has not been cold worked by flattening and closely approximates the same condition as the tubular section from which it is cut. Further, the test closely simulates service conditions in pipe lines. One testing machine unit may be used for several different sizes of pipe by the use of suitable rubber gaskets and adapters.

NOTE 13—Barlow's formula may be stated two ways:

(*1*) $P = 2St/D$

(*2*) $S = PD/2t$

where:

P = internal hydrostatic pressure, psi,
S = unit circumferential stress in the wall of the tube produced by the internal hydrostatic pressure, psi,
t = thickness of the tube wall, in., and
D = outside diameter of the tube, in.

S7.5 A roller chain type extensometer which has been found satisfactory for measuring the elongation of the ring specimen is shown in Figs. 25 and 26. Figure 25 shows the extensometer in position, but unclamped, on a ring specimen. A small pin, through which the strain is transmitted to and measured by the dial gage, extends through the hollow threaded stud. When the extensometer is clamped, as shown in Fig. 26, the desired tension which is necessary to hold the instrument in place and to remove any slack, is exerted on the roller chain by the spring. Tension on the spring may be regulated as desired by the knurled thumb screw. By removing or adding rollers, the roller chain may be adapted for different sizes of tubular sections.

S8. Hardness Tests

S8.1 Hardness tests are made either on the outside or the inside surfaces on the end of the tube as appropriate.

S8.2 The standard 3000-kgf Brinell load may cause too much deformation in a thin-walled tubular specimen. In this case the 500-kgf load shall be applied, or inside stiffening by means of an internal anvil should be used. Brinell testing shall not be applicable to tubular products less than 2 in. (51 mm) in outside diameter, or less than 0.200 in. (5.1 mm) in wall thickness.

S8.3 The Rockwell hardness tests are normally made on the inside surface, a flat on the outside surface, or on the wall cross-section depending upon the product limitation. Rockwell hardness tests are not performed on tubes smaller than $^5/_{16}$ in. (7.9 mm) in outside diameter, nor are they performed on the inside surface of tubes with less than $^1/_4$ in. (6.4 mm) inside diameter. Rockwell hardness tests are not performed on annealed tubes with walls less than 0.065 in. (1.65 mm) thick or cold worked or heat treated tubes with walls less than 0.049 in. (1.24 mm) thick. For tubes with wall thicknesses less than those permitting the regular Rockwell hardness test, the Superficial Rockwell test is sometimes substituted. Transverse Rockwell hardness readings can be made on tubes with a wall thickness of 0.187 in. (4.75 mm) or greater. The curvature and the wall thickness of the specimen impose limitations on the Rockwell hardness test. When a comparison is made between Rockwell determinations made on the outside surface and determinations made on the inside surface, adjustment of the readings will be required to compensate for the effect of curvature. The Rockwell B scale is used on all materials having an expected hardness range of B 0 to B 100. The Rockwell C scale is used on material having an expected hardness range of C 20 to C 68.

S8.4 Superficial Rockwell hardness tests are normally performed on the outside surface whenever possible and whenever excessive spring back is not encountered. Otherwise, the tests may be performed on the inside. Superficial Rockwell hardness tests shall not be performed on tubes with an inside diameter of less than ¼ in. (6.4 mm). The wall thickness limitations for the Superficial Rockwell hardness test are given in Tables 8 and 9.

S8.5 When the outside diameter, inside diameter, or wall thickness precludes the obtaining of accurate hardness values, tubular products shall be specified to tensile properties and so tested.

S9. Manipulating Tests

S9.1 The following tests are made to prove ductility of certain tubular products:

S9.1.1 *Flattening Test*—The flattening test as commonly made on specimens cut from tubular products is conducted by subjecting rings from the tube or pipe to a prescribed degree of flattening between parallel plates (Fig. 22). The severity of the flattening test is measured by the distance between the parallel plates and is varied according to the dimensions of the tube or pipe. The flattening test specimen should not be less than $2^1/_2$ in. (63.5 mm) in length and should be flattened cold to the extent required by the applicable material specifications.

S9.1.2 *Reverse Flattening Test*—The reverse flattening test is designed primarily for application to electric-welded tubing for the detection of lack of penetration or overlaps resulting from flash removal in the weld. The specimen consists of a length of tubing approximately 4 in. (102 mm) long which is split longitudinally 90 deg on each side of the weld. The sample is then opened and flattened with the weld at the point of maximum bend (Fig. 27).

S9.1.3 *Crush Test*—The crush test, sometimes referred to as an upsetting test, is usually made on boiler and other pressure tubes, for evaluating ductility (Fig. 28). The specimen is a ring cut from the tube, usually about 2½ in. (63.5 mm) long. It is placed on end and crushed endwise by hammer or press to the distance prescribed by the applicable material specifications.

S9.1.4 *Flange Test*—The flange test is intended to determine the ductility of boiler tubes and their ability to withstand the operation of bending into a tube sheet. The test is made on a ring cut from a tube, usually not less than 4 in. (100 mm) long and consists of having a flange turned over at right angles to the body of the tube to the width required by the applicable material specifications. The flaring tool and die block shown in Fig. 29 are recommended for use in making this test.

S9.1.5 *Flaring Test*—For certain types of pressure tubes, an alternate to the flange test is made. This test consists of driving a tapered mandrel having a slope of 1 in 10 as shown in Fig. 30 (*a*) or a 60 deg included angle as shown in Fig. 30 (*b*) into a section cut from the tube, approximately 4 in. (100 mm) in length, and thus expanding the specimen until the inside diameter has been increased to the extent required by the applicable material specifications.

S9.1.6 *Bend Test*—For pipe used for coiling in sizes 2 in. and under a bend test is made to determine its ductility and the soundness of weld. In this test a sufficient length of full-size pipe is bent cold through 90 deg around a cylindrical mandrel having a diameter 12 times the nominal diameter of the pipe. For close coiling, the pipe is bent cold through 180 deg around a mandrel having a diameter 8 times the nominal diameter of the pipe.

S9.1.7 *Transverse Guided Bend Test of Welds*—This bend test is used to determine the ductility of fusion welds. The specimens used are approximately $1^1/_2$ in. (38 mm) wide, at least 6 in. (152 mm) in length with the weld at the center, and are machined in accordance with Fig. 31(*a*) for face and root bend tests and in accordance with Fig. 31(*b*) for side bend tests. The dimensions of the plunger shall be as shown in Fig. 32 and the other dimensions of the bending jig shall be substantially as given in this same figure. A test shall consist of a face bend specimen and a root bend specimen or two side bend specimens. A face bend test requires bending with the inside surface of the pipe against the plunger; a root bend test requires bending with the outside surface of the pipe against the plunger; and a side bend test requires bending so that one of the side surfaces becomes the convex surface of the bend specimen.

S9.1.7.1 Failure of the bend test depends upon the appearance of cracks in the area of the bend, of the nature and extent described in the product specifications.

III. STEEL FASTENERS

S10. Scope

S10.1 This supplement covers definitions and methods of testing peculiar to steel fasteners which are not covered in the general section of Methods A 370. Standard tests required by the individual product specifications are to be performed as outlined in the general section of these methods.

S10.2 These tests are set up to facilitate production control testing and acceptance testing with certain more precise tests to be used for arbitration in case of disagreement over test results.

S11. Tension Tests

S11.1 It is preferred that bolts be tested full size, and it is customary, when so testing bolts to specify a minimum ultimate load in pounds, rather than a minimum ultimate strength in pounds per square inch. Three times the bolt nominal diameter has been established as the minimum bolt length subject to the tests described in the remainder of this section. Sections S11.1.1 through S11.1.3 apply when testing bolts full size. Section S11.1.4 shall apply where the individual product specifications permit the use of machined specimens.

S11.1.1 *Proof Load*—Due to particular uses of certain classes of bolts it is desirable to be able to stress them, while in use, to a specified value without obtaining any permanent set. To be certain of obtaining this quality the proof load is specified. The proof load test consists of stressing the bolt with a specified load which the bolt must withstand without permanent set. An alternate test which determines yield strength of a full size bolt is also allowed. Either of the following Methods, 1 or 2, may be used but Method 1 shall be the arbitration method in case of any dispute as to acceptance of the bolts.

S11.1.2 *Proof Load Testing Long Bolts*—When full size tests are required, proof load Method 1 is to be limited in application to bolts whose length does not exceed 8 in. (203 mm) or 8 times the nominal diameter, whichever is greater. For bolts longer than 8 in. or 8 times the nominal diameter, whichever is greater, proof load Method 2 shall be used.

S11.1.2.1 *Method 1, Length Measurement*—The overall length of a straight bolt shall be measured at its true center line with an instrument capable of measuring changes in length of 0.0001 in. (0.0025 mm) with an accuracy of 0.0001 in. in any 0.001-in. (0.025-mm) range. The preferred method of measuring the length shall be between conical centers machined on the center line of the bolt, with mating centers on the measuring anvils. The head or body of the bolt shall be marked so that it can be placed in the same position for all measurements. The bolt shall be assembled in the testing equipment as outlined in S11.1.4, and the proof load specified in the product specification shall be applied. Upon release of this load the length of the bolt shall be again measured and shall show no permanent elongation. A tolerance of ±0.0005 in. (0.0127 mm) shall be allowed between the measurement made before loading and that made after loading. Variables, such as straightness and thread alignment (plus measurement error), may result in apparent elongation of the fasteners when the proof load is initially applied. In such cases, the fastener may be retested using a 3 percent greater load, and may be considered satisfactory if the length after this loading is the same as before this loading (within the 0.0005-in. tolerance for measurement error).

S11.1.3 *Proof Load-Time of Loading*—The proof load is to be maintained for a period of 10 s before release of load, when using Method 1.

S11.1.3.1 *Method 2, Yield Strength*—The bolt shall be assembled in the testing equipment as outlined in S11.1.4. As the load is applied, the total elongation of the bolt or any part of the bolt which includes the exposed six threads shall be measured and recorded to produce a load-strain or a stress-strain diagram. The load or stress at an offset equal to 0.2 percent of the length of bolt occupied by 6 full threads shall be determined by the method described in 13.2.1 of these methods, A 370. This load or stress shall not be less than that prescribed in the product specification.

S11.1.4 *Axial Tension Testing of Full Size Bolts*—Bolts are to be tested in a holder with the load axially applied between the head and a nut or suitable fixture (Fig. 33), either of which shall have sufficient thread engagement to develop the full strength of the bolt. The nut or fixture shall be assembled on the bolt leaving six complete bolt threads unengaged between the grips, except for heavy hexagon structural bolts which shall have four complete threads unengaged between the grips. To meet the requirements of this test there shall be a tensile failure in the body or threaded section with no failure at the junction of the body and head. If it is necessary to record or report the tensile strength of bolts as psi values the stress area shall be calculated from the mean of the mean root and pitch diameters of Class 3 external threads as follows:

$$A_s = 0.7854\,(D - (0.9743)/n)^2$$

where:

A_s = stress area, in.^{2},
D = nominal diameter, in., and
n = number of threads per inch.

S11.1.5 *Tension Testing of Full-Size Bolts with a Wedge*—The purpose of this test is to obtain the tensile strength and demonstrate the "head quality" and ductility of a bolt with a standard head by subjecting it to eccentric loading. The ultimate load on the bolt shall be determined as described in S11.1.4, except that a 10-deg wedge shall be placed under the same bolt previously tested for the proof load (see S11.1.1). The bolt head shall be so placed that no corner of the hexagon or square takes a bearing load, that is, a flat of the head shall be aligned with the direction of uniform thickness of the wedge (Fig. 34). The wedge shall have an included angle of 10 deg between its faces and shall have a thickness of one-half of the nominal bolt diameter at the short side of the hole. The hole in the wedge shall have the following clearance over the nominal size of the bolt, and its edges, top and bottom, shall be rounded to the following radius:

Nominal Bolt Size, in.	Clearance in Hole, in. (mm)	Radius on Corners of Hole, in. (mm)
$^1/_4$ to $^1/_2$	0.030 (0.76)	0.030 (0.76)
$^9/_{16}$ to $^3/_4$	0.050 (1.3)	0.060 (1.5)
$^7/_8$ to 1	0.063 (1.5)	0.060 (1.5)
$1^1/_8$ to $1^1/_4$	0.063 (1.5)	0.125 (3.2)
$1^3/_8$ to $1^1/_2$	0.094 (2.4)	0.125 (3.2)

S11.1.6 *Wedge Testing of HT Bolts Threaded to Head*—For heat-treated bolts over 100 000 psi (690 MPa) minimum tensile strength and that are threaded 1 diameter and closer to the underside of the head, the wedge angle shall be 6 deg for sizes ¼ through ¾ in. (6.35 to 19.0 mm) and 4 deg for sizes over ¾ in.

S11.1.7 *Tension Testing of Bolts Machined to Round Test Specimens:*

S11.1.7.1 Bolts under 1½ in. (38 mm) in diameter which require machined tests shall use a standard ½-in., (13 mm) round 2-in. (51-mm) gage length test specimen, turned concentric with the axis of the bolt, leaving the head and threaded section intact as in Fig. 35. Bolts of small cross-section which will not permit taking this standard test specimen shall have a turned section as large as feasible and concentric with the axis of the bolt. The gage length for measuring the elongation shall be four times the diameter of the specimen. Figure 36 illustrates examples of these small size specimens.

S11.1.7.2 For bolts 1½ in. and over in diameter, a standard ½-in. round 2-in. gage length test specimen shall be turned from the bolt, having its axis midway between the center and outside surface of the body of the bolt as shown in Fig. 37.

S11.1.7.3 Machined specimens are to be tested in tension to determine the properties prescribed by the product specifications. The methods of testing and determination of properties shall be in accordance with Section 13 of these methods, A 370.

S12. Speed of Testing

S12.1 Speed of testing shall be as prescribed in the individual product specifications.

S13. Hardness Tests for Bolts

S13.1 When specified, the bolts shall meet a hardness test. The Brinell or Rockwell hardness test is usually taken on the side or top of the bolt head. For final arbitration the hardness shall be taken on a transverse section through the threaded section of the bolt at a point one-quarter of the nominal diameter from the axis of the bolt. This section shall be taken at a distance from the end of the bolt which is equivalent to the diameter of the bolt. Due to possible distortion from the Brinell load, care shall be taken to see that this test meets all the provisions of 17.2 of the general section of these methods. Where the Brinell hardness test is impractical, the Rockwell hardness test shall be substituted. Rockwell hardness test procedures shall conform to Section 18 of these methods.

S14. Testing of Nuts

S14.1 *Proof Load*—A sample nut shall be assembled on a hardened threaded mandrel or on a bolt conforming to the particular specification. A load axial with the mandrel or bolt and equal to the specified proof load of the nut shall be applied. The nut shall resist this load without stripping or rupture. If the threads of the mandrel are damaged during the test the individual test shall be discarded. The mandrel shall be threaded to American National Standard Class 3 tolerance, except that the major diameter shall be the minimum major diameter with a tolerance of +0.002 in. (0.051 mm).

S14.2 *Hardness Test*—Rockwell hardness of nuts shall be determined on the top or bottom face of the nut. Brinell hardness shall be determined on the side of the nuts. Either method may be used at the option of the manufacturer, taking into account the size and grade of the nuts under test. When the standard Brinell hardness test results in deforming the nut it will be necessary to use a minor load or substitute a Rockwell hardness test.

S15. Bars Heat Treated or Cold Drawn for Use in the Manufacture of Studs, Nuts or Other Bolting Material

S15.1 When the bars as received by the manufacturer have been processed and proved to meet certain specified properties, it is not necessary to test the finished product when these properties have not been changed by the process of manufacture employed for the finished product.

IV. ROUND WIRE PRODUCTS

S16. Scope

S16.1 This supplement covers the apparatus, specimens and methods of testing peculiar to steel wire products which are not covered in the general section of Methods A 370.

ASTM Logo Removed

S17. Apparatus

S17.1 *Gripping Devices*—Grips of either the wedge or snubbing types as shown in Figs. 38 and 39 shall be used (Note 14). When using grips of either type, care shall be taken that the axis of the test specimen is located approximately at the center line of the head of the testing machine (Note 15). When using wedge grips the liners used behind the grips shall be of the proper thickness.

NOTE 14—Testing machines usually are equipped with wedge grips. These wedge grips, irrespective of the type of testing machine, may be referred to as the "usual type" of wedge grips. The usual type of wedge grips generally furnish a satisfactory means of gripping wire. For tests of specimens of wire which are liable to be cut at the edges by the "usual type" of wedge grips, the snubbing type gripping device has proved satisfactory.

For testing round wire, the use of cylindrical seat in the wedge gripping device is optional.

NOTE 15—Any defect in a testing machine which may cause nonaxial application of load should be corrected.

S17.2 *Pointed Micrometer*—A micrometer with a pointed spindle and anvil suitable for reading the dimensions of the wire specimen at the fractured ends to the nearest 0.001 in. (0.025 mm) after breaking the specimen in the testing machine shall be used.

S18. Test Specimens

S18.1 Test specimens having the full cross-sectional area of the wire they represent shall be used. The standard gage length of the specimens shall be 10 in. (254 mm). However, if the determination of elongation values is not required, any convenient gage length is permissible. The total length of the specimens shall be at least equal to the gage length (10 in.) plus twice the length of wire required for the full use of the grip employed. For example, depending upon the type of testing machine and grips used, the minimum total length of specimen may vary from 14 to 24 in. (360 to 610 mm) for a 10-in. gage length specimen.

S18.2 Any specimen breaking in the grips shall be discarded and a new specimen tested.

S19. Elongation

S19.1 In determining permanent elongation, the ends of the fractured specimen shall be carefully fitted together and the distance between the gage marks measured to the nearest 0.01 in. (0.25 mm) with dividers and scale or other suitable device. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In reporting elongation values, both the percentage increase and the original gage length shall be given.

S19.2 In determining total elongation (elastic plus plastic extension) autographic or extensometer methods may be employed.

S19.3 If fracture takes place outside of the middle third of the gage length, the elongation value obtained may not be representative of the material.

S20. Reduction of Area

S20.1 The ends of the fractured specimen shall be carefully fitted together and the dimensions of the smallest cross section measured to the nearest 0.001 in. (0.025 mm) with a pointed micrometer. The difference between the area thus found and the area of the original cross section, expressed as a percentage of the original area, is the reduction of area.

S20.2 The reduction of area test is not recommended in wire diameters less than 0.092 in. (2.34 mm) due to the difficulties of measuring the reduced cross sections.

S21. Rockwell Hardness Test

S21.1 With the exception of heat treated wire of diameter 0.100 in. (2.54 mm) and larger, the Rockwell hardness test is not recommended for round wire. On such heat-treated wire the specimen shall be flattened on two parallel sides by grinding. For round wire the tensile strength test is greatly to be preferred to the Rockwell hardness test.

S22. Wrapping Test

S22.1 This test, also referred to as a coiling test or as a wrap-around bend test, is sometimes used as a means for testing the ductility of certain kinds of wire. The wrapping may be done by any hand or power device that will coil the wire closely about a mandrel of the specified diameter for a required number of turns without damage to the wire surface. The sample shall be considered to have failed if any cracks occur in the wire after the first complete turn. The test shall be repeated if a crack occurs in the first turn since the wire may have been bent locally to a radius less than that specified.

S22.2 When the wrapping test is used to determine the adherence of coating for coated wires, the mandrel diameter is commonly larger than that used in the test when used as a measure of ductility.

V. NOTES ON SIGNIFICANCE OF NOTCHED-BAR IMPACT TESTING

S23. Notch Behavior

S23.1 The Charpy and Izod type tests bring out notch behavior (brittleness versus ductility) by applying a single overload of stress. The energy values determined are quantitative comparisons on a selected specimen but cannot be converted into energy values that would serve for engineering design calculations. The notch behavior indicated in an individual test applies only to the specimen size, notch geometry, and testing conditions involved and cannot be generalized to other sizes of specimens and conditions.

S23.2 The notch behavior of the face-centered cubic metals and alloys, a large group of nonferrous materials and the austenitic steels can be judged from their common tensile properties. If they are brittle in tension they will be brittle when notched, while if they are ductile in tension, they will be ductile when notched, except for unusually sharp or deep notches (much more severe than the standard Charpy or Izod specimens). Even low temperatures do not alter this characteristic of these materials. In contrast, the behavior of the ferritic steels under notch conditions cannot be predicted from their properties as revealed by the tension test. For the study of these materials the Charpy and Izod type tests are accordingly very useful. Some metals that display normal ductility in the tension test may nevertheless break in brittle fashion when tested or when used in the notched condition. Notched conditions include restraints to deformation in directions perpendicular to the major stress, or multiaxial stresses, and stress concentrations. It is in this field that the Charpy and Izod tests prove useful for determining the susceptibility of a steel to notch-brittle behavior though they cannot be directly used to appraise the serviceability of a structure.

S23.3 The testing machine itself must be sufficiently rigid or tests on high-strength low-energy materials will result in excessive elastic energy losses either upward through the pendulum shaft or downward through the base of the machine. If the anvil supports, the pendulum striking edge, or the machine foundation bolts are not securely fastened, tests on ductile materials in the range of 80 ft·lbf (108 J) may actually indicate values in excess of 90 to 100 ft·lbf (122 to 136 J).

S24. Notch Effect

S24.1 The notch results in a combination of multiaxial stresses associated with restraints to deformation in directions perpendicular to the major stress, and a stress concentration at the base of the notch. A severely notched condition is generally not desirable, and it becomes of real concern in those cases in which it initiates a sudden and complete failure of the brittle type. Some metals can be deformed in a ductile manner even down to the low temperatures of liquid air, while others may crack. This difference in behavior can be best understood by considering the cohesive strength of a material (or the property that holds it together) and its relation to the yield point. In cases of brittle fracture, the cohesive strength is exceeded before significant plastic deformation occurs and the fracture appears crystalline. In cases of the ductile or shear type of failure, considerable deformation precedes the final fracture and the broken surface appears fibrous instead of crystalline. In intermediate cases the fracture comes after a moderate amount of deformation and is part crystalline and part fibrous in appearance.

S24.2 When a notched bar is loaded, there is a normal stress across the base of the notch which tends to initiate fracture. The property that keeps it from cleaving, or holds it together, is the "cohesive strength." The bar fractures when the normal stress exceeds the cohesive strength. When this occurs without the bar deforming it is the condition for brittle fracture.

S24.3 In testing, though not in service because of side effects, it happens more commonly that plastic deformation precedes fracture. In addition to the normal stress, the applied load also sets up shear stresses which are about 45 deg to the normal stress. The elastic behavior terminates as soon as the shear stress exceeds the shear strength of the material and deformation or plastic yielding sets in. This is the condition for ductile failure.

S24.4 This behavior, whether brittle or ductile, depends on whether the normal stress exceeds the cohesive strength before the shear stress exceeds the shear strength. Several important facts of notch behavior follow from this. If the notch is made sharper or more drastic, the normal stress at the root of the notch will be increased in relation to the shear stress and the bar will be more prone to brittle fracture (see Table 10). Also, as the speed of deformation increases, the shear strength increases and the likelihood of brittle fracture increases. On the other hand, by raising the temperature, leaving the notch and the speed of deformation the same, the shear strength is lowered and ductile behavior is promoted, leading to shear failure.

S24.5 Variations in notch dimensions will seriously affect the results of the tests. Tests on E4340 steel specimens[9] have shown the effect of dimensional variations on Charpy results (see Table 10).

S25. Size Effect

S25.1 Increasing either the width or the depth of the specimen tends to increase the volume of metal subject to distortion, and by this factor tends to increase the energy absorption when breaking the specimen. However, any increase in size, particularly in width, also tends to increase the degree of restraint and by tending to induce brittle fracture, may decrease the amount of energy absorbed. Where a standard-size specimen is on the verge of brittle fracture, this is particularly true, and a double-width specimen may actually require less energy for rupture than one of standard width.

S25.2 In studies of such effects where the size of the material precludes the use of the standard specimen, as for example when the material is $^1/_4$-in. plate, subsize specimens are necessarily used. Such specimens (see Fig. 6 of Method E 23) are based on the Type A specimen of Fig. 4 of Method E 23.

S25.3 General correlation between the energy values obtained with specimens of different size or shape is not feasible, but limited correlations may be established for specification purposes on the basis of special studies of particular materials and particular specimens. On the other hand, in a study of the relative effect of process variations, evaluation by use of some arbitrarily selected specimen with some chosen notch will in most instances place the methods in their proper order.

S26. Effects of Testing Conditions

S26.1 The testing conditions also affect the notch behavior. So pronounced is the effect of temperature on the behavior of steel when notched that comparisons are frequently made by examining specimen fractures and by plotting energy value and fracture appearance versus temperature from tests of notched bars at a series of temperatures. When the test temperature has been carried low enough to start cleavage fracture, there may be an extremely sharp drop in impact value or there may be a relatively gradual falling off toward the lower temperatures. This drop in energy value starts when a specimen begins to exhibit some crystalline appearance in the fracture. The transition temperature at which this embrittling effect takes place varies considerably with the size of the part or test specimen and with the notch geometry.

S26.2 Some of the many definitions of transition temperature currently being used are: (*1*) the lowest temperature at which the specimen exhibits 100 percent fibrous fracture, (*2*) the temperature where the fracture shows a 50 percent crystalline and a 50 percent fibrous appearance, (*3*) the temperature corresponding to the energy value 50 percent of the difference between values obtained at 100 percent and 0 percent fibrous fracture,

[9] Fahey, N. H., "Effects of Variables in Charpy Impact Testing," *Materials Research & Standards*, MTRSA Vol 1, No. 11, Nov., 1961, p. 872.

and (4) the temperature corresponding to a specific energy value.

S26.3 A problem peculiar to Charpy-type tests occurs when high-strength, low-energy specimens are tested at low temperatures. These specimens may not leave the machine in the direction of the pendulum swing but rather in a sidewise direction. To ensure that the broken halves of the specimens do not rebound off some component of the machine and contact the pendulum before it completes its swing, modifications may be necessary in older model machines. These modifications differ with machine design. Nevertheless the basic problem is the same in that provisions must be made to prevent rebounding of the fractured specimens into any part of the swinging pendulum. Where design permits, the broken specimens may be deflected out of the sides of the machine and yet in other designs it may be necessary to contain the broken specimens within a certain area until the pendulum passes through the anvils. Some low-energy high-strength steel specimens leave impact machines at speeds in excess of 50 ft (15.3 m)/s although they were struck by a pendulum traveling at speeds approximately 17 ft (5.2 m)/s. If the force exerted on the pendulum by the broken specimens is sufficient, the pendulum will slow down and erroneously high energy values will be recorded. This problem accounts for many of the inconsistencies in Charpy results reported by various investigators within the 10 to 25-ft·lbf (14 to 34 J) range. Section 5.5 of Methods E 23 discusses the two basic machine designs and a modification found to be satisfactory in minimizing jamming.

S27. Velocity of Straining

S27.1 Velocity of straining is likewise a variable that affects the notch behavior of steel. The impact test shows somewhat higher energy absorption values than the static tests above the transition temperature and yet, in some instances, the reverse is true below the transition temperature.

S28. Correlation with Service

S28.1 While Charpy or Izod tests may not directly predict the ductile or brittle behavior of steel as commonly used in large masses or as components of large structures, these tests can be used as acceptance tests of identity for different lots of the same steel or in choosing between different steels, when correlation with reliable service behavior has been established. It may be necessary to make the tests at properly chosen temperatures other than room temperature. In this, the service temperature or the transition temperature of full-scale specimens does not give the desired transition temperatures for Charpy or Izod tests since the size and notch geometry may be so different. Chemical analysis, tension, and hardness tests may not indicate the influence of some of the important processing factors that affect susceptibility to brittle fracture nor do they comprehend the effect of low temperatures in inducing brittle behavior.

VI. PROCEDURE FOR CONVERTING PERCENTAGE ELONGATION OF A STANDARD ROUND TENSION TEST SPECIMEN TO EQUIVALENT PERCENTAGE ELONGATION OF A STANDARD FLAT SPECIMEN

S29. Scope

S29.1 This method specifies a procedure for converting percentage elongation after fracture obtained in a standard 0.500-in. (12.7 mm) diameter by 2-in. (51-mm) gage length test specimen to standard flat test specimens $^1/_2$ in. by 2 in. and $1^1/_2$ in. by 8 in. (38.1 by 203 mm).

S30. Basic Equation

S30.1 The conversion data in this method are based on an equation by Bertella,[10] and used by Oliver[11] and others. The relationship between elongations in the standard 0.500-in. diameter by 2.0-in. test specimen and other standard specimens can be calculated as follows:

$$e = e_o\,(4.47\,\sqrt{A}/L)^a$$

[10] Bertella, C. A., *Giornale del Genio Civile,* Vol 60, 1922, p. 343.

[11] Oliver, D. A., *Proceedings of Institute of Mechanical Engineers,* Vol 11, 1928, p. 827.

where:

e_o = percentage elongation after fracture on a standard test specimen having a 2-in. gage length and 0.500-in. diameter,

e = percentage elongation after fracture on a standard test specimen having a gage length L and a cross-sectional area A, and

a = constant characteristic of the test material.

S31. Application

S31.1 In applying the above equation the constant a is characteristic of the test material. The value a = 0.4 has been found to give satisfactory conversions for carbon, carbon-manganese, molybdenum, and chromium-molybdenum steels within the tensile strength range of 40,000 to 85,000 psi (275 to 585 MPa) and in the hot-rolled, in the hot-rolled and normalized, or in the annealed condition, with or without tempering. Note that the cold reduced and quenched and tempered states are excluded. For annealed austenitic stainless steels, the value a = 0.127 has been found to give satisfactory conversions.

S31.2 Table 11 has been calculated taking a = 0.4, with the standard 0.500-in. (12.7 mm) diameter by 2-in. (51 mm) gage length test specimen as the reference specimen. In the case of the subsize specimens 0.350 in. (8.89 mm) in diameter by 1.4 in. (35.6 mm) gage length, and 0.250 (6.35 mm) diameter by 1.0 in. (25.4 mm) gage length the factor in the equation is 4.51 instead of 4.37. The small error introduced by using Table 11 for the subsized specimens may be neglected. Table 12 for annealed austenitic steels has been calculated taking a = 0.127, with the standard 0.500-in. diameter by 2-in. gage length test specimen as the reference specimen.

S31.3 Elongation given for a standard 0.500-in. diameter by 2-in. gage length specimen may be converted to elongation for $^1/_2$ in. by 2 in. or $1^1/_2$ in. by 8 in. (38.1 by 203 mm) flat specimens by multiplying by the indicated factor in Tables 11 and 12.

S31.4 These elongation conversions shall not be used where the width to thickness ratio of the test piece exceeds 20, as in sheet specimens under 0.025 in. (0.635 mm) in thickness.

S31.5 While the conversions are considered to be reliable within the stated limitations and may generally be used in specification writing where it is desirable to show equivalent elongation requirements for the several standard ASTM tension specimens covered in Methods A 370, consideration must be given to the metallurgical effects dependent on the thickness of the material as processed.

VII. METHOD OF TESTING UNCOATED SEVEN-WIRE STRESS-RELIEVED STRAND FOR PRESTRESSED CONCRETE

S32. Scope

S32.1 This method provides procedures for the tension testing of uncoated seven-wire stress-relieved strand for prestressed concrete. This method is intended for use in evaluating the strand for the properties prescribed in Specification A 416.

S33. General Precautions

S33.1 Premature failure of the test specimens may result if there is any appreciable notching, cutting, or bending of the specimen by the gripping devices of the testing machine.

S33.2 Errors in testing may result if the seven wires constituting the strand are not loaded uniformly.

S33.3 The mechanical properties of the strand may be materially affected by excessive heating during specimen preparation.

S33.4 These difficulties may be minimized by following the suggested methods of gripping described in Section S35.

S34. Gripping Devices

S34.1 The true mechanical properties of the strand are determined by a test in which fracture of the specimen occurs in the free span between the jaws of the testing machine. Therefore, it is desirable to establish a test procedure with suitable apparatus which will consistently produce such results. Due to inherent physical characteristics of individual machines, it is not practical to recommend a universal gripping procedure that is suitable for all testing machines. Therefore, it is necessary to determine which of the methods of gripping described in S34.2 to S34.8 is most suitable for the testing equipment available.

S34.2 *Standard V-Grips with Serrated Teeth* (*Note 16*).

S34.3 *Standard V-Grips with Serrated Teeth* (*Note 16*), *Using Cushioning Material*—In this method, some material is placed between the grips and the specimen to minimize the notching effect of the teeth. Among the materials which have been used are lead foil, aluminum foil, carborundum cloth, bra shims, etc. The type and thickness of material required is dependent on the shape, condition, and coarseness of the teeth.

S34.4 *Standard V-Grips with Serrated Teeth* (*Note 16*), *Using Special Preparation of the Gripped Portions of the Specimen*—One of the methods used is tinning, in which the gripped portions are cleaned, fluxed, and coated by multiple dips in molten tin alloy held just above the melting point. Another method of preparation is encasing the gripped portions in metal tubing or flexible conduit, using epoxy resin as the bonding agent. The encased portion should be approximately twice the length of lay of the strand.

S34.5 *Special Grips with Smooth, Semi-Cylindrical Grooves* (*Note 17*)—The grooves and the gripped portions of the specimen are coated with an abrasive slurry which holds the specimen in the smooth grooves, preventing slippage. The slurry consists of abrasive such as Grade 3-F aluminum oxide and a carrier such as water or glycerin.

S34.6 *Standard Sockets of the Type Used for Wire Rope*—The gripped portions of the specimen are anchored in the sockets with zinc. The special procedures for socketing usually employed in the wire rope industry must be followed.

S34.7 *Dead-End Eye Splices*—These devices are available in sizes designed to fit each size of strand to be tested.

S34.8 *Chucking Devices*—Use of chucking devices of the type generally employed for applying tension to strands in casting beds is not recommended for testing purposes.

NOTE 16—The number of teeth should be approximately 15 to 30 per in., and the minimum effective gripping length should be approximately 4 in. (102 mm).

NOTE 17—The radius of curvature of the grooves is approximately the same as the radius of the strand being tested, and is located 1/32 in. (0.79 mm) above the flat face of the grip. This prevents the two grips from closing tightly when the specimen is in place.

S35. Specimen Preparation

S35.1 Nonuniform loading of the seven wires in the strand may result if slippage of the individual wires of the strand, either the outside wire or the center wire, occur during the tension test. Wire slippage may be minimized by fusing together the cut ends of the specimen. This fusing can be concurrent with torch cutting of the specimens.

S35.2 If the molten-metal temperatures employed during hot-dip tinning or socketing with metallic material are too high, over approximately 700 F (370 C), the specimen may be heat affected with a subsequent loss of strength and ductility. Careful temperature controls should be maintained if such methods of specimen preparation are used.

S36. Procedure

S36.1 *Yield Strength*—For determining the yield strength use a Class B-1 extensometer (Note 18) as described in Method E 83. Apply an initial load of 10 percent of the expected minimum breaking strength to the specimen, then attach the extensometer and adjust it to a reading of 0.001 in./in. of gage length. Then increase the load until the extensometer indicates an extension of 1 percent. Record the load for this extension as the yield strength. The extensometer may be removed from the specimen after the yield strength has been determined.

S36.2 *Elongation*—For determining the elongation use a Class D extensometer (Note 18), as described in Method E 83, having a gage length of not less than 24 in. (610 mm) (Note 19). Apply an initial load of 10 percent of the required minimum breaking strength to the specimen, then attach the extensometer (Note 18) and adjust it to a zero reading. The extensometer may be removed from the specimen prior to rupture after the specified minimum elongation has been exceeded. It is not necessary to determine the final elongation value.

S36.3 *Breaking Strength*—Determine the maximum load at which one or more wires of the strand are fractured. Record this load as the breaking strength of the strand.

NOTE 18—The yield-strength extensometer and the elongation extensometer may be the same instrument or two separate instruments. Two separate instruments are advisable since the more sensitive yield-strength extensometer, which could be damaged when the strand fractures, may be removed following the determination of yield strength. The elongation extensometer may be constructed with less sensitive parts or be constructed in such a way that little damage would result if fracture occurs while the extensometer is attached to the specimen.

NOTE 19—Specimens that break outside the extensometer or in the jaws and yet meet the minimum specified values are considered as meeting the mechanical property requirements of the product Specification A 416, regardless of what procedure of gripping has been used. Specimens that break outside of the extensometer or in the jaws and do not meet the minimum specified values are subject to retest in accordance with Specification A 416. Specimens that break between the jaws of the extensometer and do not meet the minimum specified values are subject to retest as provided in Section 14 of Specification A 416.

VIII. ROUNDING OF TEST DATA

S37. Rounding

S37.1 Recommended levels for rounding reported values of test data are given in Table 13. These values are designed to provide uniformity in reporting and data storage, and should be used in all cases except where they conflict with specific requirements of a product specification.

TABLE 1 Details of Test Coupon Design for Casting (See Fig. 3)

NOTE 1—*Test Coupons for Large and Heavy Steel Castings:* The test coupons in Fig. 3 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired. This provision does not apply to ASTM Specification A 356, for Heavy-Walled Carbon and Low Alloy Steel Castings for Steam Turbines (*Annual Book of ASTM Standards*, Vol 01.02).

NOTE 2—*Bend Bar:* If a bend bar is required, an alternate design (as shown by dotted lines in Fig. 3) is indicated.

Leg Design (125mm)		Riser Design	
1. *L* (length)	A 5 in. (125 mm) minimum length will be used. This length may be increased at the option of the foundry to accommodate additional test bars (see Note 1).	1. *L* (length)	The length of the riser at the base will be the same as the top length of the leg. The length of the riser at the top therefore depends on the amount of taper added to the riser.
2. End taper	Use of and size of end taper is at the option of the foundry.	2. Width	The width of the riser at the base of a multiple-leg coupon shall be *n* (2¼) (57 mm) − ⅝ (16 mm) where *n* equals the number of legs attached to the coupon. The width of the riser at the top is therefore dependent on the amount of taper added to the riser.
3. Height	1¼ in. (32 mm)		
4. Width (at top)	1¼ in. (32 mm) (see Note 1).		
5. Radius (at bottom)	½ in. (13 mm), max		
6. Spacing between legs	A ½-in. (13-mm) radius will be used between the legs.		
7. Location of test bars	The tensile, bend, and impact bars will be taken from the lower portion of the leg (see Note 2).		
8. Number of legs	The number of legs attached to the coupon is at the option of the foundry providing they are equispaced according to Item 6.	3. *T* (riser taper)	Use of and size is at the option of the foundry.
		Height	The minimum height of the riser shall be 2 in. (51 mm). The maximum height is at the option of the foundry for the following reasons: (*a*) Many risers are cast open, (*b*) different compositions may require variation in risering for soundness, (*c*) different pouring temperatures may require variation in risering for soundness.
9. R_s	Radius from 0 to approximately 1/16 in. (2 mm).		

ASTM Logo Removed **A 370**

TABLE 2 Multiplying Factors to Be Used for Various Diameters of Round Test Specimens

Standard Specimen			Small Size Specimens Proportional to Standard					
0.500 in. Round			0.350 in. Round			0.250 in. Round		
Actual Diameter, in.	Area, in.^{2}	Multiplying Factor	Actual Diameter, in.	Area, in.^{2}	Multiplying Factor	Actual Diameter, in.	Area, in.^{2}	Multiplying Factor
0.490	0.1886	5.30	0.343	0.0924	10.82	0.245	0.0471	21.21
0.491	0.1893	5.28	0.344	0.0929	10.76	0.246	0.0475	21.04
0.492	0.1901	5.26	0.345	0.0935	10.70	0.247	0.0479	20.87
0.493	0.1909	5.24	0.346	0.0940	10.64	0.248	0.0483	20.70
0.494	0.1917	5.22	0.347	0.0946	10.57	0.249	0.0487	20.54
0.495	0.1924	5.20	0.348	0.0951	10.51	0.250	0.0491	20.37
0.496	0.1932	5.18	0.349	0.0957	10.45	0.251	0.0495	20.21
							(0.05)[a]	(20.0)[a]
0.497	0.1940	5.15	0.350	0.0962	10.39	0.252	0.0499	20.05
							(0.05)[a]	(20.0)[a]
0.498	0.1948	5.13	0.351	0.0968	10.33	0.253	0.0503	19.89
							(0.05)[a]	(20.0)[a]
0.499	0.1956	5.11	0.352	0.0973	10.28	0.254	0.0507	19.74
0.500	0.1963	5.09	0.353	0.0979	10.22	0.255	0.0511	19.58
0.501	0.1971	5.07	0.354	0.0984	10.16	...	...	...
0.502	0.1979	5.05	0.355	0.0990	10.10	...	...	...
0.503	0.1987	5.03	0.356	0.0995	10.05	...	...	...
				(0.1)[a]	(10.0)[a]	...	...	...
0.504	0.1995	5.01	0.357	0.1001	9.99	...	...	...
	(0.2)[a]	(5.0)[a]		(0.1)[a]	(10.0)[a]	...	...	...
0.505	0.2003	4.99	...	...	...	...	...	...
	(0.2)[a]	(5.0)[a]						
0.506	0.2011	4.97	...	...	...	...	...	...
	(0.2)[a]	(5.0)[a]						
0.507	0.2019	4.95	...	...	...	...	...	...
0.508	0.2027	4.93	...	...	...	...	...	...
0.509	0.2035	4.91	...	...	...	...	...	...
0.510	0.2043	4.90	...	...	...	...	...	...

[A] The values in parentheses may be used for ease in calculation of stresses, in pounds per square inch, as permitted in Note 5 of Fig. 5.

TABLE 3A Approximate Hardness Conversion Numbers for Nonaustenitic Steels[A] (Rockwell C to other Hardness Numbers)

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Vickers Hardness Number	Brinell Indentation Diameter, mm	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 15N Scale, 15-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 30N Scale 30-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 45N Scale, 45-kgf Load, Diamond Penetrator	Approximate Tensile Strength, ksi (MPa)
68	940	...	...	920	85.6	93.2	84.4	75.4	...
67	900	...	...	895	85.0	92.9	83.6	74.2	...
66	865	...	...	870	84.5	92.5	82.8	73.3	...
65	832	2.26	739	846	83.9	92.2	81.9	72.0	...
64	800	2.28	722	822	83.4	91.8	81.1	71.0	...
63	772	2.31	706	799	82.8	91.4	80.1	69.9	...
62	746	2.34	688	776	82.3	91.1	79.3	68.8	...
61	720	2.37	670	754	81.8	90.7	78.4	67.7	...
60	697	2.40	654	732	81.2	90.2	77.5	66.6	...
59	674	2.44	634	710	80.7	89.8	76.6	65.5	351 (2420)
58	653	2.47	615	690	80.1	89.3	75.7	64.3	338 (2330)
57	633	2.51	595	670	79.6	88.9	74.8	63.2	325 (2240)
56	613	2.55	577	650	79.0	88.3	73.9	62.0	313 (2160)
55	595	2.59	560	630	78.5	87.9	73.0	60.9	301 (2070)
54	577	2.63	543	612	78.0	87.4	72.0	59.8	292 (2010)
53	560	2.67	525	594	77.4	86.9	71.2	58.6	283 (1950)
52	544	2.70	512	576	76.8	86.4	70.2	57.4	273 (1880)
51	528	2.75	496	558	76.3	85.9	69.4	56.1	264 (1820)
50	513	2.79	482	542	75.9	85.5	68.5	55.0	255 (1760)
49	498	2.83	468	526	75.2	85.0	67.6	53.8	246 (1700)
48	484	2.87	455	510	74.7	84.5	66.7	52.5	238 (1640)
47	471	2.91	442	495	74.1	83.9	65.8	51.4	229 (1580)
46	458	2.94	432	480	73.6	83.5	64.8	50.3	221 (1520)
45	446	2.98	421	466	73.1	83.0	64.0	49.0	215 (1480)
44	434	3.02	409	452	72.5	82.5	63.1	47.8	208 (1430)
43	423	3.05	400	438	72.0	82.0	62.2	46.7	201 (1390)
42	412	3.09	390	426	71.5	81.5	61.3	45.5	194 (1340)
41	402	3.13	381	414	70.9	80.9	60.4	44.3	188 (1300)
40	392	3.17	371	402	70.4	80.4	59.5	43.1	182 (1250)
39	382	3.21	362	391	69.9	79.9	58.6	41.9	177 (1220)
38	372	3.24	353	380	69.4	79.4	57.7	40.8	171 (1180)
37	363	3.28	344	370	68.9	78.8	56.8	39.6	166 (1140)
36	354	3.32	336	360	68.4	78.3	55.9	38.4	161 (1110)
35	345	3.36	327	351	67.9	77.7	55.0	37.2	156 (1080)
34	336	3.41	319	342	67.4	77.2	54.2	36.1	152 (1050)
33	327	3.45	311	334	66.8	76.6	53.3	34.9	149 (1030)
32	318	3.50	301	326	66.3	76.1	52.1	33.7	146 (1010)
31	310	3.54	294	318	65.8	75.6	51.3	32.5	141 (970)

TABLE 3A—*Continued*

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Vickers Hardness Number	Brinell Indentation Diameter, mm	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 15N Scale, 15-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 30N Scale 30-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 45N Scale, 45-kgf Load, Diamond Penetrator	Approximate Tensile Strength, ksi (MPa)
30	302	3.59	286	311	65.3	75.0	50.4	31.3	138 (950)
29	294	3.64	279	304	64.6	74.5	49.5	30.1	135 (930)
28	286	3.69	271	297	64.3	73.9	48.6	28.9	131 (900)
27	279	3.73	264	290	63.8	73.3	47.7	27.8	128 (880)
26	272	3.77	258	284	63.3	72.8	46.8	26.7	125 (860)
25	266	3.81	253	278	62.8	72.2	45.9	25.5	123 (850)
24	260	3.86	247	272	62.4	71.6	45.0	24.3	119 (820)
23	254	3.89	243	266	62.0	71.0	44.0	23.1	117 (810)
22	248	3.93	237	261	61.5	70.5	43.2	22.0	115 (790)
21	243	3.98	231	256	61.0	69.9	42.3	20.7	112 (770)
20	238	4.02	226	251	60.5	69.4	41.5	19.6	110 (760)

[A] This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 3B Approximate Hardness Conversion Numbers for Nonaustenitic Steels[A] (Rockwell B to other Hardness Numbers)

Rockwell B Scale, 100-kgf Load 1/16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Indentation Diameter, mm	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness 15T Scale, 15-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness 30T Scale, 30-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness 45T Scale, 45-kgf Load, 1/16-in. (1.588-mm) Ball	Approximate Tensile Strength ksi (MPa)
100	240	3.91	240	251	61.5	...	93.1	83.1	72.9	116 (800)
99	234	3.96	234	246	60.9	...	92.8	82.5	71.9	114 (785)
98	228	4.01	228	241	60.2	...	92.5	81.8	70.9	109 (750)
97	222	4.06	222	236	59.5	...	92.1	81.1	69.9	104 (715)
96	216	4.11	216	231	58.9	...	91.8	80.4	68.9	102 (705)
95	210	4.17	210	226	58.3	...	91.5	79.8	67.9	100 (690)
94	205	4.21	205	221	57.6	...	91.2	79.1	66.9	98 (675)
93	200	4.26	200	216	57.0	...	90.8	78.4	65.9	94 (650)
92	195	4.32	195	211	56.4	...	90.5	77.8	64.8	92 (635)
91	190	4.37	190	206	55.8	...	90.2	77.1	63.8	90 (620)
90	185	4.43	185	201	55.2	...	89.9	76.4	62.8	89 (615)
89	180	4.48	180	196	54.6	...	89.5	75.8	61.8	88 (605)
88	176	4.53	176	192	54.0	...	89.2	75.1	60.8	86 (590)
87	172	4.58	172	188	53.4	...	88.9	74.4	59.8	84 (580)
86	169	4.62	169	184	52.8	...	88.6	73.8	58.8	83 (570)
85	165	4.67	165	180	52.3	...	88.2	73.1	57.8	82 (565)
84	162	4.71	162	176	51.7	...	87.9	72.4	56.8	81 (560)
83	159	4.75	159	173	51.1	...	87.6	71.8	55.8	80 (550)
82	156	4.79	156	170	50.6	...	87.3	71.1	54.8	77 (530)
81	153	4.84	153	167	50.0	...	86.9	70.4	53.8	73 (505)
80	150	4.88	150	164	49.5	...	86.6	69.7	52.8	72 (495)
79	147	4.93	147	161	48.9	...	86.3	69.1	51.8	70 (485)
78	144	4.98	144	158	48.4	...	86.0	68.4	50.8	69 (475)
77	141	5.02	141	155	47.9	...	85.6	67.7	49.8	68 (470)
76	139	5.06	139	152	47.3	...	85.3	67.1	48.8	67 (460)
75	137	5.10	137	150	46.8	99.6	85.0	66.4	47.8	66 (455)
74	135	5.13	135	147	46.3	99.1	84.7	65.7	46.8	65 (450)
73	132	51.8	132	145	45.8	98.5	84.3	65.1	45.8	64 (440)
72	130	5.22	130	143	45.3	98.0	84.0	64.4	44.8	63 (435)
71	127	5.27	127	141	44.8	97.4	83.7	63.7	43.8	62 (425)
70	125	5.32	125	139	44.3	96.8	83.4	63.1	42.8	61 (420)
69	123	5.36	123	137	43.8	96.2	83.0	62.4	41.8	60 (415)
68	121	5.40	121	135	43.3	95.6	82.7	61.7	40.8	59 (405)
67	119	5.44	119	133	42.8	95.1	82.4	61.0	39.8	58 (400)
66	117	5.48	117	131	42.3	94.5	82.1	60.4	38.7	57 (395)
65	116	5.51	116	129	41.8	93.9	81.8	59.7	37.7	56 (385)
64	114	5.54	114	127	41.4	93.4	81.4	59.0	36.7	...
63	112	5.58	112	125	40.9	92.8	81.1	58.4	35.7	...

TABLE 3B *Continued*

Rockwell B Scale, 100-kgf Load 1/16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Indentation Diameter, mm	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness: 15T Scale, 15-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness: 30T Scale, 30-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness: 45T Scale, 45-kgf Load, 1/16-in. (1.588-mm) Ball	Approximate Tensile Strength ksi (MPa)
62	110	5.63	110	124	40.4	92.2	80.8	57.7	34.7	...
61	108	5.68	108	122	40.0	91.7	80.5	57.0	33.7	...
60	107	5.70	107	120	39.5	91.1	80.1	56.4	32.7	...
59	106	5.73	106	118	39.0	90.5	79.8	55.7	31.7	...
58	104	5.77	104	117	38.6	90.0	79.5	55.0	30.7	...
57	103	5.81	103	115	38.1	89.4	79.2	54.4	29.7	...
56	101	5.85	101	114	37.7	88.8	78.8	53.7	28.7	...
55	100	5.87	100	112	37.2	88.2	78.5	53.0	27.7	...
54	...	...	...	111	36.8	87.7	78.2	52.4	26.7	...
53	...	...	...	110	36.3	86.5	77.9	51.7	25.7	...
52	...	...	...	109	35.9	86.0	77.5	51.0	24.7	...
51	...	...	...	108	35.5	85.4	77.2	50.3	23.7	...
50	...	...	...	107	35.0	84.8	76.9	49.7	22.7	...
49	...	...	...	106	34.6	84.3	76.6	49.0	21.7	...
48	...	...	...	105	34.1	83.7	76.2	48.3	20.7	...
47	...	...	...	104	33.7	83.1	75.9	47.7	19.7	...
46	...	...	...	103	33.3		75.6	47.0	18.7	...
45	...	...	...	102	32.9	82.6	75.3	46.3	17.7	
44	...	...	...	101	32.4	82.0	74.9	45.7	16.7	
43	...	...	...	100	32.0	81.4	74.6	45.0	15.7	
42	...	...	...	99	31.6	80.8	74.3	44.3	14.7	
41	...	...	...	98	31.2	80.3	74.0	43.7	13.6	
40	...	...	...	97	30.7	79.7	73.6	43.0	12.6	
39	...	...	...	96	30.3	79.1	73.3	42.3	11.6	...
38	...	...	...	95	29.9	78.6	73.0	41.6	10.6	...
37	...	...	...	94	29.5	78.0	72.7	41.0	9.6	...
36	...	...	...	93	29.1	77.4	72.3	40.3	8.6	...
35	...	...	...	92	28.7	76.9	72.0	39.6	7.6	...
34	...	...	...	91	28.2	76.3	71.7	39.0	6.6	...
33	...	...	...	90	27.8	75.7	71.4	38.3	5.6	...
32	...	...	...	89	27.4	75.2	71.0	37.6	4.6	...
31	...	...	...	88	27.0	74.6	70.7	37.0	3.6	...
30	...	...	...	87	26.6	74.0	70.4	36.3	2.6	...

[A] This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 3C Approximate Hardness Conversion Numbers for Austenitic Steels (Rockwell C to other Hardness Numbers)

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
		15N Scale, 15-kgf Load, Diamond Penetrator	30N Scale, 30-kgf Load, Diamond Penetrator	45N Scale, 45-kgf Load, Diamond Penetrator
48	74.4	84.1	66.2	52.1
47	73.9	83.6	65.3	50.9
46	73.4	83.1	64.5	49.8
45	72.9	82.6	63.6	48.7
44	72.4	82.1	62.7	47.5
43	71.9	81.6	61.8	46.4
42	71.4	81.0	61.0	45.2
41	70.9	80.5	60.1	44.1
40	70.4	80.0	59.2	43.0
39	69.9	79.5	58.4	41.8
38	69.3	79.0	57.5	40.7
37	68.8	78.5	56.6	39.6
36	68.3	78.0	55.7	38.4
35	67.8	77.5	54.9	37.3
34	67.3	77.0	54.0	36.1
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

TABLE 3D Approximate Hardness Conversion Numbers for Austenitic Steels (Rockwell B to other Hardness Numbers)

Rockwell B Scale, 100-kgf Load, 1/16-in. (1.588-mm) Ball	Brinell Indentation Diameter, mm	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
				15T Scale, 15-kgf Load, 1/16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1/16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1/16-in. (1.588-mm) Ball
100	3.79	256	61.5	91.5	80.4	70.2
99	3.85	248	60.9	91.2	79.7	69.2
98	3.91	240	60.3	90.8	79.0	68.2
97	3.96	233	59.7	90.4	78.3	67.2
96	4.02	226	59.1	90.1	77.7	66.1
95	4.08	219	58.5	89.7	77.0	65.1
94	4.14	213	58.0	89.3	76.3	64.1
93	4.20	207	57.4	88.9	75.6	63.1
92	4.24	202	56.8	88.6	74.9	62.1
91	4.30	197	56.2	88.2	74.2	61.1
90	4.35	192	55.6	87.8	73.5	60.1
89	4.40	187	55.0	87.5	72.8	59.0
88	4.45	183	54.5	87.1	72.1	58.0
87	4.51	178	53.9	86.7	71.4	57.0
86	4.55	174	53.3	86.4	70.7	56.0
85	4.60	170	52.7	86.0	70.0	55.0
84	4.65	167	52.1	85.6	69.3	54.0
83	4.70	163	51.5	85.2	68.6	52.9
82	4.74	160	50.9	84.9	67.9	51.9
81	4.79	156	50.4	84.5	67.2	50.9
80	4.84	153	49.8	84.1	66.5	49.9

TABLE 4 Percent Shear for Measurements Made in Inches

NOTE—Since Table 4 is set up for finite measurements or dimensions *A* and *B*, 100 percent shear is to be reported when either *A* or *B* is zero.

Dimension *B*, in.	Dimension *A*, in.																
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40
0.05	98	96	95	94	94	93	92	91	90	90	89	88	87	86	85	85	84
0.10	96	92	90	89	87	85	84	82	81	79	77	76	74	73	71	69	68
0.12	95	90	88	86	85	83	81	79	77	75	73	71	69	67	65	63	61
0.14	94	89	86	84	82	80	77	75	73	71	68	66	64	62	59	57	55
0.16	94	87	85	82	79	77	74	72	69	67	64	61	59	56	53	51	48
0.18	93	85	83	80	77	74	72	68	65	62	59	56	54	51	48	45	42
0.20	92	84	81	77	74	72	68	65	61	58	55	52	48	45	42	39	36
0.22	91	82	79	75	72	68	65	61	57	54	50	47	43	40	36	33	29
0.24	90	81	77	73	69	65	61	57	54	50	46	42	38	34	30	27	23
0.26	90	79	75	71	67	62	58	54	50	46	41	37	33	29	25	20	16
0.28	89	77	73	68	64	59	55	50	46	41	37	32	28	23	18	14	10
0.30	88	76	71	66	61	56	52	47	42	37	32	27	23	18	13	9	3
0.31	88	75	70	65	60	55	50	45	40	35	30	25	20	18	10	5	0

TABLE 5 Percent Shear for Measurements Made in Millimeters

NOTE—Since Table 5 is set up for finite measurements or dimensions *A* and *B*, 100 percent shear is to be reported when either *A* or *B* is zero.

Dimension *B*, mm	Dimension *A*, mm																		
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
1.0	99	98	98	97	96	96	95	94	94	93	92	92	91	91	90	89	89	88	88
1.5	98	97	96	95	94	93	92	92	91	90	89	88	87	86	85	84	83	82	81
2.0	98	96	95	94	92	91	90	89	88	86	85	84	82	81	80	79	77	76	75
2.5	97	95	94	92	91	89	88	86	84	83	81	80	78	77	75	73	72	70	69
3.0	96	94	92	91	89	87	85	83	81	79	77	76	74	72	70	68	66	64	62
3.5	96	93	91	89	87	85	82	80	78	76	74	72	69	67	65	63	61	58	56
4.0	95	92	90	88	85	82	80	77	75	72	70	67	65	62	60	57	55	52	50
4.5	94	92	89	86	83	80	77	75	72	69	66	63	61	58	55	52	49	46	44
5.0	94	91	88	85	81	78	75	72	69	66	62	59	56	53	50	47	44	41	37
5.5	93	90	96	83	79	76	72	69	66	62	59	55	52	48	45	42	38	35	31
6.0	92	89	85	81	77	74	70	66	62	59	55	51	47	44	40	36	33	29	25
6.5	92	88	84	80	76	72	67	63	59	55	51	47	43	39	35	31	27	23	19
7.0	91	87	82	78	74	69	65	61	56	52	47	43	39	34	30	26	21	17	12
7.5	91	86	81	77	72	67	62	58	53	48	44	39	34	30	25	20	16	11	6
8.0	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0

TABLE 6 Recommended Practice for Selecting Bend Test Specimens

NOTE 1—The length of all specimens is to be not less than 6 in. (150 mm).

NOTE 2—The edges of the specimen may be rounded to a radius not exceeding 1/16 in. (1.6 mm).

Flats		
Thickness, in. (mm)	Width, in. (mm)	Recommended Size
Up to ½ (13), incl	Up to ¾ (19), incl	Full section.
	Over ¾ (19)	Full section or machine to not less than ¾ in. (19 mm) in width by thickness of specimen.
Over ½ (13)	All	Full section or machine to 1 by ½ in. (25 by 13 mm) specimen from midway between center and surface.

Rounds, Squares, Hexagons, and Octagons	
Diameter or Distance Between Parallel Faces, in. (mm)	Recommended Size
Up to 1½ (38), incl	Full section.
Over 1½ (38)	Machine to 1 by ½-in. (25 by 13-mm) specimen from midway between center and surface.

TABLE 7 Recommendations for Selecting Tension Test Specimens

NOTE 1—For bar sections where it is difficult to determine the cross-sectional area by simple measurement, the area in square inches may be calculated by dividing the weight per linear inch of specimen in pounds by 0.2833 (weight of 1 in.^{3} of steel) or by dividing the weight per linear foot of specimen by 3.4 (weight of steel 1 in. square and 1 ft long).

Thickness, in. (mm)	Width, in. (mm)	Hot-Rolled Bars	Cold-Finished Bars
		Flats	
Under ⅝ (16)	Up to 1½ (38), incl	Full section by 8-in. (203-mm) gage length (Fig. 4).	Mill reduced section to 2-in. (51-mm) gage length and approximately 25 percent less than test specimen width.
	Over 1½ (38)	Full section, or mill to 1½ in. (38 mm) wide by 8-in. (203-mm) gage length (Fig. 4).	Mill reduced section to 2-in. gage length and 1½ in. wide.
⅝ to 1½ (16 to 38), excl	Up to 1½ (38), incl	Full section by 8-in. gage length or machine standard ½ by 2-in. (13 by 51-mm) gage length specimen from center of section (Fig. 5).	Mill reduced section to 2-in. (51-mm) gage length and approximately 25 percent less than test specimen width or machine standard ½ by 2-in. (13 by 51-mm) gage length specimen from center of section (Fig. 5).
	Over 1½ (38)	Full section, or mill 1½ in. (38 mm) width by 8-in. (203-mm) gage length (Fig. 4) or machine standard ½ by 2-in. gage (13 by 51-mm) gage length specimen from midway between edge and center of section (Fig. 5).	Mill reduced section to 2-in. gage length and 1½ in. wide or machine standard ½ by 2-in. gage length specimen from midway between edge and center of section (Fig. 5)
1½ (38) and over		Full section by 8-in. (203-mm) gage length, or machine standard ½ by 2-in. (13 by 51-mm) gage length specimen from midway between surface and center (Fig. 5).	Machine standard ½ by 2-in. (13 by 51-mm) gage length specimen from midway between surface and center (Fig. 5).

Rounds, Squares, Hexagons, and Octagons

Diameter or Distance Between Parallel Faces, in. (mm)	Hot-Rolled Bars	Cold-Finished Bars
Under ⅝	Full section by 8-in. (203-mm) gage length or machine to sub-size specimen (Fig. 5).	Machine to sub-size specimen (Fig. 5).
⅝ to 1½ (16 to 38), excl	Full section by 8-in. (203-mm) gage length or machine standard ½ in. by 2-in. (13 by 51-mm) gage length specimen from center of section (Fig. 5).	Machine standard ½ in. by 2-in. gage length specimen from center of section (Fig. 5).
1½ (38) and over	Full section by 8-in. (203-mm) gage length or machine standard ½ in. by 2-in. (13 by 51-mm) gage length specimen from midway between surface and center of section (Fig. 5).	Machine standard ½ in. by 2-in. (13 by 51-mm gage length specimen from midway between surface and center of section (Fig. 5).

Other Bar-Size Sections

All sizes	Full section by 8-in. (203-mm) gage length or prepare test specimen 1½ in. (38 mm) wide (if possible) by 8-in. (203-mm) gage length.	Mill reduced section to 2-in. (51-mm) gage length and approximately 25 percent less than test specimen width.

TABLE 8 Wall Thickness Limitations of Superficial Hardness Test on Annealed or Ductile Materials[a]
("T" Scale (1/16-in. Ball))

Wall Thickness, in. (mm)	Load, kgf
Over 0.050 (1.27)	45
Over 0.035 (0.89)	30
0.020 and over (0.51)	15

[a] The heaviest load recommended for a given wall thickness is generally used.

TABLE 9 Wall Thickness Limitations of Superficial Hardness Test on Cold Worked or Heat Treated Material[a]
("N" Scale (Diamond Penetrator))

Wall Thickness, in. (mm)	Load, kgf
Over 0.035 (0.89)	45
Over 0.025 (0.51)	30
0.015 and over (0.38)	15

[a] The heaviest load recommended for a given wall thickness is generally used.

TABLE 10 Effect of Varying Notch Dimensions on Standard Specimens

	High-Energy Specimens, ft · lbf (J)	High-Energy Specimens, ft · lbf (J)	Low-Energy Specimens, ft · lbf (J)
Specimen with standard dimensions	76.0 ± 3.8 (103.0 ± 5.2)	44.5 ± 2.2 (60.3 ± 3.0)	12.5 ± 1.0 (16.9 ± 1.4)
Depth of notch, 0.084 in. (2.13 mm)[a]	72.2 (97.9)	41.3 (56.0)	11.4 (15.5)
Depth of notch, 0.0805 in. (2.04 mm)[a]	75.1 (101.8)	42.2 (57.2)	12.4 (16.8)
Depth of notch, 0.0775 in. (1.77 mm)[a]	76.8 (104.1)	45.3 (61.4)	12.7 (17.2)
Depth of notch, 0.074 in. (1.57 mm)[a]	79.6 (107.9)	46.0 (62.4)	12.8 (17.3)
Radius at base of notch, 0.005 in. (0.127 mm)[b]	72.3 (98.0)	41.7 (56.5)	10.8 (14.6)
Radius at base of notch, 0.015 in. (0.381 mm)[b]	80.0 (108.5)	47.4 (64.3)	15.8 (21.4)

[a] Standard 0.079 ± 0.002 in. (2.00 ± 0.05 mm).
[b] Standard 0.010 ± 0.001 in. (0.25 ± 0.025 mm).

ASTM Logo Removed A 370

TABLE 11 Carbon and Alloy Steels—Material Constant *a* = 0.4. Multiplication Factors for Converting Percent Elongation from ½-in. Diameter by 2-in. Gage Length Standard Tension Test Specimen to Standard ½ by 2-in. and 1½ by 8-in. Flat Specimens

Thickness, in.	½ by 2-in. Specimen	1½ by 8-in. Specimen	Thickness, in.	1½ by 8-in. Specimen
0.025	0.574	...	0.800	0.822
0.030	0.596	...	0.850	0.832
0.035	0.614	...	0.900	0.841
0.040	0.631	...	0.950	0.850
0.045	0.646	...	1.000	0.859
0.050	0.660	...	1.125	0.880
0.055	0.672	...	1.250	0.898
0.060	0.684	...	1.375	0.916
0.065	0.695	...	1.500	0.932
0.070	0.706	...	1.625	0.947
0.075	0.715	...	1.750	0.961
0.080	0.725	...	1.875	0.974
0.085	0.733	...	2.000	0.987
0.090	0.742	0.531	2.125	0.999
0.100	0.758	0.542	2.250	1.010
0.110	0.772	0.553	2.375	1.021
0.120	0.786	0.562	2.500	1.032
0.130	0.799	0.571	2.625	1.042
0.140	0.810	0.580	2.750	1.052
0.150	0.821	0.588	2.875	1.061
0.160	0.832	0.596	3.000	1.070
0.170	0.843	0.603	3.125	1.079
0.180	0.852	0.610	3.250	1.088
0.190	0.862	0.616	3.375	1.096
0.200	0.870	0.623	3.500	1.104
0.225	0.891	0.638	3.625	1.112
0.250	0.910	0.651	3.750	1.119
0.275	0.928	0.664	3.875	1.127
0.300	0.944	0.675	4.000	1.134
0.325	0.959	0.686	...	...
0.350	0.973	0.696	...	...
0.375	0.987	0.706	...	...
0.400	1.000	0.715	...	...
0.425	1.012	0.724	...	...
0.450	1.024	0.732	...	...
0.475	1.035	0.740	...	...
0.500	1.045	0.748	...	...
0.525	1.056	0.755	...	...
0.550	1.066	0.762	...	...
0.575	1.075	0.770	...	...
0.600	1.084	0.776	...	...
0.625	1.093	0.782	...	...
0.650	1.101	0.788	...	...
0.675	1.110	...	...	...
0.700	1.118	0.800	...	...
0.725	1.126	...	...	...
0.750	1.134	0.811	...	...

TABLE 12 Annealed Austenitic Stainless Steels—Material Constant *a* = 0.127. Multiplication Factors for Converting Percent Elongation from ½-in. Diameter by 2-in. Gage Length Standard Tension Test Specimen to Standard ½ by 2-in. and 1½ by 8-in. Flat Specimens

Thickness, in.	½ by 2-in. Specimen	1½ by 8-in. Specimen	Thickness, in.	1½ by 8-in. Specimen
0.025	0.839	...	0.800	0.940
0.030	0.848	...	0.850	0.943
0.035	0.857	...	0.900	0.947
0.040	0.864	...	0.950	0.950
0.045	0.870	...	1.000	0.953
0.050	0.876	...	1.125	0.960
0.055	0.882	...	1.250	0.966
0.060	0.886	...	1.375	0.972
0.065	0.891	...	1.500	0.978
0.070	0.895	...	1.625	0.983
0.075	0.899	...	1.750	0.987
0.080	0.903	...	1.875	0.992
0.085	0.906	...	2.000	0.996
0.090	0.909	0.818	2.125	1.000
0.095	0.913	0.821	2.250	1.003
0.100	0.916	0.823	2.375	1.007
0.110	0.921	0.828	2.500	1.010
0.120	0.926	0.833	2.625	1.013
0.130	0.931	0.837	2.750	1.016
0.140	0.935	0.841	2.875	1.019
0.150	0.940	0.845	3.000	1.022
0.160	0.943	0.848	3.125	1.024
0.170	0.947	0.852	3.250	1.027
0.180	0.950	0.855	3.375	1.029
0.190	0.954	0.858	3.500	1.032
0.200	0.957	0.860	3.625	1.034
0.225	0.964	0.867	3.750	1.036
0.250	0.970	0.873	3.875	1.038
0.275	0.976	0.878	4.000	1.041
0.300	0.982	0.883	...	...
0.325	0.987	0.887	...	...
0.350	0.991	0.892	...	...
0.375	0.996	0.895	...	...
0.400	1.000	0.899	...	...
0.425	1.004	0.903	...	...
0.450	1.007	0.906	...	...
0.475	1.011	0.909	...	...
0.500	1.014	0.912	...	...
0.525	1.017	0.915	...	...
0.550	1.020	0.917	...	...
0.575	1.023	0.920	...	...
0.600	1.026	0.922	...	...
0.625	1.029	0.925	...	...
0.650	1.031	0.927	...	...
0.675	1.034	...	...	...
0.700	1.036	0.932	...	...
0.725	1.038	...	...	...
0.750	1.041	0.936	...	...

ASTM Logo Removed

TABLE 13 Recommended Values for Rounding Test Data

Test Quantity	Test Data Range	Rounded Value[A]
Yield Point, Yield Strength, Tensile Strength	up to 50 000 psi, excl	100 psi
	50 000 to 100 000 psi, excl	500 psi
	100 000 psi and above	1000 psi
	up to 500 MPa, excl	1 MPa
	500 to 1000 MPa, excl	5 MPa
	1000 MPa and above	10 MPa
Elongation	0 to 10 %, excl	0.5 %
	10 % and above	1 %
Reduction of Area	0 to 10 %, excl	0.5 %
	10 % and above	1 %
Impact Energy	0 to 240 ft·lbf (or 0 to 325 J)	1 ft·lbf (or 1 J)[B]
Brinell Hardness	all values	tabular value[C]
Rockwell Hardness	all scales	1 Rockwell Number

[A] Round test data to the nearest integral multiple of the values in this column. If the data value is exactly midway between two rounded values, round to the higher value.

[B] These units are not equivalent but the rounding occurs in the same numerical ranges for each. (1 ft·lbf = 1.356 J.)

[C] Round the mean diameter of the Brinell impression to the nearest 0.05 mm and report the corresponding Brinell hardness number read from the table without further rounding.

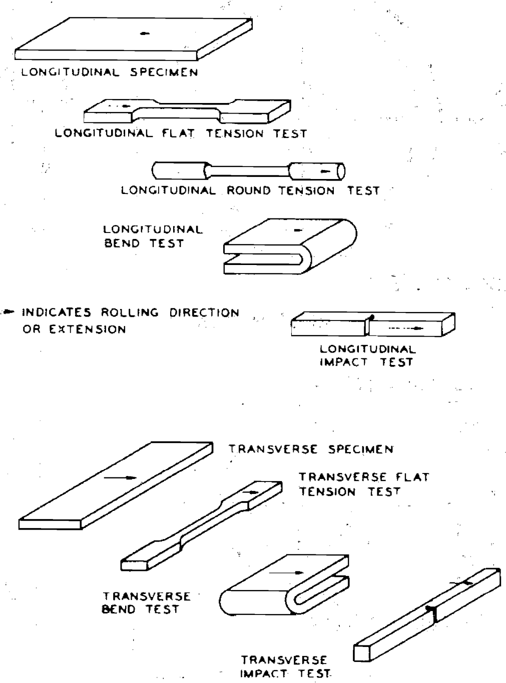


FIG. 1 The Relation of Test Coupons and Test Specimens to Rolling Direction or Extension (Applicable to General Wrought Products).

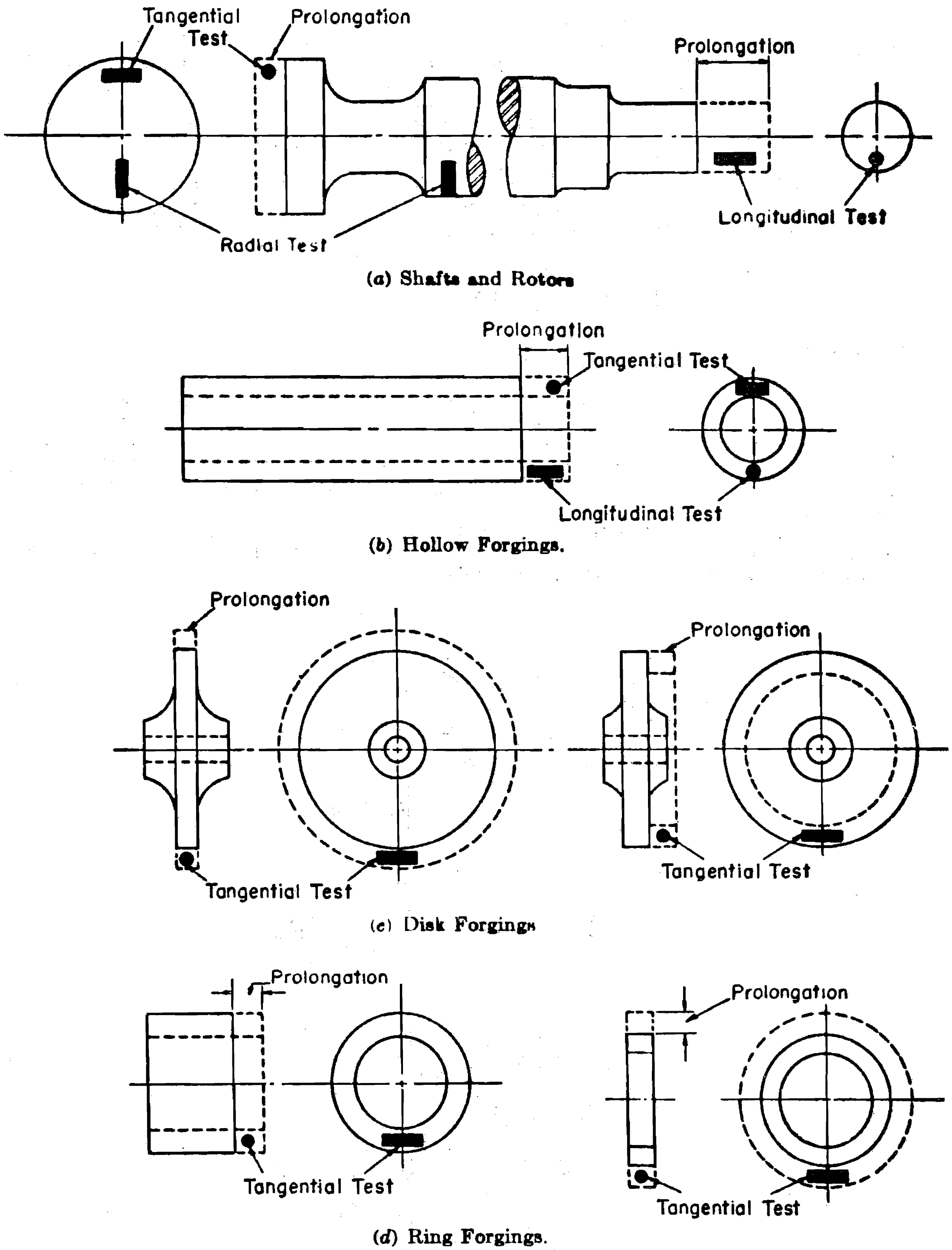
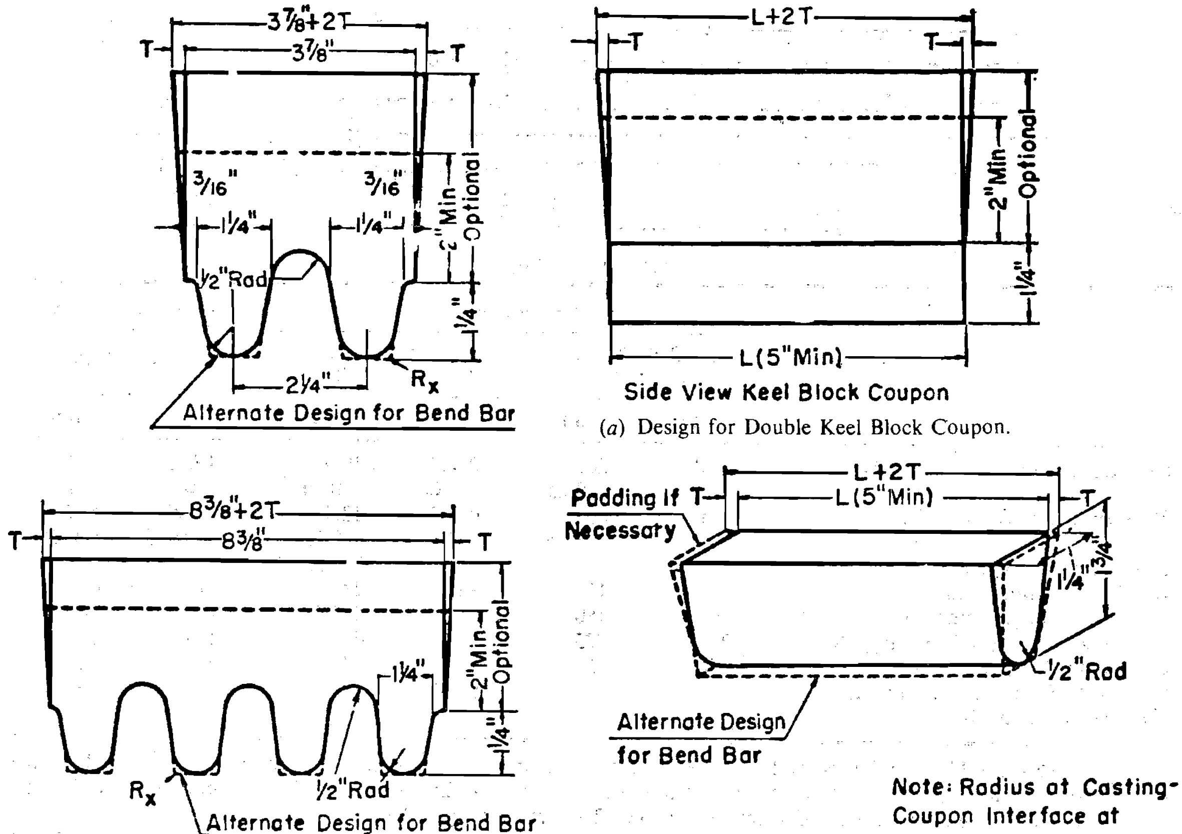


FIG. 2 Locations of Test Specimens for Various Types of Forgings.

ASTM Logo Removed **A 370**



(*a*) Design for Double Keel Block Coupon.

(*b*) Design for Multiple Keel Block Coupon (4 Legs).

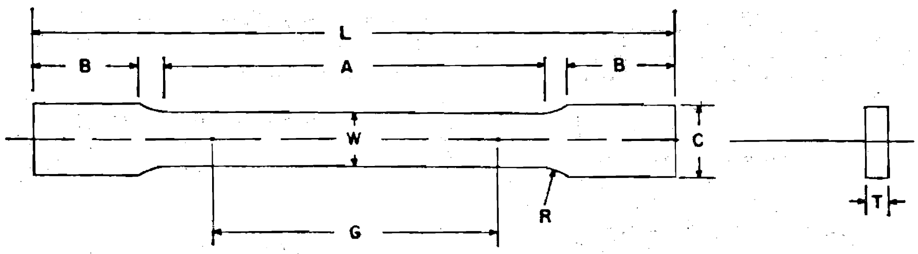
(*c*) Design for "Attached" Coupon.

Metric Equivalents

in.	3/16	½	1¼	1¾	2	2¼	3⅞	5	8⅜
mm	4.8	13	32	45	51	57	98	127	213

FIG. 3 Test Coupons for Castings (see Table 1 for Details of Design).

ASTM Logo Removed **A 370**



DIMENSIONS

	Standard Specimens				Subsize Specimen	
	Plate-Type, 1½-in. Wide		Sheet-Type, ½-in. Wide		¼-in. Wide	
	in.	mm	in.	mm	in.	mm
G—Gage length (Notes 1 and 2)	8.00 ± 0.01	200 ± 0.25	2.000 ± 0.005	50.0 ± 0.10	1.000 ± 0.003	25.0 ± 0.08
W—Width (Notes 3, 4, and 5)	1½ + ⅛ − ¼	40 + 3 − 6	0.500 ± 0.010	12.5 ± 0.25	0.250 ± 0.002	6.25 ± 0.05
T—Thickness (Note 6)			thickness of material			
R—Radius of fillet, min	½	13	½	13	¼	6
L—Over-all length, min (Notes 2 and 7)	18	450	8	200	4	100
A—Length of reduced section, min	9	225	2¼	60	1¼	32
B—Length of grip section, min (Note 8)	3	75	2	50	1¼	32
C—Width of grip section, approximate (Notes 4, 9, and 10)	2	50	¾	20	⅜	10

NOTE 1—For the 1½-in. (40-mm) wide specimen, punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the reduced section. Either a set of nine or more punch marks 1 in. (25 mm) apart, or one or more pairs of punch marks 8 in. (200 mm) apart may be used.

NOTE 2—When elongation measurements of 1½-in. (40-mm) wide specimens are not required, a gage length (*G*) of 2.000 in. ± 0.005 in. (50.0 mm ± 0.10 mm) with all other dimensions similar to the plate-type specimen may be used.

NOTE 3—For the three sizes of specimens, the ends of the reduced section shall not differ in width by more than 0.004, 0.002 or 0.001 in. (0.10, 0.05 or 0.025 mm), respectively. Also, there may be a gradual decrease in width from the ends to the center, but the width at either end shall not be more than 0.015 in., 0.005 in., or 0.003 in. (0.40, 0.10 or 0.08 mm), respectively, larger than the width at the center.

NOTE 4—For each of the three sizes of specimens, narrower widths (*W* and *C*) may be used when necessary. In such cases the width of the reduced section should be as large as the width of the material being tested permits; however, unless stated specifically, the requirements for elongation in a product specification shall not apply when these narrower specimens are used. If the width of the material is less than *W*, the sides may be parallel throughout the length of the specimen.

NOTE 5—The specimen may be modified by making the sides parallel throughout the length of the specimen, the width and tolerances being the same as those specified above. When necessary a narrower specimen may be used, in which case the width should be as great as the width of the material being tested permits. If the width is 1½ in. (38 mm) or less, the sides may be parallel throughout the length of the specimen.

NOTE 6—The dimension *T* is the thickness of the test specimen as provided for in the applicable material specifications. Minimum nominal thickness of 1½-in. (40-mm) wide specimens shall be 3/16 in. (5 mm), except as permitted by the product specification. Maximum nominal thickness of ½-in. (12.5-mm) and ¼-in. (6-mm) wide specimens shall be ¾ in. (19 mm) and ¼ in. (6 mm), respectively.

NOTE 7—To aid in obtaining axial loading during testing of ¼-in. (6-mm) wide specimens, the over-all length should be as the material will permit.

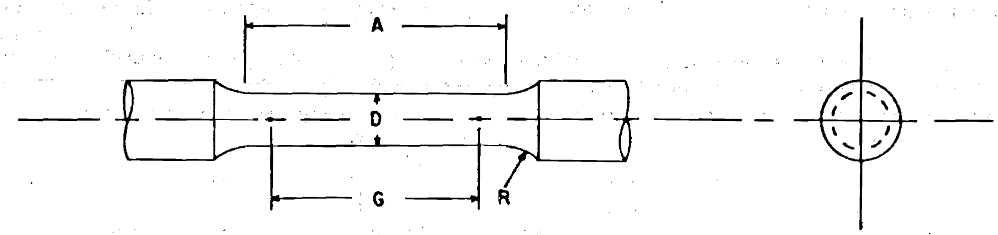
NOTE 8—It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips. If the thickness of ½-in. (13-mm) wide specimens is over ⅜ in. (10 mm), longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.

NOTE 9—For standard sheet-type specimens and subsize specimens the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.01 and 0.005 in. (0.25 and 0.13 mm), respectively. However, for steel if the ends of the ½-in. (12.5-mm) wide specimen are symmetrical within 0.05 in. (1.0 mm) a specimen may be considered satisfactory for all but referee testing.

NOTE 10—For standard plate-type specimens the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.25 in. (6.35 mm) except for referee testing in which case the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in. (2.5 mm).

FIG. 4 Rectangular Tension Test Specimens.

ASTM Logo Removed



DIMENSIONS

Nominal Diameter	Standard Specimen		Small-Size Specimens Proportional to Standard							
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
	0.500	12.5	0.350	8.75	0.250	6.25	0.160	4.00	0.113	2.50
G—Gage length	2.000 ± 0.005	50.0 ± 0.10	1.400 ± 0.005	35.0 ± 0.10	1.000 ± 0.005	25.0 ± 0.10	0.640 ± 0.005	16.0 ± 0.10	0.450 ± 0.005	10.0 ± 0.10
—Diameter (Note 1)	0.500 ± 0.010	12.5 ± 0.25	0.350 ± 0.007	8.75 ± 0.18	0.250 ± 0.005	6.25 ± 0.12	0.160 ± 0.003	4.00 ± 0.08	0.113 ± 0.002	2.50 ± 0.05
R—Radius of fillet, min	3/8	10	1/4	6	3/16	5	5/32	4	3/32	2
A—Length of reduced section, min (Note 2)	2 1/4	60	1 3/4	45	1 1/4	32	3/4	20	5/8	16

NOTE 1—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 percent larger in diameter than the center (controlling dimension).

NOTE 2—If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gage length. Reference marks for the measurement of elongation should, nevertheless, be spaced at the indicated gage length.

NOTE 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial (see Fig. 9). If the ends are to be held in wedge grips it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

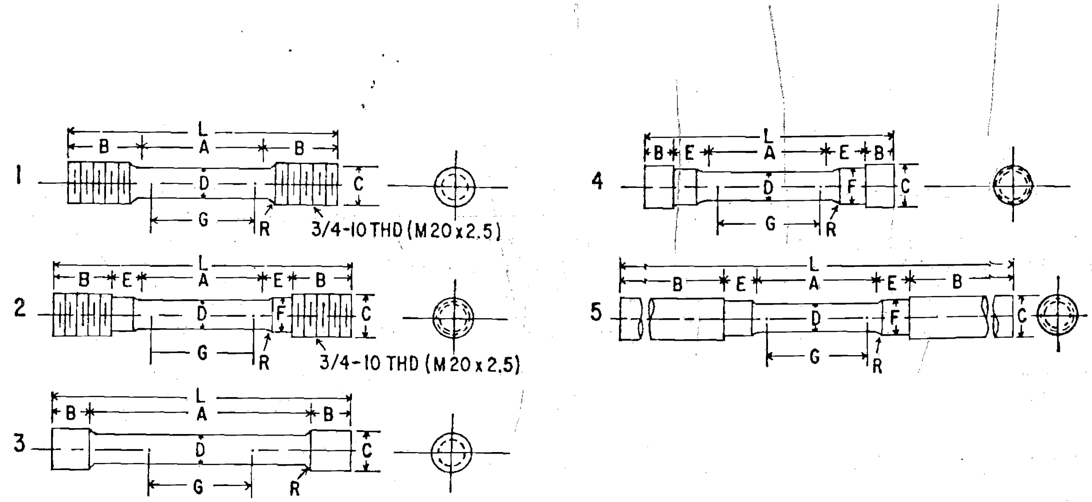
NOTE 4—On the round specimens in Figs. 5 and 6, the gage lengths are equal to four times the nominal diameter. In some product specifications other specimens may be provided for, but unless the 4-to-1 ratio is maintained within dimensional tolerances, the elongation values may not be comparable with those obtained from the standard test specimen.

NOTE 5—The use of specimens smaller than 0.250-in. (6.25-mm) diameter shall be restricted to cases when the material to be tested is of insufficient size to obtain larger specimens or when all parties agree to their use for acceptance testing. Smaller specimens require suitable equipment and greater skill in both machining and testing.

NOTE 6—Five sizes of specimens often used have diameters of approximately 0.505, 0.357, 0.252, 0.160, and 0.113 in., the reason being to permit easy calculations of stress from loads, since the corresponding cross sectional areas are equal or close to 0.200, 0.100, 0.0500, 0.0200, and 0.0100 in.^{2}, respectively. Thus, when the actual diameters agree with these values, the stresses (or strengths) may be computed using the simple multiplying factors 5, 10, 20, 50, and 100, respectively. (The metric equivalents of these fixed diameters do not result in correspondingly convenient cross sectional areas and multiplying factors.)

FIG. 5 Standard 0.500-in. (12.5-mm) Round Tension Test Specimen with 2-in. (50-mm) Gage Length and Examples of Small-Size Specimens Proportional to the Standard Specimen.

ASTM Logo Removed **A 370**



DIMENSIONS

	Specimen 1		Specimen 2		Specimen 3		Specimen 4		Specimen 5	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
G—Gage length	2.000 ± 0.005	50.0 ± 0.10	2.000 ± 0.005	50.0 ± 0.10	2.000 ± 0.005	50.0 ± 0.10	2.000 ± 0.005	50.0 ± 0.10	2.000 ± 0.005	50.0 ± 0.10
D—Diameter (Note 1)	0.500 ± 0.010	12.5 ± 0.25	0.500 ± 0.010	12.5 ± 0.25	0.500 ± 0.010	12.5 ± 0.25	0.500 ± 0.010	12.5 ± 0.25	0.500 ± 0.010	12.5 ± 0.25
R—Radius of fillet, min	⅜	10	⅜	10	1⁄16	2	⅜	10	⅜	10
A—Length of reduced section	2¼, min	60, min	2¼, min	60, min	4, approximately	100, approximately	2¼, min	60, min	2¼, min	60, min
L—Over-all length, approximate	5	125	5½	140	5½	140	4¾	120	9½	240
B—Length of end section (Note 2)	1⅜, approximately	35, approximately	1, approximately	25, approximately	¾, approximately	20, approximately	½, approximately	13, approximately	3, min	75, min
C—Diameter of end section	¾	20	¾	20	23⁄32	18	⅞	22	¾	20
E—Length of shoulder and fillet section, approximate	. . .	. . .	⅝	16	. . .	. . .	¾	20	⅝	16
F—Diameter of shoulder	. . .	. . .	⅝	16	. . .	. . .	⅝	16	19⁄32	15

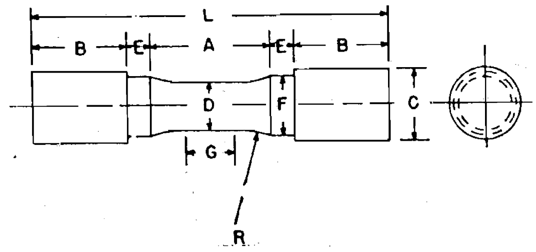
NOTE 1—The reduced section may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. (0.10 mm) larger in diameter than the center.

NOTE 2—On Specimen 5 it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

NOTE 3—The use of UNF series of threads (¾ by 16, ½ by 20, ⅜ by 24, and ¼ by 28) is recommended for high-strength, brittle materials to avoid fracture in the thread portion.

FIG. 6 Various Types of Ends for Standard Round Tension Test Specimen.

ASTM Logo Removed **A 370**



DIMENSIONS

	Specimen 1		Specimen 2		Specimen 3	
	in.	mm	in.	mm	in.	mm
G—Length of parallel	Shall be equal to or greater than diameter *D*					
D—Diameter	0.500 ± 0.010	12.5 ± 0.25	0.750 ± 0.015	20.0 ± 0.40	1.25 ± 0.025	30.0 ± 0.60
R—Radius of fillet, min	1	25	1	25	2	50
A—Length of reduced section, min	1¼	32	1½	38	2¼	60
L—Over-all length, min	3¾	95	4	100	6⅜	160
B—Length of end section, approximate	1	25	1	25	1¾	45
C—Diameter of end section, approximate	¾	20	1⅛	30	1⅞	48
E—Length of shoulder, min	¼	6	¼	6	5/16	8
F—Diameter of shoulder	⅝ ± 1/64	16.0 ± 0.40	15/16 ± 1/64	24.0 ± 0.40	1 7/16 ± 1/64	36.5 ± 0.40

NOTE—The reduced section and shoulders (dimensions *A*, *D*, *E*, *F*, *G*, and *R*) shall be shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. Commonly the ends are threaded and have the dimensions *B* and *C* given above.

FIG. 7 Standard Tension Test Specimen for Cast Iron.

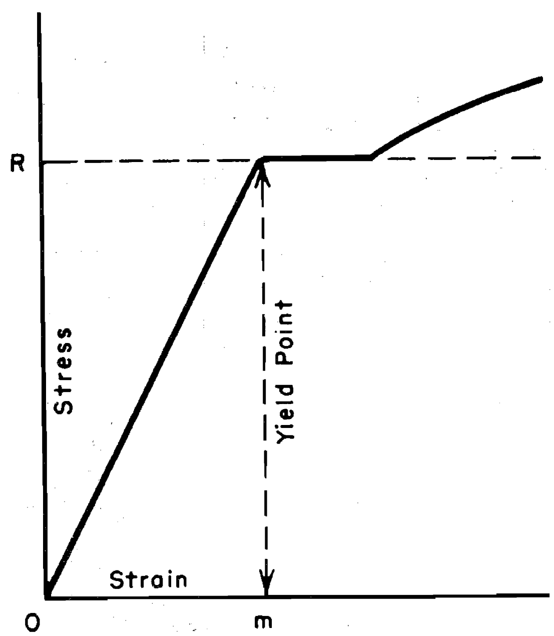


FIG. 8 Stress-Strain Diagram Showing Yield Point Corresponding with Top of Knee.

ASTM Logo Removed

A 370

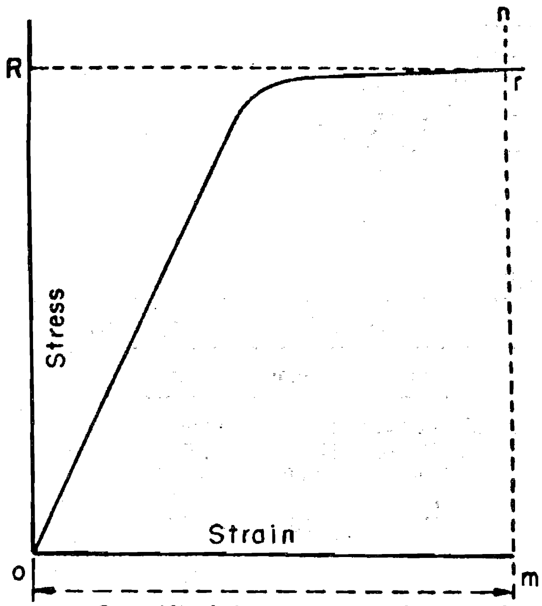


FIG. 9 Stress-Strain Diagram Showing Yield Point or Yield Strength by Extension Under Load Method.

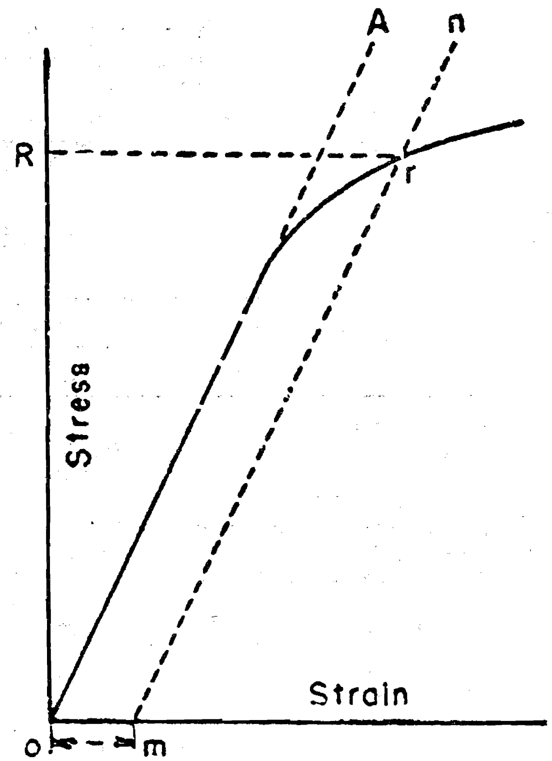
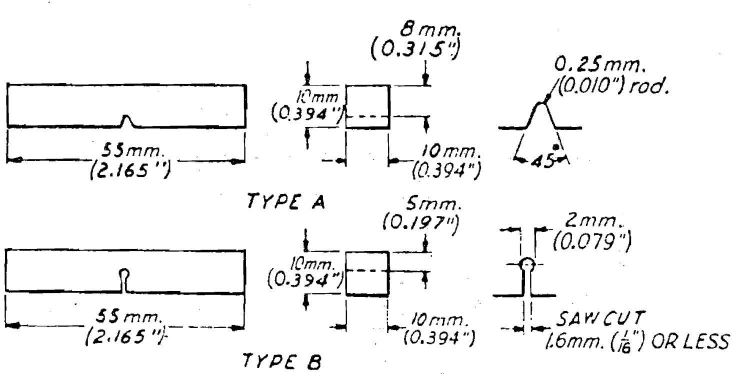


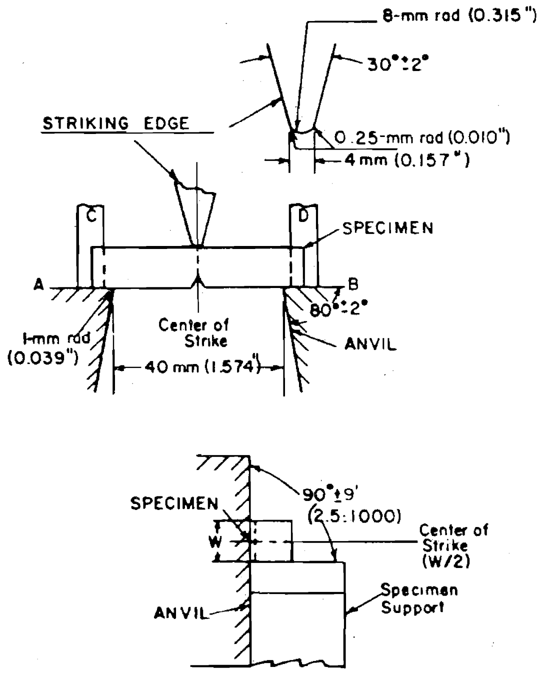
FIG. 10 Stress-Strain Diagram for Determination of Yield Strength by the Offset Method.



NOTE—Permissible variations shall be as follows:

Adjacent sides shall be at	90 deg ± 10 min
Cross section dimensions	±0.025 mm (0.001 in.)
Length of specimen	+0, −2.5 mm (0.100 in.)
Angle of notch	±1 deg
Radius of notch	±0.025 mm (0.001 in.)
Dimensions to bottom of notch:	
Specimen, Type A	8 ± 0.025 mm (0.315 ± 0.001 in.)
Specimen, Type B	5 ± 0.05 mm (0.197 ± 0.002 in.)
Finish	63 µin. (1.6 µm) max on notched surface and opposite face; 125 µin. (3.2 µm) max on other two surfaces

FIG. 11 Simple Beam Impact Test Specimens, Types A and B.



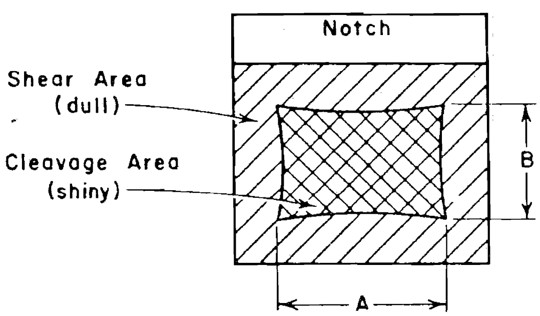
All dimensional tolerances shall be ± 0.05 mm (0.002 in.) unless otherwise specified.

NOTE 1—A shall be parallel to B within 2:1000 and coplanar with B within 0.05 mm (0.002 in.).

NOTE 2—C shall be parallel to D within 20:1000 and coplanar with D within 0.125 mm (0.005 in.).

NOTE 3—Finish on unmarked parts shall be 4 μm (125 μin.

FIG. 12 Charpy (Simple-Beam) Impact Test.



NOTE 1—Measure average dimensions *A* and *B* to the nearest 0.02 in. or 0.5 mm.

NOTE 2—Determine the percent shear fracture using Table 4 or Table 5.

FIG. 14 Determination of percent Shear Fracture.

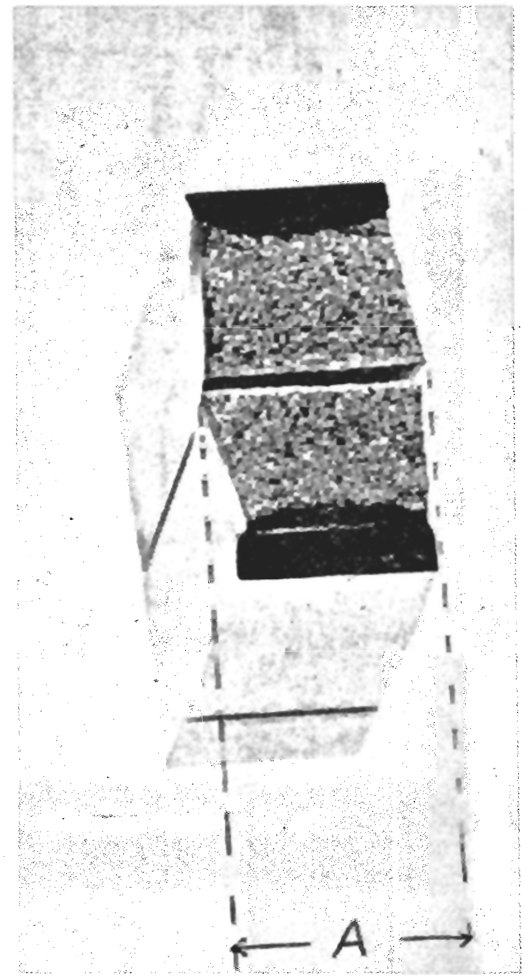


FIG. 13 Halves of Broken Charpy V-Notch Impact Specimen Joined for the Measurement of Lateral Expansion, Dimension *A*.

Removed

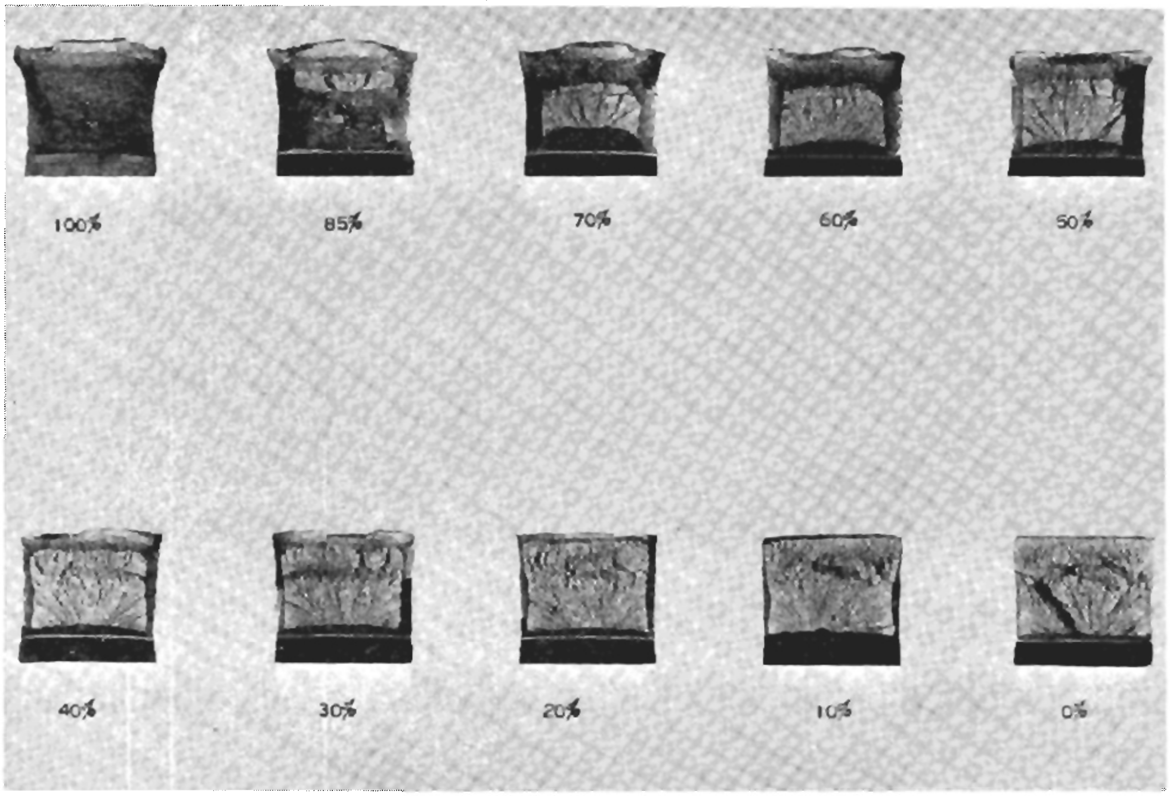


FIG. 15 Fracture Appearance Charts and percent Shear Fracture Comparator.

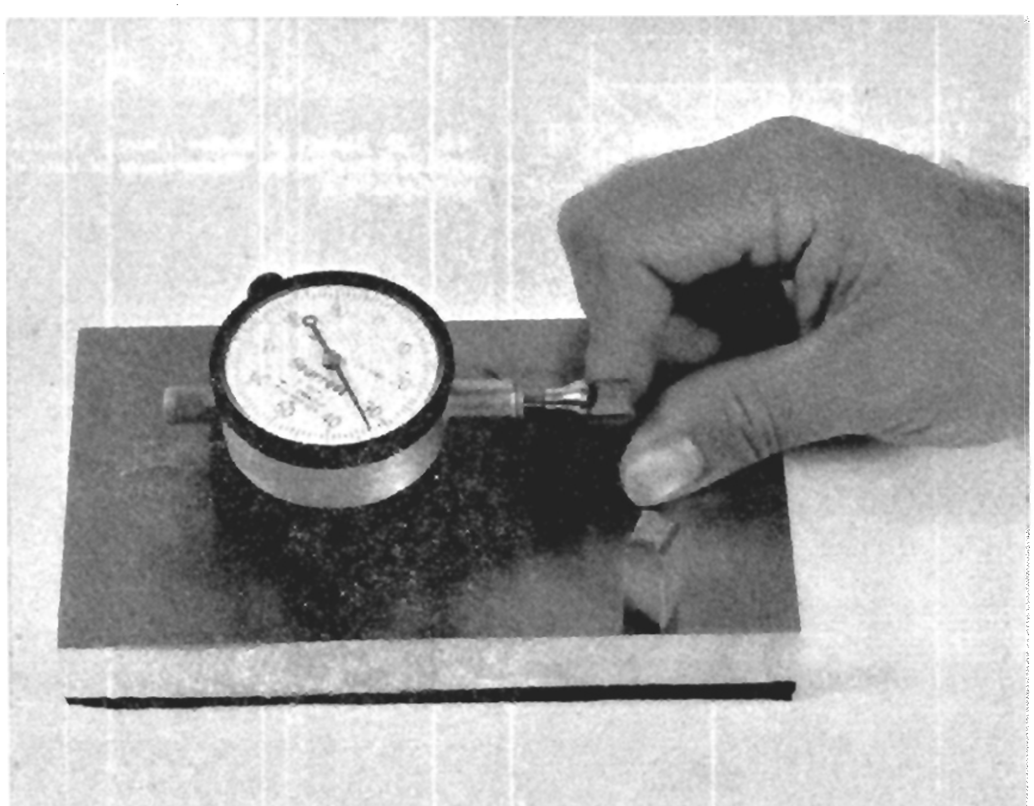
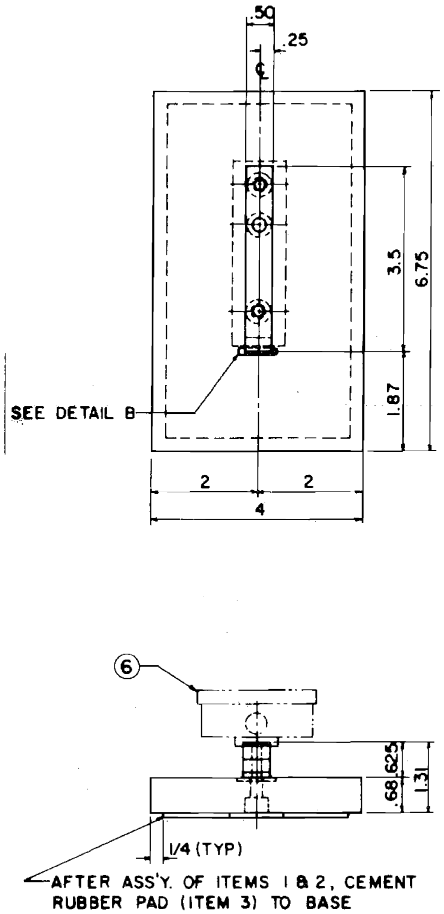
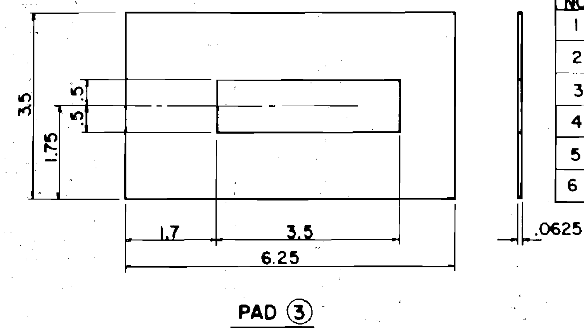


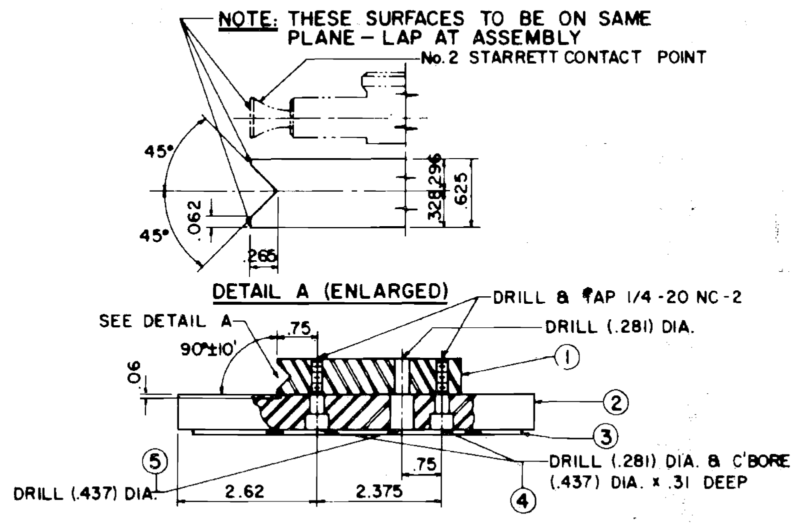
FIG. 16 Lateral Expansion Gage for Charpy Impact Specimens.

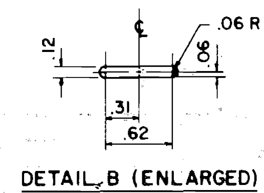
ASTM Logo Removed

BILL OF MATERIAL			
ITEM NO.	QUAN.	DESCRIPTION	MATERIAL AND SIZE
1	1	DIAL MOUNT & STOP 4×5/8×1/2	STEEL SAE 1015-1020
2	1	BASE PLATE 7×4×3/4	STEEL SAE 1015-1020
3	1	PAD 6-1/4×3-1/2×1/16	RUBBER
4	2	SCREW-SOCKET HEAD CAP	STEEL 1/4-20×1" LG.
5	1	SCREW-SOCKET HEAD CAP	STEEL 1/4-20×3/4" LG.
6	1	DIAL INDICATOR	(SEE NOTE 2)









NOTES:

1.) FLASH CHROME PLATE ITEMS 1 & 2

2.) DIAL INDICATOR – STARRETT NO. 25-241
RANGE .001 – .250
BACK-ADJUSTABLE BRACKET
CONTACT POINT NO. 2

FIG. 17 Assembly and Details for Lateral Expansion Gage.

ASTM Logo Removed

A 370

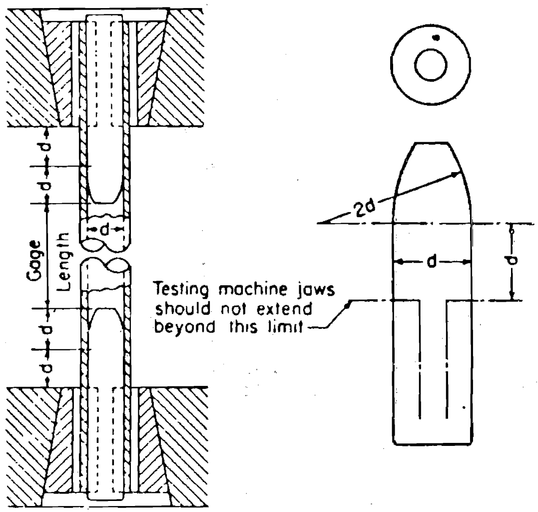


FIG. 18 Metal Plugs for Testing Tubular Specimens, Proper Location of Plugs in Specimen and of Specimen in Heads of Testing Machine.

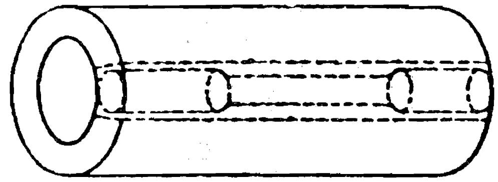
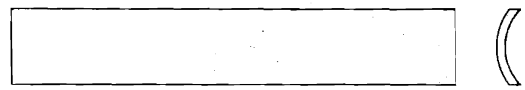
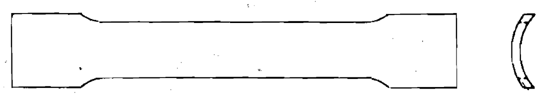


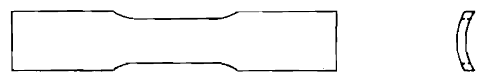
FIG. 19 Location of Longitudinal Tension Test Specimens in Large Diameter Tubing.



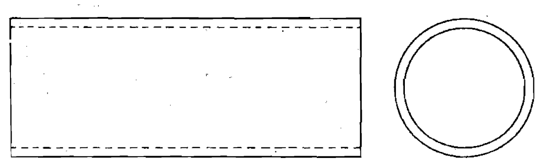
(*a*) Specimen for 8-in. Gage Length Test (Welded Only).



(*b*) Specimen for 8-in. Gage Length Test.

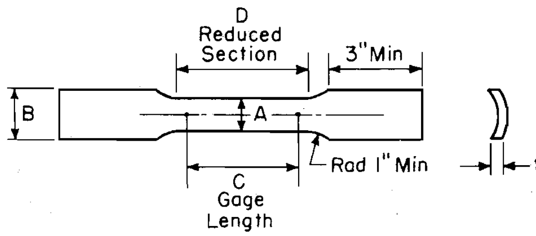


(*c*) Specimen for 2-in. Gage Length Test.



(*d*) Specimen for Full-Section Test.

FIG. 20 Longitudinal Tension Test Specimens for Large Diameter Tubing.



DIMENSIONS

Specimen No.	Dimensions, in.			
	A	*B*	*C*	*D*
1	½ ± 0.015	†11/16 approximately	2 ± 0.005	2¼ min
2	¾ ± 0.031	1 approximately	2 ± 0.005	2¼ min
			4 ± 0.005	4½ min
3	1 ± 0.062	1½ approximately	2 ± 0.005	2¼ min
			4 ± 0.005	4½ min
4	1½ ± ⅛	2 approximately	2 ± 0.010	2¼ min
			4 ± 0.015	4½ min
			8 ± 0.020	9 min

† Editorially corrected.

NOTE 1—Cross-sectional area may be calculated by multiplying *A* and *t*.

NOTE 2—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.

NOTE 3—The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center, with the ends not more than 0.010 in. wider than the center.

NOTE 4—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.

NOTE 5—Metric equivalent: 1 in. = 25.4 mm.

FIG. 21 Dimensions and Tolerances for Longitudinal Tension Test Specimens for Large Diameter Tubing.

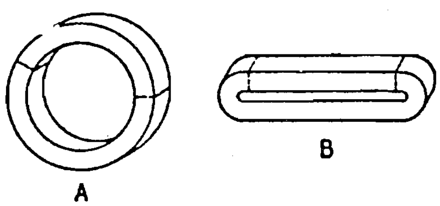


FIG. 22 Location of Transverse Tension Test Specimens in Ring Cut from Tubular Products.

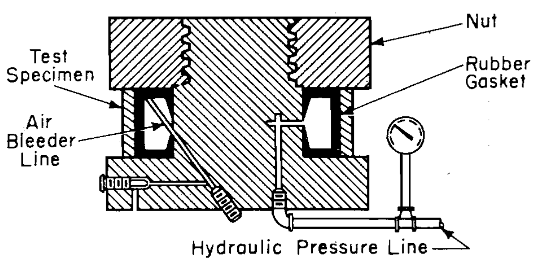
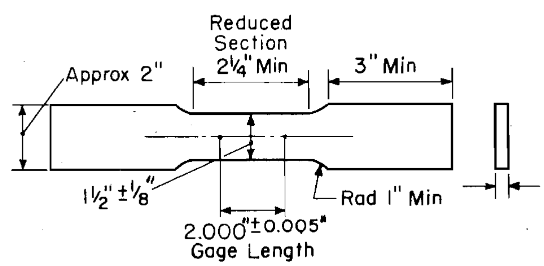


FIG. 24 Testing Machine for Determination of Transverse Yield Strength from Annular Ring Specimens.



NOTE 1—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.

NOTE 2—The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center, with the ends not more than 0.010 in. wider than the center.

NOTE 3—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.

NOTE 4—Metric equivalent: 1 in. = 25.4 mm.

FIG. 23 Transverse Tension Test Specimen Machined from Ring Cut from Tubular Products.

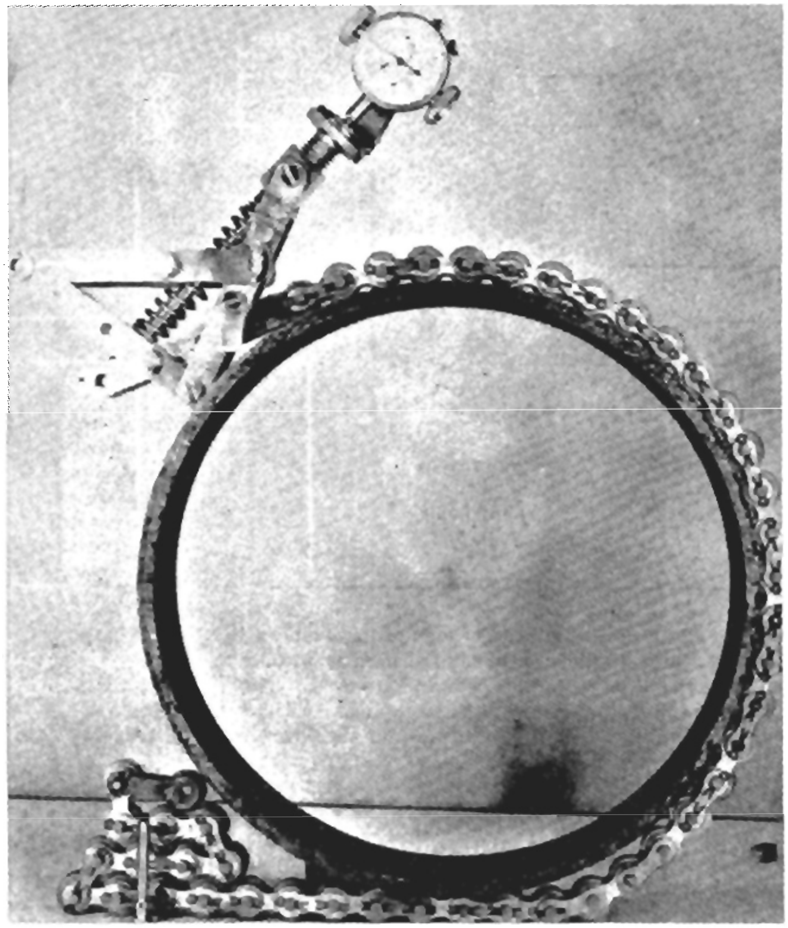


FIG. 25 Roller Chain Type Extensometer, Unclamped.

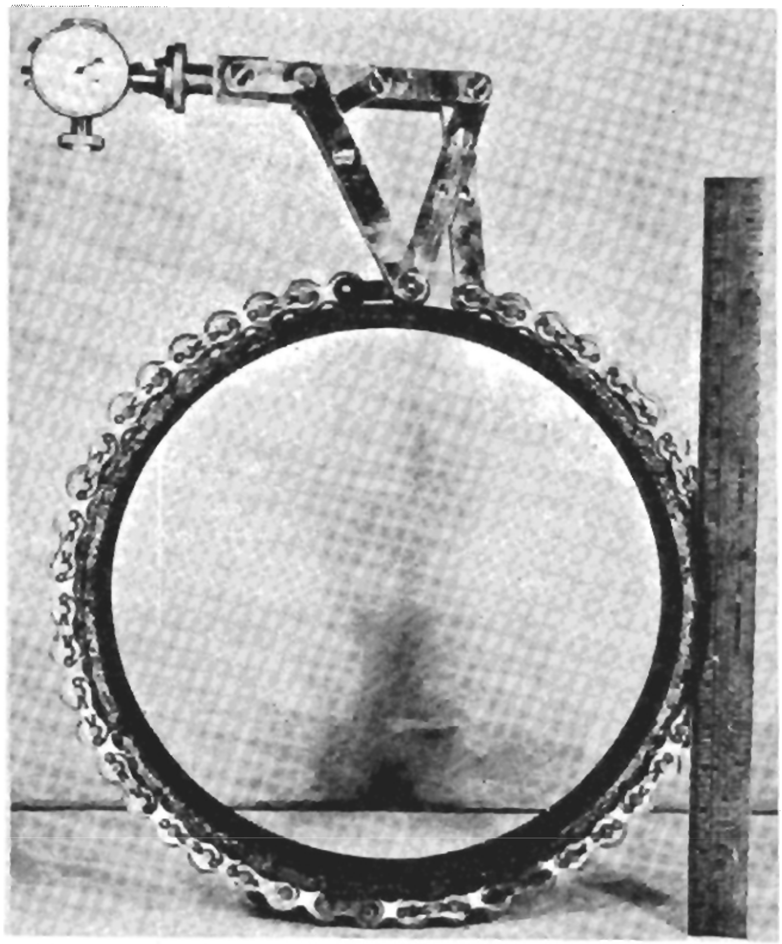


FIG. 26 Roller Chain Type Extensometer, Clamped.

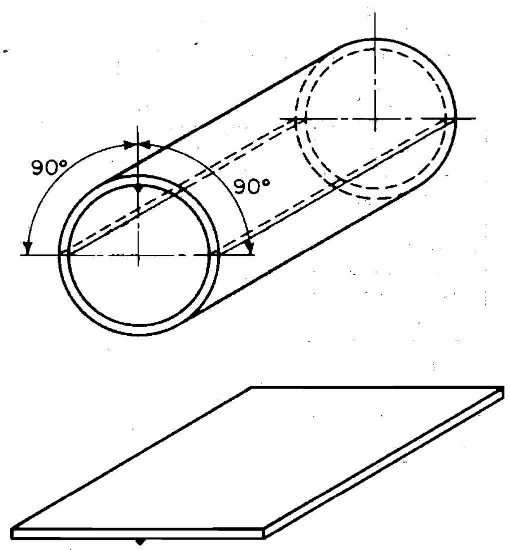


FIG. 27 Reverse Flattening Test.

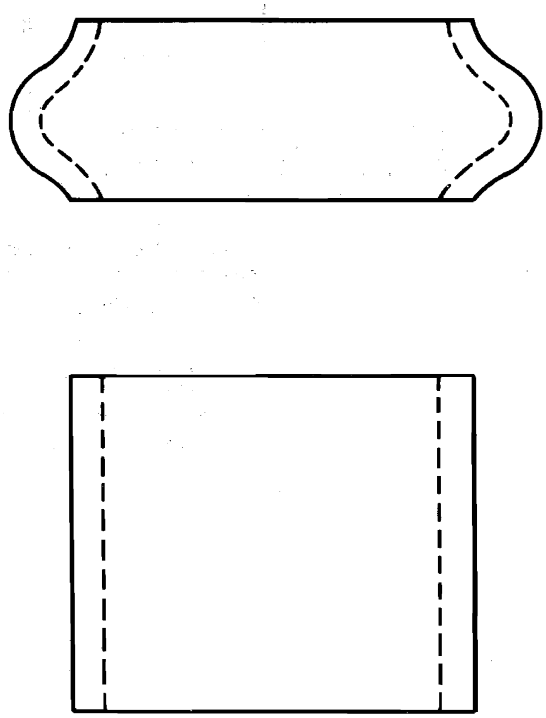
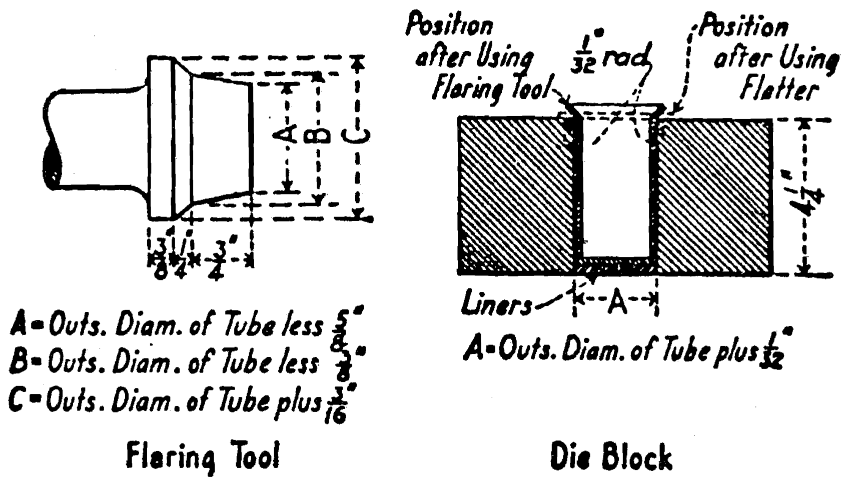


FIG. 28 Crush Test Specimen.



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

FIG. 29 Flaring Tool and Die Block for Flange Test.

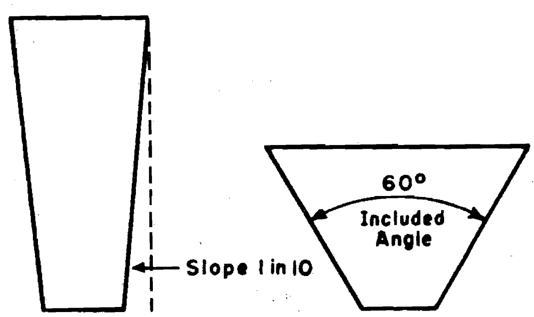
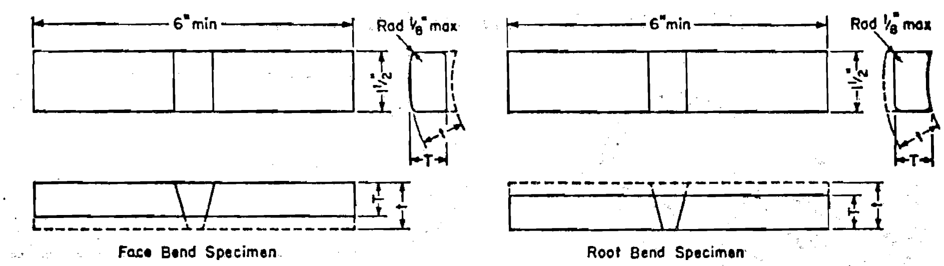


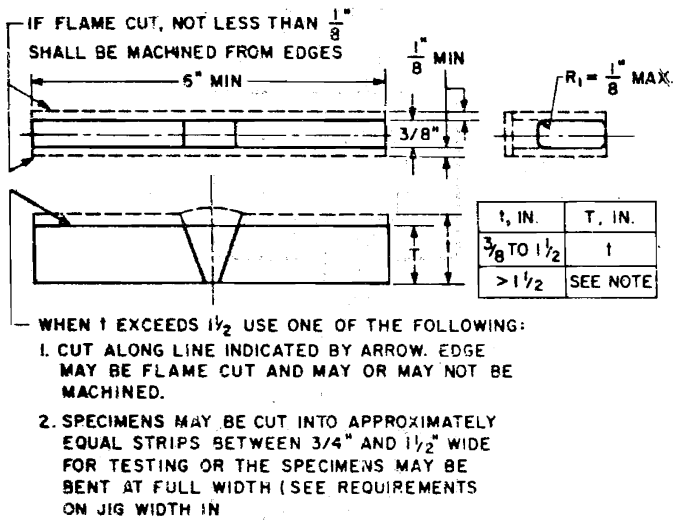
FIG. 30 Tapered Mandrels for Flaring Test.



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

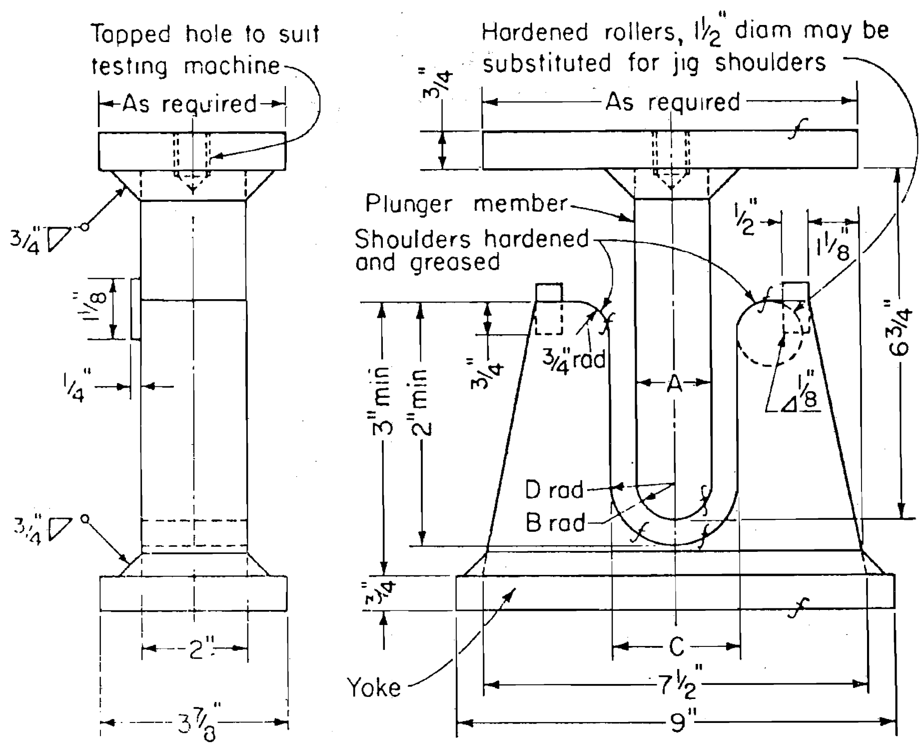
Pipe Wall Thickness (t), in.	Test Specimen Thickness, in.
Up to 3/8, incl	t
Over 3/8	3/8

FIG. 31(a) Transverse Face- and Root-Bend Test Specimens



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

FIG. 31(*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	1³⁄₁₆
t	$4t$	$2t$	$6t + ⅛$	$3t + ¹⁄₁₆$

FIG. 32 Guided-Bend Test Jig.

ASTM Logo Removed

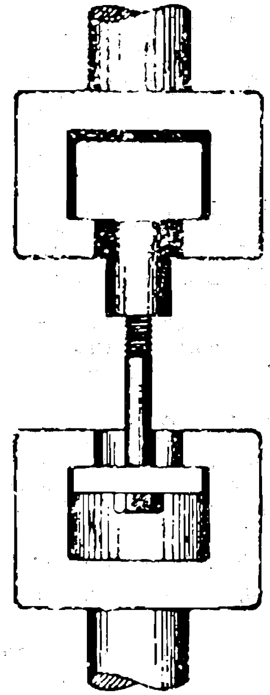
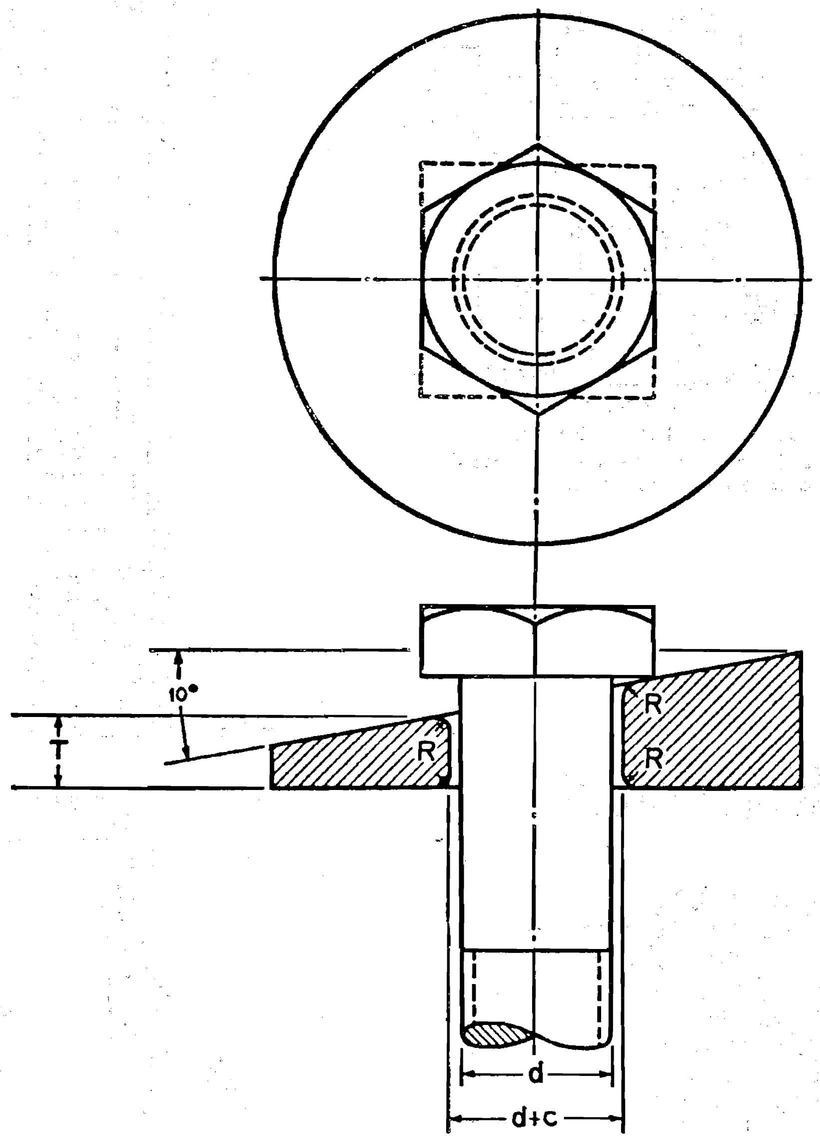
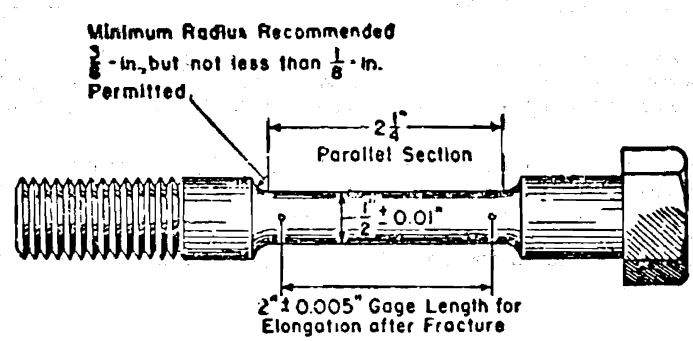


FIG. 33 Tension Testing Full-Size Bolt.



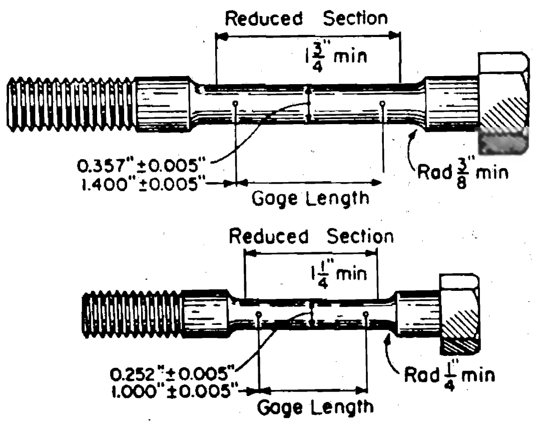
c = Clearance of wedge hole.
d = Diameter of bolt.
R = Radius.
T = Thickness of wedge at short side of hole equal to one-half diameter of bolt.

FIG. 34 Wedge Test Details.



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

FIG. 35 Tension Test Specimen for Bolt with Turned-Down Shank.



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

FIG. 36 Examples of Small Size Specimens Proportional to Standard 2-in. Gage Length Specimen.

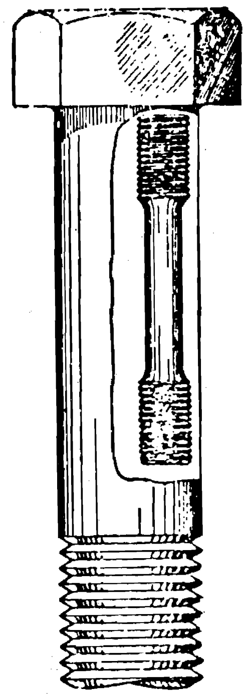


FIG. 37 Location of Standard Round 2-in. Gage Length Tension Test Specimen When Turned from Large Size Bolt.

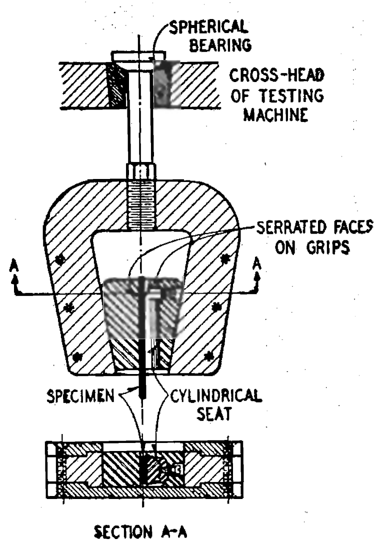


FIG. 38 Wedge-Type Gripping Device.

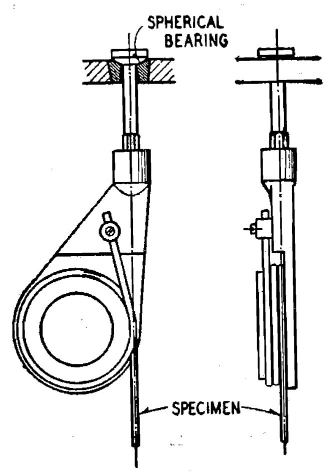


FIG. 39 Snubbing-Type Gripping Device.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A441: High-Strength Low-Alloy Structural Manganese Vanadium Steel

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Remov

AMERICAN NATIONAL STANDARD ANSI/ASTM A 441 – 79

American Association State Highway and Transportation Officials Standard
AASHTO No.: M 188

Standard Specification for
HIGH-STRENGTH LOW-ALLOY STRUCTURAL MANGANESE VANADIUM STEEL[1]

This Standard is issued under the fixed designation A 441; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers high-strength low alloy structural steel shapes, plates, and bars for welded, riveted, or bolted construction but intended primarily for use in welded bridges and buildings where saving in weight or added durability are important. The atmospheric corrosion resistance of this steel is approximately twice that of structural carbon steel. This specification is limited to material up to 8 in. (203 mm) incl. in thickness.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

2. General Requirements for Delivery

2.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 6 for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use.[2]

3. Process

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

4. Chemical Requirements

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

4.2 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6.

5. Tensile Requirements

5.1 The material as represented by the test specimens shall conform to the tensile properties prescribed in Table 2.

5.2 For material under 5/16 in. (7.94 mm) in thickness or diameter, as represented by the test specimen, a deduction of 1.25% from the percentage of elongation in 8 in. or 200 mm specified in Table 2 shall be made for each decrease of 1/32 in. (0.79 mm) of the specified thickness or diameter below 5/16 in.

---

[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 Nov. 5, 1979. Published January 1980. Originally published as A 441 – 60 T. Last previous edition A 441 – 77.

[2] *Annual Book of ASTM Standards*, Part 4.

SUPPLEMENTARY REQUIREMENTS

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

S14. Bend Test.

S18. Maximum Tensile Strength.

TABLE 1 Chemical Requirements

	Heat Analysis, %
Carbon, max	0.22
Manganese	0.85–1.25
Phosphorus, max	0.04
Sulfur, max	0.05
Silicon, max	0.40
Copper, min	0.20
Vanadium, min	0.02

TABLE 2 Tensile Requirements

	Plates and Bars[a]				Structural Shapes[b]		
	For Thicknesses ¾ in. (19 mm) and under	For Thicknesses over ¾ to 1½ in. (19 to 38 mm), incl	For Thicknesses over 1½ to 4 in. (38 to 102 mm), incl	For Thicknesses over 4 to 8 in. (102 to 203 mm), incl	Groups 1 and 2	Group 3	Groups 4 and 5
Tensile strength min, psi (MPa)[c]	70 000 (485)	67 000 (460)	63 000 (435)	60 000 (415)	70 000 (485)	67 000 (460)	63 000 (435)
Yield point min, psi (MPa)[c]	50 000 (345)	46 000 (315)	42 000 (290)	40 000 (275)	50 000 (345)	46 000 (315)	42 000 (290)
Elongation in 8 in. or 200 mm, min, %	18[d,e,f]	18[e,f]	18[e,f]	...	18[d]	18	18
Elongation in 2 in. or 50 mm, min, %	...	21[e,f]	21[e,f]	21[e,f]	...	...	21[g]

[a] For plates wider than 24 in. (610 mm), the test specimen is taken in the transverse direction. See 11.2 of Specification A 6.

[b] See Specification A 6, Table A.

[c] When the material is normalized the minimum yield point and minimum tensile strength required shall be reduced 5000 psi (35 MPa).

[d] See 5.2.

[e] Elongation not required to be determined for floor plate.

[f] For plates wider than 24 in. (610 mm), the elongation requirement is reduced two percentage points.

[g] For wide flange shapes over 426 lb/ft elongation in 2 in. or 50 mm of 19% minimum applies.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A449: Quenched and Tempered Steel Bolts and Studs

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD ANSI/ASTM A 449 – 78a

Standard Specification for
QUENCHED AND TEMPERED STEEL BOLTS AND STUDS[1]

This standard is issued under the fixed designation A 449; 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.

1. Scope

1.1 This specification covers the chemical and mechanical requirements for quenched and tempered, medium carbon steel bolts and studs 3 in. and under in diameter for general applications where high strength is required.

1.2 Suitable nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut shall be as follows:

Fastener Size and Surface Finish	Nut Grade and Style[A]
¼ to 1½ in., plain (or with a coating of insufficient thickness to require over-tapped nuts)	B, hex
over 1½ to 3 in., plain (or with a coating of insufficient thickness to require over-tapped nuts)	A, heavy hex
¼ to 3 in., galvanized (or with a coating thickness requiring over-tapped nuts)	C, heavy hex

[A] Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are suitable.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware[2]

A 370 Methods and Definitions for Mechanical Testing of Steel Products.[3]

A 563 Specification for Carbon and Alloy Steel Nuts[4]

2.2 *American National Standards:*[5]

ANSI B1.1 Unified Screw Threads

ANSI B18.2.1 Square and Hex Bolts and Screws

3. Material and Manufacture

3.1 Steel for bolts and studs shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

3.2 The bolts and studs shall be heat treated by quenching in a liquid medium from above the transformation temperature and then tempering by reheating to a temperature of not less than 800°F (427°C).

3.3 Threads of bolts and studs shall be rolled, cut, or ground.

3.4 When specified, galvanized fasteners shall be hot-dip galvanized in accordance with the requirements of Class C of Specification A 153. When specified by the purchaser to be mechanically galvanized, fasteners covered by this specification shall be mechanically zinc-coated, and the coating shall conform to requirements for Class 50 of Specification B 454, or to the coating thickness, adherence, and quality requirements for Class C of Specification A 153.

NOTE 2—When the intended application requires that assembled tension exceeds 50 % of minimum bolt or stud proof load, an anti-galling lubricant may be needed. Application of such a lubricant to nuts and a test of the lubricant efficiency are provided in Supplementary Requirement S1 of Specification A 563 and should be specified when required.

4. Chemical Requirements

4.1 The bolts and studs shall conform to requirements as to the chemical composition specified in Table 1.

4.2 Product analyses may be made by the

[1] This specification is under the jurisdiction of ASTM Committee F-16 on Fasteners, and is the direct responsibility of Subcommittee F 16.02 on Steel Bolting.

Current edition approved Sept. 29 and Oct. 27, 1978. Published December 1978. Originally published as A 449 – 63 T. Last previous edition A 449 – 77.

[2] *Annual Book of ASTM Standards,* Part 3.

[3] *Annual Book of ASTM Standards,* Parts 1 to 5 and 10.

[4] *Annual Book of ASTM Standards,* Parts 1 and 4.

[5] May be obtained from American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ASTM Logo Removed

purchaser from finished material representing each lot. The chemical composition thus determined shall conform to the requirements prescribed for product analysis in Table 1.

4.3 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5. Mechanical Requirements

5.1 Bolts and studs shall not exceed the maximum hardness specified in Table 2. Bolts less than three diameters in length and studs less than four diameters in length shall have hardness values not less than the minimum nor more than the maximum hardness limits required in Table 2, as hardness is the only requirement.

5.2 Bolts and studs 1¼ in. in diameter or less, other than those excepted in 4.1, shall be tested full size and shall conform to the tensile strength and either the proof load or yield strength requirements specified in Tables 3 and 4.

5.3 Bolts and studs larger than 1¼ in. in diameter as above, other than those excepted in 5.1, shall preferably be tested full size and when so tested, shall conform to the tensile strength and either the proof load or yield strength requirements specified in Tables 3 or 4 respectively. When equipment of sufficient capacity for full-size testing is not available, or when the length of the bolt or stud makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements of Table 5. In the event that bolts are tested by both full size and by the machined test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

5.4 For bolts and studs on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence over low readings of hardness tests.

6. Dimensions

6.1 Unless otherwise specified, the bolts shall be finished hexagon head with dimensions conforming to the latest issue of ANSI B18.2.1.

6.2 Studs shall have dimensions conforming to those specified by the purchaser.

6.3 Unless otherwise specified, threads shall be Coarse Thread Series as specified in the latest issue of ANSI B1.1, and shall have Class 2A tolerances.

6.4 Unless otherwise specified, bolts to be used with nuts or tapped holes that have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot dip or mechanical galvanizing. After galvanizing, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

Diameter, in.	Oversize Limit, in. (mm)[A]
Up to 7/16, incl	0.016(0.41)
Over 7/16 to 1, incl	0.021(0.53)
Over 1	0.031(0.79)

[A] These values are the same as the minimum overtapping required for galvanized nuts in Specification A 563.

6.5 The gaging limit for bolts shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown above. In case of dispute, a calibrated thread ring gage of that same size (Class X tolerance, gage tolerance plus) is to be used. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, are to be performed at the frequency and quality described in Table 6.

7. Test Methods

7.1 Bolts and studs shall be tested in accordance with Supplement III of Methods A 370.

7.2 The wedge test shall be applicable only to square and hexagon head bolts.

7.3 Studs shall be tested by the Axial Tension Method as described in S11.1.3.1, Supplement III of Methods A 370.

8. Number of Tests and Retests

8.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

8.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

8.3 When testing on a lot basis is specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material of one type, that is, bolts or studs having the same nominal diameter and length offered for inspection at one time. From each lot, the number of tests for each specified property shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and less	1
Over 800 to 8 000, incl	2
Over 8 000 to 22 000, incl	3
Over 22 000	5

8.4 Should any sample fail to meet the requirements of a specified test, double the original number of samples from the same lot shall be retested for the requirement(s) in which it failed. All the additional samples shall conform to the specification or the lot shall be rejected.

8.5 If any test specimen shows defective machining, it may be discarded and another specimen substituted.

9. Workmanship

9.1 The bolts and studs shall be commercially smooth and free from burrs, laps, seams, cracks, and other injurious material or manufacturing defects which would make them unsuitable for the intended application.

10. Marking

10.1 Bolt heads shall be marked with 3 radial lines 120 deg apart and with a symbol identifying the manufacturer. Markings may be raised or depressed at the option of the manufacturer.

11. Inspection

11.1 If the inspection described in 8.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

11.2 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of manufacturer's works that concern the manufacture and testing of the material ordered. The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

12. Rejection

12.1 Rejections based on requirements specified herein shall be reported to the manufacturer within 30 days after receipt of material by the purchaser.

TABLE 1 Chemical Requirements

	Composition, %	
	Heat Analysis	Product Analysis
Carbon	0.28–0.55	0.25–0.58
Manganese, min	0.60	0.57
Phosphorus, max	0.040	0.048
Sulfur, max	0.050	0.058

TABLE 2 Hardness Requirements

Bolt or Stud Diameter, in.	Hardness	
	Brinell Hardness Number	Rockwell C
¼ to 1, incl	255 to 321	25 to 34
Over 1 to 1½, incl	223 to 285	19 to 30
Over 1½ to 3, incl	183 to 235	...

ASTM Logo Removed

A 449

TABLE 3 Tensile Requirements for Coarse-Thread Full-Size Bolts and Studs

Bolt or Stud Diameter, in.	Threads per inch[A]	Stress Area, in.[2B]	Tensile Load, min, lbf[C]	Proof Load, Length Measurement Method, lbf[C]	Alternative Proof Load, Yield Strength Method (0.2 % Off-set), lbf[C]
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
¼	20	0.0318	3 800	2 700	2 900
5⁄16	18	0.0524	6 300	4 450	4 800
⅜	16	0.0775	9 300	6 600	7 100
7⁄16	14	0.1063	12 750	9 050	9 800
½	13	0.1419	17 050	12 050	13 050
9⁄16	12	0.182	21 850	15 450	16 750
⅝	11	0.226	27 100	19 200	20 800
¾	10	0.334	40 100	28 400	30 700
⅞	9	0.462	55 450	39 250	42 500
1	8	0.606	72 700	51 500	55 750
1⅛	7	0.763	80 100	56 450	61 800
1¼	7	0.969	101 700	71 700	78 500
1⅜	6	1.155	121 300	85 450	93 550
1½	6	1.405	147 500	104 000	113 800
1¾	5	1.90	171 000	104 500	110 200
2	4½	2.50	225 000	137 500	145 000
2¼	4½	3.25	292 500	178 750	188 500
2½	4	4.00	360 000	220 000	232 000
2¾	4	4.93	443 700	271 150	286 000
3	4	5.97	537 300	328 350	346 200

[A] For 8 threads per inch in sizes 1⅛ to 1½ in., incl, stresses of 105,000 psi (725 MPa), 74,000 psi (510 MPa), and 81,000 psi (560 MPa) shall be used for calculating the values in columns 4, 5, and 6 respectively.

[B] Stress area calculated from the formula:

$$A_s = 0.7854\,[D - 0.9743/n)]^2$$

where:
A_s = stress area,
D = nominal diameter, and
n = threads per inch.

[C] Values tabulated are based on the following:

Bolt Size, in.	Column 4, psi (MPa)	Column 5, psi (MPa)	Column 6, psi (MPa)
¼ to 1, incl	120 000 (825)	85 000 (585)	92 000 (635)
1⅛ to 1½, incl	105 000 (725)	74 000 (510)	81 000 (560)
1¾ to 3, incl	90 000 (620)	55 000 (380)	58 000 (400)

ASTM Logo Removed

TABLE 4 Tensile Requirements for Fine-Thread Full-Size Bolts and Studs

Bolt or Stud Diameter, in.	Threads per inch	Stress Area, in.^{2} [A]	Tensile Load, min, lbf [B]	Proof Load, Length Measurement Method, lbf [B]	Alternative Proof Load, Yield Strength Method (0.2 % Off-set), min, lbf [B]
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
¼	28	0.0364	4 350	3 100	3 500
5⁄16	24	0.0580	6 950	4 950	5 350
⅜	24	0.0878	10 550	7 450	8 100
7⁄16	20	0.1187	14 500	10 100	10 900
½	20	0.1599	19 200	13 600	14 700
9⁄16	18	0.203	24 350	17 250	18 700
⅝	18	0.256	30 700	21 750	23 500
¾	16	0.373	44 750	31 700	34 300
⅞	14	0.509	61 100	43 250	46 800
1	12	0.663	79 550	56 350	61 000
1⅛	12	0.856	89 900	63 350	69 350
1¼	12	1.073	112 650	79 400	86 900
1⅜	12	1.315	138 100	97 300	106 500
1½	12	1.581	166 000	117 000	128 000

[A] See footnote [B] below Table 3.
[B] See footnote [C] below Table 3.

TABLE 5 Tensile Requirements for Specimens Machined from Bolts and Studs

Bolt or Stud Diameter, in.	Tensile Strength, min, psi (MPa)	Yield Strength, min, psi (MPa)	Elongation in 4 *D* min, %	Reduction of Area, min, %
¼ to 1, incl	120 000 (825)	92 000 (635)	14	35
Over 1 to 1½, incl	105 000 (725)	81 000 (560)	14	35
Over 1½ to 3, incl	90 000 (620)	58 000 (400)	14	35

TABLE 6 Sample Sizes and Acceptance Numbers for Inspection of Hot Dip or Mechanically Galvanized Threads

Lot Size	Sample Size [A, B]	Acceptance Number [A]
2 to 90	13	1
91 to 150	20	2
151 to 280	32	3
281 to 500	50	5
501 to 1 200	80	7
1 201 to 3 200	125	10
3 201 to 10 000	200	14
10 001 and over	315	21

[A] Sample sizes of acceptance numbers are extracted from "Single Sampling Plan for Normal Inspection" Table IIA, MIL-STD-105D.
[B] Inspect all bolts in the lot if the lot size is less than the sample size.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A475: Standard Specification for Zinc-Coated Steel Wire Strand

CFR Section(s): 7 CFR 1755.370(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: A 475 – 78 (Reapproved 1984)$^{\epsilon 1}$

Standard Specification for Zinc-Coated Steel Wire Strand[1]

This standard is issued under the fixed designation A 475; 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 specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

$^{\epsilon 1}$ NOTE—Section 2 was added editorially and subsequent sections were renumbered in April 1984.

1. Scope

1.1 This specification covers five grades of zinc-coated, steel wire strand, composed of a number of round, steel wires, with four weights of zinc coatings, suitable for use as guys, messengers, span wires, and for similar purposes.

1.2 The five grades covered are as follows:

1.2.1 Utilities,

1.2.2 Common,

1.2.3 Siemens-Martin,

1.2.4 High-Strength, and

1.2.5 Extra High-Strength.

1.2.6 Minimum breaking strengths of strand for each grade are specified in Table 1.

1.3 The four weights of zinc coatings are: Type 1 and Classes A, B, and C. Minimum weights of zinc coatings are specified in Table 4.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 90 Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles[2]

B 6 Specification for Zinc (Slab Zinc)[3]

3. Description of Strand

3.1 The designation of the finished strand shall be expressed as the nominal diameter of the strand, the number of the wires in the strand, and the minimum breaking strength of the strand as prescribed in Table 1, and the type or class of coating as prescribed in Table 4.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity of strand in feet,

4.1.2 Nominal strand diameter, number of wires, grade, and minimum breaking strength of strand (Section 8 and Table 1),

4.1.3 Weight (type and class) of zinc-coating (Section 12 and Table 4), and

4.1.4 Length of strand in coils or on reels (Section 17).

5. Material

5.1 The base metal shall be steel made by the open-hearth, basic-oxygen, or electric-furnace process and of such quality and purity that, when drawn to the size of wire specified and coated with zinc, the finished strand and the individual wires shall be of uniform quality and have the properties and characteristics as prescribed in this specification.

5.2 The slab zinc, when used for the coating, shall be any grade of zinc conforming to Specification B 6.

6. Stranding

6.1 Unless otherwise specified, strand shall have a left lay. A left lay is defined as a counter-clockwise twist away from the observer. All wires shall be stranded with uniform tension. Stranding shall be sufficiently close to ensure no appreciable reduction in diameter when stressed to 10 % of the specified strength.

6.2 The 3-wire strand shall consist of three wires concentrically twisted with a uniform pitch of not less than 14 nor more than 20× the specified nominal diameter of the strand.

6.3 The 7-wire strand shall consist of a center wire with a 6-wire layer concentrically twisted over it with a uniform pitch of not more than 16× the specified nominal diameter of the strand.

6.4 The 19-wire strand shall consist of a center wire with a 6-wire layer concentrically twisted over it, having a right lay and a uniform pitch of not more than 16× the nominal diameter of this 7-wire core. The nominal diameter of this 7-wire core shall be considered to be 3× the nominal diameter of the wires. A 12-wire outer layer, having a left lay shall be concentrically twisted over the 7-wire core and shall have a uniform pitch of not more than 16× the specified nominal diameter of the strand.

6.5 The 37-wire strand shall consist of a center wire with a 6-wire layer concentrically twisted over it, having a left lay and a uniform pitch of not more than 16× the nominal diameter of this 7-wire inner core. The nominal diameter of this 7-wire inner core shall be considered to be 3× the nominal diameter of the wire. An intermediate layer of 12

[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 A05.12 on Wire Specifications.

Current edition approved March 31, 1978. Published May 1978. Originally published as A 475 – 62 T. Last previous edition A 475 – 72a (1976).

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

[3] *Annual Book of ASTM Standards*, Vols 02.03 and 02.04.

wires having a right lay shall be concentrically twisted over this 7-wire core and shall have a uniform pitch of not more than 16× the nominal diameter of this 19-wire core. The nominal diameter of this 19-wire core shall be considered as 5× the nominal diameter of the wires. An 18-wire outer layer, having a left lay shall be concentrically twisted over the 19-wire core and shall have a uniform pitch of not more than 16× the specified nominal diameter of the strand.

6.6 All wires in the strand shall lie naturally in their true positions in the completed strand and, when the strand is cut, the ends shall remain in position or be readily replaced by hand and then remain in position. This may be accomplished by any means or process, such as preforming, post forming or form setting.

7. Joints and Splices

7.1 Electric-welded butt joints made prior to the start of cold drawing of the wire are permitted.

7.2 In 3-wire strand, there shall be no joints made in the individual finished wire. In 7-wire strand, joints made in individual finished wires shall be acceptable provided there is not more than one joint in any 150-ft (45.7-m) section of the completed strand and the location of each joint is marked on the strand with paint or some other distinguishing mark. Factory joints made in the individual finished wires of 19 and 37-wire strand shall be kept well spaced and at a minimum in number.

7.3 Joints in the wires composing the strand shall be either the brazed-lap type or electric-butt-welded type. When the brazed type of joint is used, the length of the lap shall be not less than 3× the diameter of the wire and the overlapping faces shall be smooth, clean, properly fluxed, and completely covered by the brazing metal. When the electric-welded type of joint is used, care shall be taken to prevent injury to the wire during electric-butt welding. All joints shall be well made and shall be coated with zinc after completion so that the joints shall have protection from corrosion equivalent to that of the zinc-coated wire itself.

7.4 There shall be no strand joints or strand splices in any length of the completed strand unless specifically permitted by the purchaser.

8. Breaking Strength and Weight

8.1 The approximate weight per 1000 ft or 305 m, of strand, and the minimum breaking strength of the finished strand shall be as specified in Table 1.

8.2 A test in which the breaking strength is below the minimum specified and which may have been caused by the slipping of the specimen in the jaws of the testing machine, by breaking within the jaws or within 1 in. (25.4 mm) of the jaws, or by the improper socketing of a specimen shall be disregarded and another sample from the same coil or reel shall be tested. Tests shall be made on lengths of strand that do not contain wire joints or splices.

9. Elongation

9.1 The elongation of the strand in 24 in. (610 mm) shall be not less than that specified in Table 2.

9.2 The elongation shall be determined as the percent increase in separation between the jaws of the testing machine from the position after application of the initial load to the position at the initial failure in the test specimen. The separation of the jaws of the testing machine shall be approximately 2 ft when under an initial load equal to 10 % of the required minimum breaking strength of the strand. The elongation values shall be recorded only for specimens which break over 1 in. from the jaws of the testing machine. Additional samples shall be taken from the same coil or reel when the previous tests are to be disregarded.

9.3 Elongation tests shall be made on lengths of strand which do not contain wire joints of splices.

10. Permissible Variations in Size

10.1 The diameter of the zinc-coated wire forming the strand specified in Table 1 shall be within the limits prescribed in Table 3.

11. Sampling

11.1 Sampling for determination of compliance to this specification shall be performed on each lot of material. A lot shall consist of all the strand of one size and one grade in each shipment. The number of samples to be taken shall be as follows:

	Number of Samples
5000 ft (1524 m) or less	1
Over 5000 to 30 000 ft (1524 to 9144 m)	2
Over 30 000 to 150 000 ft (9144 to 45 720 m)	3
Over 150 000 ft (45 720 m)	4

11.2 Each sample taken shall be subjected to all tests prescribed in Sections 6, 8, and 9.

11.3 In addition to the strand testing in 11.2, the individual wires shall be tested. The number of individual wires to be selected from each sample of strand and tested to determine compliance with Sections 10, 12, 14, and 15 shhll be as follows:

3-wire strand—3 wires
7-wire strand—4 wires
19-wire strand—3 wires from each layer (total of 6 wires)
37-wire strand—3 wires from each layer (total of 9 wires)

NOTE 1—Individual wire samples selected for compliance to Section 10 shall be discarded if any distortion of the wire occurred during the stranding operation.

11.4 Instead of testing the wires from the completed strand in accordance with 11.3, the producer may elect to establish compliance with Sections 10, 12, 14, and 15 of this specification by tests made on the wires prior to stranding, unless otherwise stipulated by the purchaser. However, if the producer makes this election, the purchaser still reserves the right to test wires from the completed strand for compliance.

12. Weight of Coating

12.1 The weight of zinc-coating, in ounces per square foot or grams per square metre of uncoated wire surface, shall not be less than that specified in Table 4.

13. Tests of Coating

13.1 The weight of the zinc-coating shall be determined by a stripping test in accordance with Test Method A 90.

TABLE 1 Physical Properties of Zinc-Coated Steel Wire Strand

NOTE—The numbers in **boldface type** indicate sizes and grades most commonly used and readily available.

Nominal Diameter of Strand, in. (mm)	Number of Wires in Strand	Nominal Diameter of Coated Wires in Strand, in. (mm)	Approximate Weight of Strand, lb/1000 ft (kg/304.8 m)	Minimum Breaking Strength of Strand, lbf (kN): Utilities Grade[A]	Common Grade	Siemens-Martin Grade	High-Strength Grade	Extra High-Strength Grade
1/8 (3.18)	7	0.041 (1.04)	32 (15)	. . .	**540 (2.402)**	910 (4.048)	1 330 (5.916)	1 830 (8.140)
5/32 (3.97)	7	0.052 (1.32)	51 (23)	. . .	**870 (3.870)**	1 470 (6.539)	2 140 (9.519)	2 940 (13.078)
3/16 (4.76)	7	0.062 (1.57)	73 (33)	. . .	**1 150 (5.115)**	1 900 (8.452)	2 850 (12.677)	3 990 (17.748)
3/16 (4.76)	7	0.065 (1.65)	80 (36)	**2 400 (10.676)** (1)[B]	. . .	. . .	. . .	. . .
7/32 (5.56)	3	0.104 (2.64)	88 (40)	. . .	1 400 (6.228)	2 340 (10.409)	3 500 (15.569)	4 900 (21.796)
7/32 (5.56)	7	0.072 (1.83)	98 (44)	. . .	1 540 (6.850)	2 560 (11.387)	3 850 (17.126)	5 400 (24.020)
1/4 (6.35)	3	0.120 (3.05)	117 (53)	**3 150 (14.012)** (2)[B]	1 860 (8.274)	3 040 (13.523)	4 730 (21.040)	6 740 (29.981)
1/4 (6.35)	3	0.120 (3.05)	117 (53)	**4 500 (20.017)** (3)[B]	. . .	. . .	. . .	. . .
1/4 (6.35)	7	0.080 (2.03)	121 (55)	. . .	**1 900 (8.452)**	**3 150 (14.012)**	4 750 (21.129)	6 650 (29.581)
9/32 (7.14)	3	0.130 (3.30)	137 (62)	. . .	2 080 (9.252)	3 380 (15.035)	5 260 (23.398)	7 500 (33.362)
9/32 (7.14)	7	0.093 (2.36)	164 (74)	**4 600 (20.462)** (1)[B]	2 570 (11.432)	4 250 (18.905)	6 400 (28.469)	8 950 (39.812)
5/16 (7.94)	3	0.145 (3.68)	171 (78)	**6 500 (28.913)** (3)[B]	2 490 (11.076)	4 090 (18.193)	6 350 (28.246)	9 100 (40.479)
5/16 (7.94)	7	0.104 (2.64)	205 (93)	. . .	**3 200 (14.234)**	5 350 (23.798)	**8 000 (35.586)**	11 200 (49.820)
5/16 (7.94)	7	0.109 (2.77)	225 (102)	**6 000 (26.689)** (1)[B]	. . .	. . .	. . .	. . .
3/8 (9.52)	3	0.165 (4.19)	220 (100)	**8 500 (37.810)** (3)[B]	3 330 (14.813)	5 560 (24.732)	8 360 (37.187)	11 800 (52.489)
3/8 (9.52)	7	0.120 (3.05)	273 (124)	**11 500 (51.155)** (4)[B]	**4 250 (18.905)**	**6 950 (30.915)**	10 800 (48.040)	15 400 (68.503)
7/16 (11.11)	7	0.145 (3.68)	399 (181)	**18 000 (80.068)** (4)[B]	**5 700 (25.355)**	**9 350 (41.591)**	**14 500 (64.499)**	20 800 (92.523)
1/2 (12.70)	7	0.165 (4.19)	517 (234)	**25 000 (111.206)** (4)[B]	**7 400 (32.917)**	**12 100 (53.823)**	**18 800 (83.627)**	26 900 (119.657)
1/2 (12.70)	19	0.100 (2.54)	504 (229)	. . .	7 620 (33.895)	12 700 (56.492)	19 100 (84.961)	26 700 (118.768)
9/16 (14.29)	7	0.188 (4.78)	671 (304)	. . .	9 600 (42.703)	15 700 (69.837)	24 500 (108.981)	35 000 (155.688)
9/16 (14.29)	19	0.113 (2.87)	637 (289)	. . .	9 640 (42.881)	16 100 (71.616)	24 100 (107.202)	33 700 (149.905)
5/8 (1.588)	7	0.207 (5.26)	813 (369)	. . .	11 600 (51.599)	19 100 (84.961)	29 600 (131.667)	42 400 (188.605)
5/8 (15.88)	19	0.125 (3.18)	796 (361)	. . .	11 000 (48.930)	18 100 (80.513)	28 100 (124.995)	40 200 (178.819)
3/4 (19.05)	19	0.150 (3.81)	1 155 (524)	. . .	16 000 (71.172)	26 200 (116.543)	40 800 (181.487)	58 300 (259.331)
7/8 (22.22)	19	0.177 (4.50)	1 581 (717)	. . .	21 900 (97.416)	35 900 (159.691)	55 800 (248.211)	79 700 (354.523)
1 (25.40)	19	0.200 (5.08)	2 073 (940)	. . .	28 700 (127.664)	47 000 (209.066)	73 200 (325.610)	104 500 (464.839)
1 (25.40)	37	0.143 (3.63)	2 057 (933)	. . .	28 300 (125.885)	46 200 (205.508)	71 900 (319.827)	102 700 (456.832)
1 1/8 (28.58)	37	0.161 (4.09)	2 691 (1 221)	. . .	36 000 (160.136)	58 900 (262.000)	91 600 (407.457)	130 800 (581.827)
1 1/4 (31.75)	37	0.179 (4.55)	3 248 (1 473)	. . .	44 600 (198.391)	73 000 (324.720)	113 600 (505.318)	162 200 (721.502)

[A] The Utilities Grade is used principally by communication and power and light industries.
[B] Refer to elongation requirements specified in Section 9.

TABLE 2 Elongation Requirements for Grades of Strand

Grade of Strand	Elongation in 24 in. (610 mm), min, %
Utilities Grade (1)[A] and Common Strand	10
Utilities Grade (2)[A] and Siemens-Martin	8
Utilities Grade (3)[A] and High-Strength	5
Utilities Grade (4)[A] and Extra High-Strength	4

[A] See Table 1, Footnote *B*.

14. Adherence of Coating

14.1 The zinc-coated wire shall be capable of being wrapped at a rate not exceeding 15 turns/min in a close helix of at least two turns around a cylindrical mandrel equal to 3× the nominal diameter of the wire under test, without cracking or flaking the zinc coating to such an extent that any zinc can be removed by rubbing with the bare fingers.

NOTE 2—Loosening or detachment during the adhesion test of superficial, small particles of zinc formed by mechanical polishing of the surface of zinc-coated wire shall not be considered cause for rejection.

15. Ductility of Steel

15.1 The zinc-coated wire shall not fracture when wrapped at a rate not exceeding 15 turns/min in a close helix of at least 2 turns around a cylindrical mandrel. The mandrel diameter for testing Common and Siemens-Martin grade strand shall be equal to the nominal diameter of the individual wires of the strand. The mandrel diameter for Utilities, High-Strength, and Extra High-Strength grade strand, shall be equal to 3× the nominal diameter of the individual wires of the strand.

16. Finish

16.1 The zinc-coated wire shall be free of imperfections not consistent with good commercial practice. The zinc-coating shall be continuous and of reasonably uniform thickness.

17. Packaging and Marking

17.1 Wire strand shall be furnished in standard lengths (see 17.1.1) and in compact coils or on reels (see 17.1.2) as specified by the purchaser; otherwise lengths shall be as agreed upon at the time of purchase. Only one length of strand shall be furnished in each coil or on each reel. Lengths of strand may vary between the standard (nominal) length and 10 % over the standard (nominal) length, unless otherwise specified by the purchaser.

17.1.1 Standard lengths of strand are as follows: 250, 500, 1000, 2500, and 5000 ft (76, 152, 304, 760, and 1520 m).

TABLE 3 Permissible Variations in Diameter of Individual Zinc-Coated Wires

Nominal Diameter of Coated Wires in the Strand, in. (mm)	Permissible Variations, plus and minus, in. (mm)
0.041 to 0.060 (1.04 to 1.52)	0.002 (0.05)
0.061 to 0.090 (1.55 to 2.29)	0.003 (0.08)
0.091 to 0.120 (2.31 to 3.05)	0.004 (0.10)
0.121 and over (3.07 and over)	0.005 (0.13)

TABLE 4 Nominal Diameters and Minimum Weights of Coating for Zinc-Coated Steel Wires[A]

Nominal Diameter of Coated Wire in the Strand, in. (mm)	Minimum Weight of Coating, oz/ft^2 (g/m^2) of Uncoated Wire Surface			
	Type 1[B]	Class A[C]	Class B[D]	Class C[D]
0.041 (1.04)	0.15 (46)	0.40 (122)	0.80 (244)	1.20 (366)
0.052 (1.32)	0.15 (46)	0.40 (122)	0.80 (244)	1.20 (366)
0.062 (1.57)	0.15 (46)	0.50 (153)	1.00 (305)	1.50 (458)
0.065 (1.65)	0.15 (46)	0.50 (153)	1.00 (305)	1.50 (458)
0.072 (1.83)	0.15 (46)	0.50 (153)	1.00 (305)	1.50 (458)
0.080 (2.03)	0.30 (92)	0.60 (183)	1.20 (366)	1.80 (549)
0.093 (2.36)	0.30 (92)	0.70 (214)	1.40 (427)	2.10 (641)
0.100 (2.54)	0.30 (92)	0.70 (214)	1.40 (427)	2.10 (641)
0.104 (2.64)	0.30 (92)	0.80 (244)	1.60 (488)	2.40 (732)
0.109 (2.77)	0.30 (92)	0.80 (244)	1.60 (488)	2.40 (732)
0.113 (2.87)	0.30 (92)	0.80 (244)	1.60 (488)	2.40 (732)
0.120 (3.05)	0.30 (92)	0.85 (259)	1.70 (519)	2.55 (778)
0.125 (3.18)	0.30 (92)	0.85 (259)	1.70 (519)	2.55 (778)
0.130 (3.30)	0.30 (92)	0.85 (259)	1.70 (519)	2.55 (778)
0.143 (3.63)	0.40 (122)	0.90 (275)	1.80 (549)	2.70 (824)
0.145 (3.68)	0.40 (122)	0.90 (275)	1.80 (549)	2.70 (824)
0.150 (3.81)	0.40 (122)	0.90 (275)	1.80 (549)	2.70 (824)
0.161 (4.09)	0.40 (122)	0.90 (275)	1.80 (549)	2.70 (824)
0.165 (4.19)	0.40 (122)	0.90 (275)	1.80 (549)	2.70 (824)
0.177 (4.50)	0.40 (122)	0.90 (275)	1.80 (549)	2.70 (824)
0.179 (4.55)	0.40 (122)	0.90 (275)	1.80 (549)	2.70 (824)
0.188 (4.78)	0.40 (122)	1.00 (305)	2.00 (610)	3.00 (915)
0.200 (5.08)	0.40 (122)	1.00 (305)	2.00 (610)	3.00 (915)
0.207 (5.26)	0.40 (122)	1.00 (305)	2.00 (610)	3.00 (915)

[A] For intermediate sizes of wire in the strand, the weight designations are the same as for the next finer size shown in this table.
[B] Type 1 (formerly "Galvanized") coating applies to "Common" Grade of strand only.
[C] Class A, "Extra Galvanized" and "Double Galvanized" are equivalent terms.
[D] Class A, Class B, and Class C coatings apply to all grades of strand.

17.1.2 Standard practice is to furnish all strand 7⁄16 in. (11.11 mm) and over in diameter on reels in lengths of 1000 ft (304 m) and over. Strand lengths of less than 1000 ft are regularly furnished in coils.

17.2 Each coil or reel shall have a strong weather-resistant tag securely fastened to it showing the length, nominal diameter, number of wires, grade of the strand, type, or class of coating, ASTM designation A 475, and the name or mark of the manufacturer. If additional information is required on the tag, it shall be so specified at the time of purchase.

18. Inspection

18.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

19. Rejection

19.1 If the wire or strand fails in the first test to meet any requirement of this specification, two additional tests shall be made on samples of wire or strand from the same coil or reel. If failure occurs in either of these tests, the lot of wire or strand shall be rejected.

ASTM Logo Removed **A 475**

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A490: Quenched and Tempered Alloy Steel Bolts for Structural Steel Joints

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD

ANSI/ASTM A 490 - 79

American Association State Highway and Transportation Officials Standard
AASHTO No.: M 253

Standard Specification for
QUENCHED AND TEMPERED ALLOY STEEL BOLTS FOR STRUCTURAL STEEL JOINTS[1]

This standard is issued under the fixed designation A 490; 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.

This specification has been approved for use by agencies of the Department of Defense for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers the chemical and mechanical requirements of quenched and tempered alloy steel bolts, $^1/_2$ to $1^1/_2$ in., incl, in diameter. These bolts are intended for use in structural joints that are made under the Specification for Structural Joints Using ASTM A 325 or A 490 Bolts[2] issued by the Research Council on Riveted and Bolted Structural Joints of The Engineering Foundation. The various types of bolts covered by this specification are:

1.1.1 *Type 1*—Bolts made of alloy steel, supplied in sizes $^1/_2$ to $1^1/_2$ in., inclusive, in diameter.

1.1.2 *Type 2*—Bolts made from what is generally described as low-carbon martensite steel, supplied in sizes $^1/_2$ to 1 in., inclusive, in diameter.

1.1.3 *Type 3*—Bolts $^1/_2$ to $1^1/_2$ in., inclusive, in diameter having atmospheric corrosion resistance and weathering characteristics comparable to that of the steels covered in Specifications A 588, A 242, and A 709 (these steels have atmospheric corrosion resistance approximately two times that of carbon structural steel with copper.

1.2 When the bolt type is not specified Type 1 shall be supplied. Type 3 may be supplied by the manufacturer, if agreed upon by the purchaser.

1.3 When atmospheric corrosion resistance and weathering characteristics are required, Type 3 bolts should be specified by the purchaser.

1.4 Suitable nuts are covered in Specification A 563. Unless otherwise specified, Grade DH heavy hex nuts shall be furnished for use with Type 1 and Type 2 bolts. Grade 2H heavy hex nuts, as specified in Specification A 194 are acceptable alternatives. Grade DH3 heavy hex nuts as specified in Specification A 563 shall be furnished for use with Type 3 bolts.

1.5 Hardened washers are covered in Specification F 436. Unless otherwise specified, Type 3 weathering steel washers shall be furnished when Type 3 bolts are specified.

1.6 This specification provides that heavy hex structural bolts shall be furnished unless other dimensional requirements are stipulated in the purchase inquiry and order.

NOTE 1—For quenched and tempered alloy steel bolts, studs, and other externally threaded fasteners with diameters greater than $1^1/_2$ in., but with similar mechanical properties, refer to Grade BD of ASTM Specification A 354, for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners.[5]

2. Applicable Documents

2.1 *ASTM Standards:*

A 194 Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service[3]

A 242 Specification for High-Strength Low-Alloy Structural Steel[4]

A 325 Specification for High-Strength Bolts for Structural Steel Joints[4]

---

[1] This specification is under the jurisdiction of ASTM Committee F-16 on Fasteners, and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.

Current edition approved May 25, 1979. Published September 1979. Originally published as A 490-64. Last previous edition A 490-78.

[2] Published by the American Institute of Steel Construction, New York, N.Y.

[3] *Annual Book of ASTM Standards,* Part 1.

[4] *Annual Book of ASTM Standards,* Part 4.

ASTM Logo Removed **A 490**

A 370 Methods and Definitions for Mechanical Testing of Steel Products[5]
A 563 Specification for Carbon and Alloy Steel Nuts[3, 4]
A 588 Specification for High-Strength Low-Alloy Structural Steel with 50,000 psi Minimum Yield Point to 4 in. Thick[4]
A 709 Specification for Structural Steel for Bridges[4]
E 109 Dry Powder Magnetic Particle Inspection[6]
E 138 Wet Magnetic Particle Inspection[6]
F 436 Specification for Hardened Steel Washers for Use with High-Strength Bolts

2.2 *American National Standards:*[7]
B1.1 Unified Screw Threads
B18.2.1 Square and Hex Bolts and Screws
B18.2.2 Square and Hex Nuts

2.3 *Military Standard:*[8]
MIL-STD-105D Sampling Procedure and Tables for Inspection by Attributes

3. Definitions

3.1 Surface discontinuities as covered by this specification are defined as follows:

3.1.1 *crack*—a clean crystalline break passing through the grain boundary without inclusion of foreign elements.

3.1.2 *seam or lap*—a noncrystalline break through the metal which is inherent in the raw material.

3.1.3 *burst*—a break located at the periphery of the bolt head.

3.1.4 *acceptable quality level* (AQL)—as defined in MIL-STD-105D, the maximum percent defective that, for purposes of sampling inspection, can be considered satisfactory as the process average.

3.1.5 *process average*—as defined in MIL-STD-105D, the average percent defective of product as the time or original inspection. Original inspection is that first inspection of a particular quantity of product which is being reinspected after rejection and reconditioning.

4. Ordering Information

4.1 Orders for products under this specification shall include the following:

4.1.1 Quantity (number of pieces of bolts and accessories),

4.1.2 Name of products, including accessories such as nuts and washers when desired,

4.1.3 Dimensions, including nominal bolt diameter and length. For bolts of dimensional requirements other than heavy hex structural bolts (see 1.6) it is normally necessary to specify grip length,

4.1.4 Type of bolt (that is, Type 1, 2, or 3). Note that Type 1, 2, or 3 bolts may be supplied by the manufacturer when bolt type is not specified, if agreed upon by the purchaser,

4.1.5 ASTM designation and date of issue, and

4.1.6 Any special requirements.

NOTE 2—Two examples of ordering descriptions follow: (*1*) 1000 pieces, heavy hex structural bolts, each with two hardened washers, ASTM F 436, and one heavy hex nut, ASTM A 563 Grade DH, 1 by 4, ASTM A 490 dated ____. (*2*) 1000 pieces, heavy hex structural bolts, no nuts or washers, 7/8 by 2 1/4 Type 1, ASTM A 490 dated ____.

5. Materials and Manufacture

5.1 Steel shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

5.2 Type 1 bolts shall be heat treated by quenching in oil from above the transformation temperature. Type 2 and Type 3 bolts shall be quenched in a suitable liquid from above the transformation temperature. Type 1 and Type 3 bolts shall be tempered by reheating to a temperature of not less than 900°F (480°C). Type 2 bolts shall be tempered by reheating to a temperature of not less than 650°F (340°C). If heat treatment is performed by a subcontractor, the heat-treated material shall be returned to the manufacturer for testing.

5.3 Threads of bolts may be cut or rolled.

6. Chemical Requirements

6.1 Type 1 bolts shall be made from alloy steel conforming to the chemical composition requirements given in Table 1. The steel shall contain sufficient alloying elements to qualify it as an alloy steel.

NOTE 3—Steel is considered to be alloy, by the American Iron and Steel Institute, when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits:

[5] *Annual Book of ASTM Standards*, Parts 1–5 and 10.
[6] *Annual Book of ASTM Standards*, Part 11.
[7] Available from American National Standards Institute, 1430 Broadway, New York, N. Y. 10018.
[8] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120.

manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

6.2 Type 2 bolts shall be made from steel conforming to the chemical compositon requirements given in Table 2.

6.3 Type 3 bolts shall be made from steel conforming to the chemical composition requirements given in Table 2.

6.4 Product analyses may be made by the purchaser from finished material representing each lot of bolts. The chemical composition thus determined shall conform to the requirements given in Tables 1, 2, or 3, as applicable.

6.5 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for bolts.

7. Mechanical Requirements

7.1 Bolts less than three diameters in length shall have hardness values not less than the minimum nor more than the maximum hardness limits required in Table 4, as hardness is the only requirement.

7.2 Bolts 1 in. in diameter or less, other than those excepted in 7.1, shall be tested full size and conform to the minimum and maximum tensile strength and either proof load or alternative proof load requirements specified in Table 5.

7.3 Bolts larger than 1 in. in diameter, other than those excepted in 7.1, shall preferably be tested full size and when so tested, shall conform to the minimum and maximum tensile strength and either proof load or alternative proof load requirements as specified in Table 5. When equipment of sufficient capacity for full-size testing is not available, or when the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements of Table 6. In the event that bolts are tested by both full-size and by the machined test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

7.4 For bolts on which hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low or high readings of hardness tests.

7.5 Surface hardness of bolts as taken at a maximum of 0.003 in. from the surface shall not be more than the equivalent of 3 points Rockwell C higher than the hardness taken at a distance of 1/8 in. from the surface. Both hardness readings shall be taken on the same axial longitudinal section through the threaded length of the bolt, shall be taken at the same time, and the same hardness scale shall be used.

8. Dimensions

8.1 Unless otherwise specified, bolts shall conform to the dimensions for heavy hex structural bolts specified in ANSI B18.2.1.

8.2 Threads shall be the Unified Coarse Thread Series as specified in ANSI B1.1, and shall have Class 2A tolerances. When specified, 8 pitch thread series shall be used on bolts over 1 in. in diameter.

9. Quality Assurance of Mechanical Requirements

9.1 The manufacturer shall make sample inspections of every lot of bolts to ensure that properties of bolts are in conformance with the requirements of this specification. All bolts shall be inspected tested prior to shipment in accordance with one of the two quality assurance procedures described in 9.3 and 9.4, respectively. The manufacturer shall have the option of which procedure will be followed when furnishing bolts to any single purchase order.

9.2 The purpose of a lot inspection testing program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective, it is essential that following delivery the purchaser continue to maintain the identification and integrity of each lot until the product is installed in its service application.

9.3 *Production Lot Method:*

9.3.1 All bolts shall be processed in accordance with a lot-identification-control quality assurance plan. The manufacturer shall identify and maintain the integrity of each production lot of bolts from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.3.2 A production lot, for purposes of assigning an identification number and from which test samples shall be selected, shall consist of all bolts processed essentially together through all operations to the shipping container that are of the same nominal size, the same nominal length, and produced from the same mill heat of steel.

9.3.3 The manufacturer shall make tests for proof load, tensile strength (wedge test), and hardness of each lot of bolts. Alternatively, in accordance with 7.3, tests may be tensile strength, yield strength, reduction of area, elongation, and hardness.

9.3.4 From each production lot, the minimum number of tests of each required property shall be as follows:

Number of Pieces in Production Lot	Number of Specimens
800 and less	1
801 to 8 000	2
8 001 to 35 000	3
35 001 to 150 000	8
150 001 and over	13

9.3.5 If any test specimen shows defective machining, it may be discarded and another specimen substituted.

9.3.6 Bolts shall be packed in shipping containers as soon as practicable following final processing. Shipping containers shall be marked with the lot identification number.

9.3.7 A copy of the inspection test report for each production lot from which bolts are supplied to fill the requirements of a shipment shall be furnished to the purchaser when specified in the order. Individual heats of steel need not be identified on the test report.

9.4 *Shipping Lot Method:*

9.4.1 In-process inspection during all manufacturing operations and treatments and storage of manufactured bolts shall be in accordance with the practices of the individual manufacturer.

9.4.2 Before packing bolts for shipment, the manufacturer shall make tests of sample bolts taken at random from each shipping lot. A shipping lot, for purposes of selecting test samples, is defined as that quantity of bolts of the same nominal size and same nominal length necessary to fill the requirements of a single purchase order.

9.4.3 The manufacturer shall make tests for proof load, tensile strength (wedge test), and hardness of each lot of bolts. Alternatively, in accordance with 7.3, tests may be tensile strength, yield strength, reduction of area, elongation, and hardness.

9.4.4 From each shipping lot, the minimum number of tests of each required property shall be as follows:

Number of Pieces in Shipping Lot	Number of Specimens
150 and less	1
151 to 280	2
281 to 500	3
501 to 1 200	5
1 201 to 3 200	8
3 201 to 10 000	13
10 001 and over	20

9.4.5 If any test specimen shows defective machining, it may be discarded and another specimen substituted.

9.4.6 A copy of the inspection test report for each shipping lot shall be furnished to the purchaser when specified in the order. Individual heats of steel are not identified in the finished product.

10. Test Methods

10.1 Tests shall be conducted in accordance with Supplement III of Methods A 370.

10.2 Proof load testing of bolts tested in full size shall preferably be conducted in accordance with Method 1, Length Measurement, described in Supplement III of Methods A 370.

10.3 Bolts tested in full size shall be tested in accordance with the Wedge Test method described in Supplement III of Methods A 370. Fracture shall be in the body or threads of the bolt, without any fracture at the junction of the head and body.

10.4 Machined specimens shall be tested in accordance with the method described in S11.1.7, Supplement III of Methods A 370.

10.5 The speed of testing as determined with a free-running cross head shall be a maximum of 0.125 in./min for the bolt proof load determination, and a maximum of 1 in./min for the bolt tensile strength determination.

11. Magnetic Particle and Visual Inspection for Surface Discontinuities

11.1 Bolts shall be examined by magnetic particle inspection for longitudinal discontinuities and transverse cracks, and shall conform to an AQL of 0.25 when inspected in accordance with the sampling plan described in 11.4. Eddy-current inspection may be substituted, at the option of the manufacturer, for the 100 % magnetic particle inspection specified in 11.4.1 and 11.4.2, provided that the bolts, after eddy current inspection, are subsequently randomly sampled according to Table 7 and subjected to the magnetic particle inspection and acceptance requirements as described above. In the case of dispute, the magnetic particle test shall govern.

11.2 Bolts shall be examined visually for bursts and shall meet an AQL of 2.5 when inspected in accordance with the sampling plan described in 11.5.

11.3 A lot, for purposes of selecting a sample for magnetic particle or visual inspection, shall consist of all bolts of one type, having the same nominal diameter and length offered for inspection at one time. No lot shall contain more than 10 000 pieces.

11.4 *Longitudinal Discontinuities and Transverse Cracks:*

11.4.1 From each lot of bolts a representative sample shall be picked at random and magnetic particle inspected for longitudinal discontinuities and transverse cracks in accordance with Method E 109. (See Note 4). The sample size shall be as specified for an AQL of 0.25 in Table 7. If any defectives are found during inspection by the manufacturer all bolts in the lot shall be magnetic particle inspected and all defectives shall be removed and destroyed. If any defectives are found during inspection by the purchaser the lot shall be subject to rejection.

NOTE 4—Magnetic particle inspection may be conducted in accordance with Method E 138. For referee purposes Method E 109 shall be used.

11.4.2 Any bolt with a longitudinal discontinuity (located parallel to the axis of the bolt in the threads, body, fillet, or underside of head), with a depth normal to the surface greater than 0.03*D*, where *D* is the normal bolt size in inches, shall be considered defective. In addition, any bolt with a transverse crack (located perpendicular to the axis of the bolt in the threads, body, fillet, or underside of head), shall be considered defective.

NOTE 5—Magnetic particle indications of themselves shall not be cause for rejection. If in the opinion of the inspector the indications may be cause for rejection, a representative sample shall be taken from those bolts showing indications and shall be further examined by microscopical examination to determine whether the indicated discontinuities are in accordance with the specific limits.

11.5 *Bursts:*

11.5.1 From each lot of bolts a representative sample shall be picked at random and visually inspected for bursts. The sample size shall be as specified for an AQL of 2.5 in Table 7. If the number of defectives found during inspection by the manufacturer is greater than the acceptance number given in Table 7 for the sample size, all bolts in the lot shall be visually inspected and all defectives shall be removed and destroyed. If the number of defectives found during inspection by the purchaser is greater than the acceptance number given in Table 7 for the sample size, the lot shall be subject to rejection.

11.5.2 Any bolt with a burst having a width greater than 0.010 in. plus 0.025*D*, where *D* is the nominal bolt size in inches, shall be considered defective.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection

13.1 Unless otherwise specified, any rejec-

ASTM Logo Removed

tion based on requirements specified herein shall be reported to the manufacturer within 30 working days from the receipt of the material by the purchaser.

14. Certification

14.1 When specified on the order the manufacturer shall furnish the test reports described in 9.3.7 or 9.4.6, depending on whether the bolts are furnished by the production lot or shipping lot method.

15. Marking

15.1 Bolt heads shall be marked A 490, and shall also be marked to identify the manufacturer. Markings may be either raised or depressed, at the option of the manufacturer.

15.2 In addition to the markings required in 15.1, Type 2 bolts shall be marked with six radial lines 30 deg apart.

15.3 In addition to the markings required in 15.1, Type 3 bolts shall have the A 490 underlined, and the manufacturer may add other distinguishing marks indicating that the bolt is atmospheric corrosion resistant and of a weathering type.

TABLE 1 Chemical Requirements for Type 1 Bolts

Element	Heat Analysis, %	Product Analysis, %
Carbon		
For sizes through 1[3]/8 in.	0.30–0.48	0.28–0.50
For size 1[1]/2 in.	0.35–0.53	0.33–0.55
Phosphorus, max	0.040	0.045
Sulfur, max	0.040	0.045

TABLE 2 Chemical Requirements for Type 2 Bolts

Element	Heat Analysis, %	Product Analysis, %
Carbon	0.15–0.34	0.13–0.37
Manganese, min	0.70	0.67
Phosphorus, max	0.040	0.048
Sulfur, max	0.050	0.058
Boron, min	0.0005	0.0005

TABLE 3 Chemical Requirements for Type 3 Bolts

Element	Heat Analysis, %	Product Analysis, %
Carbon	0.20–0.53	0.19–0.55
Manganese, min	0.40	0.37
Phosphorus, max	0.040	0.045
Sulfur, max	0.050	0.055
Copper, max	0.60	0.63
Chromium, min	0.45	0.42
Nickel, min	0.20	0.17
or		
Molybdenum, min	0.15	0.14

TABLE 4 Hardness Requirements for Bolts

Bolt Size, in.	Hardness Number			
	Brinell		Rockwell C	
	min	max	min	max
1/2 to 1[1]/2, incl	311	352	33	38

TABLE 5 Tensile Requirements for Full-Size Bolts

Bolt Size, Threads per Inch, and Series Designation	Stress Area,[A] in.^{2} (cm^2)	Tensile Load,[B] lbf(kN)		Proof Load,[B] lbf(kN)	Alternative Proof Load,[B] min, lbf(kN)
		min	max	Length Measurement Method	Yield Strength Method
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
1/2-13 UNC	0.142 (0.92)	21 300 (95)	24 150 (107)	17 050 (76)	18 500 (82)
5/8-11 UNC	0.226 (1.46)	33 900 (151)	38 400 (171)	27 100 (121)	29 400 (131)
3/4-10 UNC	0.334 (2.15)	50 100 (223)	56 800 (253)	40 100 (178)	43 400 (193)
7/8-9 UNC	0.462 (2.98)	69 300 (308)	78 550 (349)	55 450 (247)	60 100 (267)
1-8 UNC	0.606 (3.91)	90 900 (404)	103 000 (458)	72 700 (323)	78 800 (351)
1 1/8-7 UNC	0.763 (4.92)	114 450 (509)	129 700 (577)	91 550 (407)	99 200 (441)
1 1/8-8 UN	0.790 (5.10)	118 500 (527)	134 300 (597)	94 800 (422)	102 700 (457)
1 1/4-7 UNC	0.969 (6.25)	145 350 (647)	164 750 (733)	116 300 (517)	126 000 (560)
1 1/4-8 UN	1.000 (6.45)	150 000 (667)	170 000 (756)	120 000 (534)	130 000 (578)
1 3/8-6 UNC	1.155 (7.45)	173 250 (771)	196 350 (873)	138 600 (617)	150 200 (668)
1 3/8-8 UN	1.233 (7.95)	185 000 (823)	209 600 (932)	148 000 (658)	160 300 (713)
1 1/2-6 UNC	1.405 (9.06)	210 750 (937)	238 850 (1062)	168 600 (750)	182 600 (812)
1 1/2-8 UN	1.492 (9.63)	223 800 (996)	253 650 (1128)	175 050 (779)	194 000 (863)

[A] The stress area is calculated as follows:

$$A_s = 0.7854\,[D - (0.9743/n)]^2$$

where:
A_s = stress area, in.^{2},
D = nominal bolt size, and
n = threads per inch.

[B] Loads tabulated and loads to be used for tests of full size bolts larger than 1 1/2 in. in diameter are based on the following:

Bolt Size	Column 3	Column 4	Column 5	Column 6
1/2 to 1 1/2 in., incl	150 000 psi (1035 MPa)	170 000 psi (1170 MPa)	120 000 psi (825 MPa)	130 000 psi (895 MPa)

TABLE 6 Tensile Requirements for Specimens Machined from Bolts

Bolt Size, in.	Tensile Strength, psi (MPa)		Yield Strength (0.2 % offset), min, psi (MPa)	Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
	min	max			
1/2 to 1 1/2 in., incl	150 000 (1035)	170 000 (1170)	130 000 (895)	14	40

TABLE 7 Sample Sizes and Acceptance Numbers for Inspection of Longitudinal Discontinuities, Transverse Cracks and Bursts

Lot Size	0.25 AQL		2.5 AQL	
	Sample Size[A, B]	Acceptance Number[A]	Sample Size[A, B]	Acceptance Number[A]
1 to 150	50	0	5	0
151 to 500	50	0	20	1
501 to 1 200	50	0	32	2
1 201 to 3 200	50	0	50	3
3 201 to 10 000	50	0	80	5

[A] Sample sizes and acceptance numbers are extracted from "Single Sampling Plan for Normal Inspection" Table 11A, MIL-STD-105D.

[B] Inspect all bolts in the lot if lot size is less than sample size.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A496: Deformed Steel Wire for Concrete Reinforcement

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD ANSI/ASTM A 496 – 78

American Association State Highway and Transportation Officials Standard
AASHTO No.: M 225

Standard Specification for DEFORMED STEEL WIRE FOR CONCRETE REINFORCEMENT[1]

This standard is issued under the fixed designation A 496; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers cold-worked, deformed steel wire to be used as such, or in fabricated form, for the reinforcement of concrete in sizes having nominal cross-sectional areas not less than 0.01 $in.^2$ (6.45 mm^2) nor greater than 0.31 $in.^2$ (200 mm^2).

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards:*

A 370 Methods and Definitions for Mechanical Testing of Steel Products[2]

A 700 Recommended Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[3]

2.2 *Military Standards:*[4]

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.3 *Federal Standard:*[4]

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

3. Ordering Information

3.1 When deformed wire is ordered by size number, the dimensional requirements shall be as given in Tables 1 and 1a. When deformed wire is ordered to dimensions other than the sizes shown, the nominal dimensions shall be developed from the applicable unit weight per foot of the section.

3.2 Orders for material to this specification shall include the following information:

3.2.1 Quantity (weight),

3.2.2 Name of material (deformed steel wire for concrete reinforcement),

3.2.3 Wire diameter (see Tables 1 and 1a),

3.2.4 Packaging (see Section 15), and

3.2.5 ASTM designation and date of issue.

NOTE 2—A typical ordering description is as follows: 50 000 lb deformed steel wire for concrete reinforcement, size No. D-12, on pipe carriers, polyethylene shrouded, to ASTM A 496 dated ———— ——.

4. Descriptions of Terms

4.1 *Deformed Steel Wire for Reinforcement*, as used within the scope and intent of this specification, shall mean any cold-worked, deformed steel wire intended for use as reinforcement in concrete construction, the wire surface having deformations which (*1*) inhibit longitudinal movement of the wire in such construction, and (*2*) conform to the provisions of Section 5.

4.2 *Size Number*, as used in this specification refers to the numerical designation of the wire as tabulated in Table 1 under the column head *Deformed Wire Size Number*, or a number indicating the nominal cross sectional areas of

---

[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 A01.05 on Steel Reinforcement.

Current edition approved Dec. 29, 1978. Published June 1979. Originally published as A 496 – 64. Last previous edition A 496 – 72.

[2] *Annual Book of ASTM Standards*, Parts 1–5, 10.

[3] *Annual Book of ASTM Standards*, Parts 1, 3, 4, 5.

[4] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120.

the deformed wire section in hundredths of a square inch.

5. Requirements

5.1 Deformations shall be spaced along the wire at a substantially uniform distance and shall be symmetrically disposed around the perimeter of the section. The deformations on all longitudinal lines of the wire shall be similar in size and shape. A minimum of 25 percent of the total surface area shall be deformed by measurable indentations.

5.2 Deformed wire shall have two, four, or six lines of deformations.

5.3 The average longitudinal spacing of deformations shall be not less than 3.5 nor more than 5.5 deformations per inch in each line of deformations on the wire.

5.4 The minimum average height at the center of typical deformations based on the nominal wire diameters shown in Tables 1 and 1a shall be as follows:

Wire Sizes	Minimum Average Height of Deformations, Percent of Nominal Wire Diameter
D-3 and finer	4
Coarser than D-3 through D-10	4½
Coarser than D-10	5

5.5 The deformations shall be placed in respect to the axis of the wire so that the included angle is not less than 45 deg; or if deformations are curvilinear, the angle formed by the transverse axis of the deformation and the wire axis shall be not less than 45 deg. Where the line of deformations forms an included angle with the axis of the wire from 45 to 70 deg inclusive, the deformations shall alternately reverse in direction on each side, or those on one side shall be reversed in direction from those on the opposite side. Where the line of deformations is over 70 deg, a reversal in direction is not required.

6. Measurements

6.1 The average spacing of deformations shall be determined by dividing a measured length of the wire specimen by the number of individual deformations in any one row of deformations on any side of the wire specimens. A measured length of the wire specimen shall be considered the distance from a point on a deformation to a corresponding point on any other deformation in the same line of deformations on the wire.

6.2 The minimum average height of deformations shall be determined from measurements made on not less than two typical deformations from each line of deformations on the wire. Measurements shall be made at the center of indentations.

7. Number of Measurements

7.1 To indicate adequately the conformity to dimensional requirements, measurements shall be made on one wire from each 10 tons (9072 kg) of each wire size, or fraction thereof.

8. Process

8.1 The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, acid-bessemer, or basic-oxygen.

8.2 The deformed steel wire shall be produced from rods or bars that have been hot rolled from billets.

9. Tensile Properties

9.1 Deformed wire shall conform to the following requirements for tensile properties in Methods and Definitions A 370:

	psi (MPa), min
Tensile strength	85 000 (586)
Yield strength	75 000 (517)

9.2 For material to be used in the fabrication of welded fabric, the following tensile and yield strength properties shall apply:

	psi (MPa), min
Tensile strength	80 000 (552)
Yield strength	70 000 (483)

9.3 The yield strength shall be determined at an extension at 0.005 in./in. of specimen length. The manufacturer is not required to test for yield strength, but is responsible for supplying a product that will meet the stipulated limit.

9.4 The material shall not exhibit a definite yield point as evidenced by a distinct drop of the beam or halt in the gage of the testing machine prior to reaching ultimate tensile load. The purchaser may, at his option, accept this feature as sufficient evidence of compliance with the specified minimum yield strength.

9.5 The tensile strength and yield strength are to be based on the nominal area of the wire.

10. Bending Properties

10.1 The bend test specimen shall stand

being bent through 90 deg without cracking on the outside of the bent portion, as follows:

Size Number	Bend Test
D-6 and finer	Bend around a pin the diameter of which is equal to twice the nominal diameter of the specimen.
Coarser than D-6	Bend around a pin the diameter of which is equal to four times the nominal diameter of the specimen.

10.2 The bend test shall be made at room temperature on specimens of sufficient length to ensure free bending and with apparatus which provides continuous and uniform application of force throughout the duration of the bending operation, unrestricted movement of the specimen at points of contact with the apparatus, and close wrapping of the specimen around the pin.

11. Test Specimens

11.1 Tension and bend test specimens shall be of the full section of deformed wire.

12. Number of Tests

12.1 One tension test and one bend test shall be made from each 10 tons (9072 kg) or less of each size and wire.

12.2 If any test specimen shows imperfections or develops flaws, it may be discarded and another substituted.

13. Variations in Weight

13.1 The permissible variation in weight of any deformed wire is ±6 percent of its normal weight. The theoretical weights shown in Tables 1 and 1a, or similar calculations on unlisted sizes, shall be used to establish the variation.

14. Finish

14.1 The wire shall be free from injurious imperfections and shall have a workmanlike finish.

15. Packaging, Marking, and Shipping

15.1 The size of the wire, ASTM specification number, and name or mark of the manufacturer shall be marked on a tag securely attached to each coil of wire.

15.2 When specified in the purchase order, packaging shall be in accordance with the procedures in Recommended Practices A 700.

15.3 *For Government Procurement Only*—When specified in the contract or order, and for direct procurement by or direct shipment to the U. S. government, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

16. Inspection

16.1 The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification.

16.2 Except for yield strength, all tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified. Such tests shall be so conducted as not to interfere unnecessarily with the operation of the works.

16.3 If the purchaser considers it desirable to determine compliance with the yield strength requirements in 9.1 and 9.2, he may have yield strength tests made in a recognized laboratory, or his representative may make the test at the mill if such tests do not interfere unnecessarily with the mill operations.

16.4 *For Government Procurement Only*—Except as otherwise specified in the contract, the contractor is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at the time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

17. Rejection

17.1 Material that shows injurious imperfections subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

17.2 Rust, surface seams, or surface irregularities on wire not intended for the manufacture of fabric shall not be cause for rejection, provided the minimum dimensions and physical properties of a hand wire-brushed test specimen are not less than the requirements of this specification.

18. Rehearing

18.1 Rejected materials shall be preserved for a period of at least 2 weeks from the date of inspection, during which time the manufacturer may make claim for a rehearing and retesting.

TABLE 1 Dimensional Requirements for Deformed Steel Wire for Concrete Reinforcement (Inch-Pound Units)

Deformed Wire Size Number[a,e]	Nominal Dimensions			Deformation Requirements			
	Unit Weight, lb/ft	Diameter, in.[b]	Cross-Sectional Area, in.[2c]	Perimeter, in.	Spacing: Maximum in.	Spacing: Minimum in.	Minimum Average Height of Deformations, in.[d]
D-1	0.034	0.113	0.01	0.355	0.285	0.182	0.0045
D-2	0.068	0.159	0.02	0.499	0.285	0.182	0.0063
D-3	0.102	0.195	0.03	0.612	0.285	0.182	0.0078
D-4	0.136	0.225	0.04	0.706	0.285	0.182	0.0101
D-5	0.170	0.252	0.05	0.791	0.285	0.182	0.0113
D-6	0.204	0.276	0.06	0.867	0.285	0.182	0.0124
D-7	0.238	0.299	0.07	0.936	0.285	0.182	0.0134
D-8	0.272	0.319	0.08	1.002	0.285	0.182	0.0143
D-9	0.306	0.338	0.09	1.061	0.285	0.182	0.0152
D-10	0.340	0.356	0.10	1.118	0.285	0.182	0.0160
D-11	0.374	0.374	0.11	1.174	0.285	0.182	0.0187
D-12	0.408	0.390	0.12	1.225	0.285	0.182	0.0195
D-13	0.442	0.406	0.13	1.275	0.285	0.182	0.0203
D-14	0.476	0.422	0.14	1.325	0.285	0.182	0.0211
D-15	0.510	0.437	0.15	1.372	0.285	0.182	0.0218
D-16	0.544	0.451	0.16	1.416	0.285	0.182	0.0225
D-17	0.578	0.465	0.17	1.460	0.285	0.182	0.0232
D-18	0.612	0.478	0.18	1.501	0.285	0.182	0.0239
D-19	0.646	0.491	0.19	1.542	0.285	0.182	0.0245
D-20	0.680	0.504	0.20	1.583	0.285	0.182	0.0252
D-21	0.714	0.517	0.21	1.624	0.285	0.182	0.0259
D-22	0.748	0.529	0.22	1.662	0.285	0.182	0.0265
D-23	0.782	0.541	0.23	1.700	0.285	0.182	0.0271
D-24	0.816	0.553	0.24	1.737	0.285	0.182	0.0277
D-25	0.850	0.564	0.25	1.772	0.285	0.182	0.0282
D-26	0.884	0.575	0.26	1.806	0.285	0.182	0.0288
D-27	0.918	0.586	0.27	1.841	0.285	0.182	0.0293
D-28	0.952	0.597	0.28	1.876	0.285	0.182	0.0299
D-29	0.986	0.608	0.29	1.910	0.285	0.182	0.0304
D-30	1.020	0.618	0.30	1.942	0.285	0.182	0.0309
D-31	1.054	0.628	0.31	1.973	0.285	0.182	0.0314

[a] The number following the prefix D identifies the nominal cross-sectional area of the deformed wire in hundredths of a square inch.

[b] The nominal diameter of a deformed wire is equivalent to the diameter of a plain wire having the same weight per foot as the deformed wire.

[c] The cross-sectional area is based on the nominal diameter. The area in square inches may be calculated by dividing the weight per linear inch of the specimen in pounds by 0.2833 (weight of 1 in.^{3} of steel), or by dividing the weight per lineal foot of specimen in pounds by 3.4 (weight of steel 1 in. square and 1 ft long).

[d] The minimum average height of deformations shall be determined from measurements made on not less than two typical deformations from each line of deformations on the wire. Measurements shall be made at the center of indentations as described in 6.2.

[e] For sizes other than those listed above, the Size Number shall be the number of one hundredths of a square inch in the nominal area of the deformed wire cross section, prefixed by the letter "D".

TABLE 1a Dimensional Requirements for Deformed Steel Wire for Concrete Reinforcements (SI Units)

	Nominal Dimensions				Deformation Requirements		
					Spacing		
Deformed Wire Size Number[a,e]	Unit Weight, kg/m	Diameter, mm[b]	Cross-Sectional Area, (mm^2)[c]	Perimeter, mm	Maximum mm	Minimum mm	Minimum Average Height of Deformations, mm[d]
D-1	0.0510	2.87	6.45	9.02	7.24	4.62	0.114
D-2	0.1013	4.04	12.90	12.67	7.24	4.62	0.160
D-3	0.1523	4.95	19.35	15.54	7.24	4.62	0.198
D-4	0.2025	5.72	25.81	17.93	7.24	4.62	0.257
D-5	0.2532	6.40	32.26	20.09	7.24	4.62	0.287
D-6	0.3038	7.01	38.71	22.02	7.24	4.62	0.315
D-7	0.3548	7.57	45.16	23.77	7.24	4.62	0.340
D-8	0.4051	8.10	51.61	25.45	7.24	4.62	0.363
D-9	0.4561	8.59	58.96	26.95	7.24	4.62	0.386
D-10	0.5063	9.04	64.52	28.40	7.24	4.62	0.406
D-11	0.5574	9.50	70.97	29.82	7.24	4.62	0.475
D-12	0.6076	9.91	77.42	31.12	7.24	4.62	0.495
D-13	0.6586	10.31	83.87	32.39	7.24	4.62	0.516
D-14	0.7089	10.72	90.32	33.66	7.24	4.62	0.536
D-15	0.7599	11.10	96.77	34.85	7.24	4.62	0.554
D-16	0.8101	11.46	103.23	35.97	7.24	4.62	0.572
D-17	0.8611	11.81	109.68	37.08	7.24	4.62	0.589
D-18	0.9114	12.14	116.13	38.13	7.24	4.62	0.607
D-19	0.9624	12.47	122.58	39.17	7.24	4.62	0.622
D-20	1.0127	12.80	129.03	40.21	7.24	4.62	0.640
D-21	1.0637	13.13	135.48	41.25	7.24	4.62	0.658
D-22	1.1139	13.44	141.94	42.21	7.24	4.62	0.673
D-23	1.1649	13.74	148.39	43.18	7.24	4.62	0.688
D-24	1.2152	14.05	154.84	44.12	7.24	4.62	0.704
D-25	1.2662	14.33	161.29	45.01	7.24	4.62	0.716
D-26	1.3164	14.61	167.74	45.87	7.24	4.62	0.732
D-27	1.3675	14.88	174.19	46.76	7.24	4.62	0.744
D-28	1.4177	15.16	180.64	47.65	7.24	4.62	0.759
D-29	1.4687	15.44	187.10	48.51	7.24	4.62	0.772
D-30	1.5190	15.70	193.55	49.33	7.24	4.62	0.785
D-31	1.5700	15.95	200.00	50.11	7.24	4.62	0.798

[a] The number following the prefix D identifies the nominal cross-sectional area of the deformed wire in hundredths of a square inch.

[b] The nominal diameter of a deformed wire is equivalent to the diameter of a plain wire having the same weight per foot as the deformed wire.

[c] The cross-sectional area is based on the nominal diameter. The area in square inches may be calculated by dividing the weight per lineal inch of the specimen in pounds by 0.2833 (weight of 1 $in.^3$ of steel), or by dividing the weight per lineal foot of specimen in pounds by 3.4 (weight of steel 1 in. square and 1 ft long).

[d] The minimum average height of deformations shall be determined from measurements made on not less than two typical deformations from each line of deformations on the wire. Measurements shall be made at the center of indentations as described in 6.2.

[e] For sizes other than those listed above, the Size Number shall be the number of one hundredths of a square inch in the nominal area of the deformed wire cross section, prefixed by the letter "D".

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A497: Welded Deformed Steel Wire, Fabric for Concrete Reinforcement

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD ANSI/ASTM A 497 – 79

American Association State Highway and Transportation Officials Standard
AASHTO No.: M 221

Standard Specification for
WELDED DEFORMED STEEL WIRE FABRIC FOR CONCRETE REINFORCEMENT[1]

This standard is issued under the fixed designation A 497; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers welded wire fabric made from cold-worked, deformed wire, or a combination of deformed and nondeformed wires, to be used for the reinforcement of concrete.

NOTE 1—The values states in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards*:

A 82, Specification for Cold-Drawn Steel Wire for Concrete Reinforcement[2]

A 496, Specification for Deformed Steel Wire for Concrete Reinforcement[2]

A 700 Recommended Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[3]

2.2 *Military Standards*:

MIL-STD-129 Marking for Shipment and Storage[4]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[4]

2.3 *Federal Standard*:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[4]

3. Description of Term

3.1 *Welded Wire Fabric*, as used in this specification, designates a material composed of cold-drawn steel wires "as drawn" or galvanized, fabricated into sheet (or so-called "mesh") formed by the process of electric welding. The finished material shall consist essentially of a series of longitudinal and transverse wires arranged substantially at right angles to each other and welded together at all points of intersection.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 Quantity (weight or square area),

4.1.2 Name of material (welded deformed wire fabric for concrete reinforcement),

4.1.3 Wire spacing and sizes,

4.1.4 Length and width of sheets or rolls,

4.1.5 Packaging (see Section 19), and

4.1.6 ASTM designation and date of issue.

NOTE 2—A typical ordering description is as follows: 10 000 ft^2 welded deformed wire fabric for concrete reinforcement, 6 x 12-D6 x D4, in flat sheets 96 in. wide by 240 in. long, in secured lifts, in accordance with ASTM A 497 dated ___.

5. Grade of Wire

5.1 The wire used in the manufacture of welded wire fabric shall conform to Specification A 496, either solely or in combination with Specification A 82.

6. Fabrication

6.1 The wires shall be assembled by automatic machines or by other suitable mechanical means which will assure accurate spacing and alignment of all members of the finished fabric.

---

[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 A01.05 on Steel Reinforcement.

Current edition approved July 27, 1979. Published September 1979. Originally published as A 497 – 64. Last previous edition A 497 – 72.

[2] *Annual Book of ASTM Standards*, Part 4.

[3] *Annual Book of ASTM Standards*, Parts 1, 3, 4, and 5.

[4] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120.

6.2 Longitudinal and transverse members shall be securely connected at every intersection by a process of electrical-resistance welding which employs the principle of fusion combined with pressure.

6.3 Wire of proper grade and quality when fabricated in the manner required in this specification shall result in a strong, serviceable, mesh-type product having substantially square or rectangular openings. It shall be fabricated and finished in a workmanlike manner, shall be free from injurious imperfections, and shall conform to this specification.

7. Mechanical Requirements

7.1 All wire of the finished fabric shall meet the minimum requirements for tensile properties and shall also withstand the bend test as prescribed for the wire before fabrication in Specification A 496 and, where applicable, Specification A 82.

7.2 In order to assure adequate weld shear strength between longitudinal and transverse wires, weld shear tests as described in 7.2 shall be made. The minimum average shear value in pounds-force shall be not less than 20 000 multiplied by the area of the larger wire in square inches (or in newtons shall not be less than 138 multiplied by the area in square millimeters) where the area of the smaller wire is 35 % or more of the area of the larger wire, and provided that the smaller wire is not smaller than D-4.

7.3 Fabric having a relationship of larger and smaller wires other than that covered in 7.2 shall meet an average weld shear strength requirement of not less than 800 lbf (3.6 kN) provided that the smaller wire is not smaller than D-4.

8. Tension Tests and Weld Shear Tests

8.1 Tests for determination of conformance to the requirements of 7.1 may be made on the welded wire fabric after fabrication either across or between the welds. Not less than 50 % of the samples tested shall be across a weld.

8.2 Weld shear tests for determination of conformance to the requirements of 7.2 shall be conducted using a fixture as described in Section 11.

8.3 Four welds selected at random from a specimen representing the entire width of the fabric shall be tested for weld shear strength. The material shall be deemed to conform to the requirements for weld shear strength if the average of the four samples complies with the values stipulated in 7.2. If this average fails to meet the prescribed minimum value, all the welds across the specimen shall then be tested. The fabric will be acceptable if the average of all weld shear test values across the specimen meets the prescribed minimum value.

9. Bend Tests

9.1 The bend test shall be made on a specimen between the welds.

10. Test Specimens

10.1 Test specimens for testing tensile properties shall be obtained by cutting from the finished fabric units of suitable size to enable proper performance of the intended tests.

10.2 Specimens used for testing tensile properties across a weld shall have the welded joint located approximately at the center of the wire being tested, and the cross wire forming the welded joint shall extend approximately 1 in. (25 mm) beyond each side of the welded joint.

10.3 Test specimens for determining weld shear properties shall be obtained by cutting from the finished fabric a section, including one transverse wire, across the entire width of the sheet or roll. From this specimen four welds shall be selected at random for testing. The transverse wire of each test specimen shall extend approximately 1 in. (25 mm) on each side of the longitudinal wire. The longitudinal wire of each test specimen shall be of such length below the transverse wire so as to be adequately engaged by the grips of the testing machine and of such length above the transverse wire that its end shall be above the center line of the upper bearing of the testing device.

10.4 Tests for conformance to dimensional characteristics shall be made on full sheets or rolls.

10.5 If any test specimen shows imperfections or develops flaws, it may be discarded and another substituted.

11. Weld Shear Test Apparatus and Methods

11.1 As the welds in welded wire fabric contribute to the bonding and anchorage value of the wires in concrete it is imperative that the weld acceptance tests be made in a jig which will stress the weld in a manner similar to which it is stressed in concrete. In order to accomplish this the longitudinal wire in the jig must be stressed in an axis close to its center line. Also the transverse wire must be held closely to the longitudinal wire, and in the same relative position, so as to prevent rotation of the transverse wire.

11.2 Figure 1[5] shows the complete details of a typical testing jig together with two anvils which make it possible to test welds for wires up to ⅝ in. (15.88 mm) in diameter. This testing jig can be used in most tension testing machines and should be hung in a ball and socket arrangement at the center of the machine. This, or a similarly effective fixture designed on the same principle, is acceptable.

11.3 Test specimens should be inserted through the notch in the anvil using the smallest notch available in which the longitudinal wire will fit loosely. The longitudinal wire will be in contact with the surface of the free rotating rollers while the transverse wire shall be supported by the anvil on each side of the slot. The bottom jaws of the testing machines shall grip the lower end of the longitudinal wire and the load shall be applied at a rate of stressing not to exceed 100 000 psi (689 MPa)/min.

12. Number of Tests

12.1 One test for conformance with the provisions of 6.1 shall be made for each 75 000 ft^2 (6968 m^2) of fabric, or remaining fraction thereof.

12.2 One specimen for each 300 000 ft^2 (27 870 m^2) of fabric, or remaining fraction thereof and as defined in 10.3, shall be tested for conformance to the requirements of 7.2.

13. Sizes, Spacing Deformations, and Dimensions

13.1 Sizes, spacing, presence of deformations, arrangement of wires, and dimensions of units in flat sheet form or rolls shall conform to the requirements specified by the purchaser.

14. Width of Fabric

14.1 The width of the fabric shall be considered to be the center-to-center distance between outside longitudinal wires. The permissible variation shall not exceed ½ in. (13 mm) greater or less than the specified width.

14.2 Transverse wires shall not project beyond the centerline of each longitudinal edge wire more than a distance of 1 in. (25 mm) unless otherwise specified.

14.3 When transverse wires are specified to project a specific length beyond the centerline of a longitudinal edge wire, the permissible variation shall not exceed ½ in. (13 mm) greater or less than the specified length; however, the over-all width (total of projection one side plus width plus projection other side) shall not exceed 1 in. (25 mm) greater or less than specified.

15. Variations in Wire Diameter and Weight

15.1 The permissible variation in weight of any deformed wire in the fabric or the permissible variation in diameter of any nondeformed wire shall conform to the tolerances prescribed in the appropriate wire specification before fabrication (see Section 5). Such measurements shall be made between the welds.

16. Spacings

16.1 The average spacing of wires shall be such that the total number of wires contained in a sheet or roll is equal to, or greater than, that determined by the specific spacing, but the center-to-center distance between individual members may vary not more than ¼ in. (6.35 mm) from the specified spacing. It is understood that sheets of fabric of the same specified length may not always contain an identical number of transverse wires and, therefore, may have various lengths of longitudinal overhang.

17. Over-All Dimensions

17.1 The over-all length of flat sheets, measured on any wire, may vary ±1 in. (25.4 mm) or 1 percent, whichever is greater.

17.2 In case the width of flat sheets or rolls is specified as the over-all width (tip-to-tip length of cross wires), the width shall be not more than ±1 in. (25.4 mm) of the specified width.

18. Rolls or Sheets

18.1 Welded wire fabric may be furnished either in flat sheets or in rolls as specified by the purchaser.

19. Packaging

19.1 When fabric is furnished in flat sheets,

[5] The detailed drawing may be obtained from ASTM Headquarters, 1916 Race St., Philadelphia, Pa. 19103. Request Adjunct No. 12-101850-00.

it shall be assembled in bundles of convenient size containing not more than 150 sheets securely fastened together.

19.2 When fabric is furnished in rolls, each roll shall be secured so as to prevent unwinding during shipping and handling.

19.3 When specified in the purchase order, packaging shall be in accordance with the procedures in Recommended Practices A 700.

20. Marking

20.1 Each bundle of flat sheets and each roll shall have attached thereto a suitable tag bearing the name of the manufacturer, a description of the material, and such other information as may be specified by the purchaser.

20.2 *For Government Procurement Only*—When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

21. Inspection

21.1 The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification.

21.2 Except for yield strength, all tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified. Such tests shall be so conducted as not to interfere unnecessarily with the operation of the works.

21.3 If the purchaser considers it desirable to determine compliance with the yield strength requirements of Specifications A 496 or A 82, he may have yield strength tests made in a recognized laboratory, or his representative may make the test at the mill if such tests do not interfere unnecessarily with the mill operations.

21.4 *For Government Procurement Only*—Except as otherwise specified in the contract, the contractor is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at the time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

22. Rejection and Retests

22.1 Material that does not meet the requirements of this specification may be rejected. Unless otherwise specified, any rejection shall be reported to the manufacturer within 5 days from the time of selection of test specimens.

22.2 In case a specimen fails to meet the tension or bend test, the material shall not be rejected until two additional specimens taken from other wires in the same sheet or roll have been tested. The material shall be considered as meeting this specification in respect to any prescribed tensile property provided the tested average for the three specimens, including the specimen originally tested, is at least equal to the required minimum for the particular property in question; and further provided that none of the three specimens develops less than 80 percent of the required minimum for the tensile property in question. The material shall be considered as meeting this specification in respect to bend test requirements provided both additional specimens satisfactorily pass the prescribed bend test.

22.3 Any material that shows injurious imperfections subsequent to its acceptance at the manufacturer's works may be rejected and the manufacturer shall be promptly notified.

22.4 Welded joints shall withstand normal shipping and handling without being broken, but the presence of broken welds, regardless of cause, shall not constitute cause for rejection unless the number of broken welds per sheet exceeds 1 percent of the total number of joints in a sheet, or if the material is furnished in rolls, 1 percent of the total number of joints in

150 ft^2 (14 m^2) of fabric and, furthermore, provided not more than one half the permissible maximum number of broken welds are located on any one wire.

22.5 In case of rejection by reason of failure to meet the weld shear requirements, four additional specimens shall be taken from four different sheets or rolls and tested in accordance with 8.2. If the average of all the weld shear tests does not meet the requirement, the material shall be rejected.

22.6 In case rejection is justified by reason of failure to meet the requirements for dimensions, the amount of material rejected shall be limited to those individual sheets or rolls which fail to meet the requirements of this specification. If, however, the total number of sheets or rolls thus rejected exceeds 25 percent of the total number in the shipment, the entire shipment may be rejected.

22.7 Rust, surface seams, or surface irregularities will not be cause for rejection, provided the minimum dimensional cross-sectional area and tensile properties of a hand wire-brushed test specimen are not less than the requirements of this specification.

23. Rehearing

23.1 Rejected materials shall be preserved for a period of at least 2 weeks from the date of inspection, during which time the manufacturer may make claim for a rehearing and retesting.

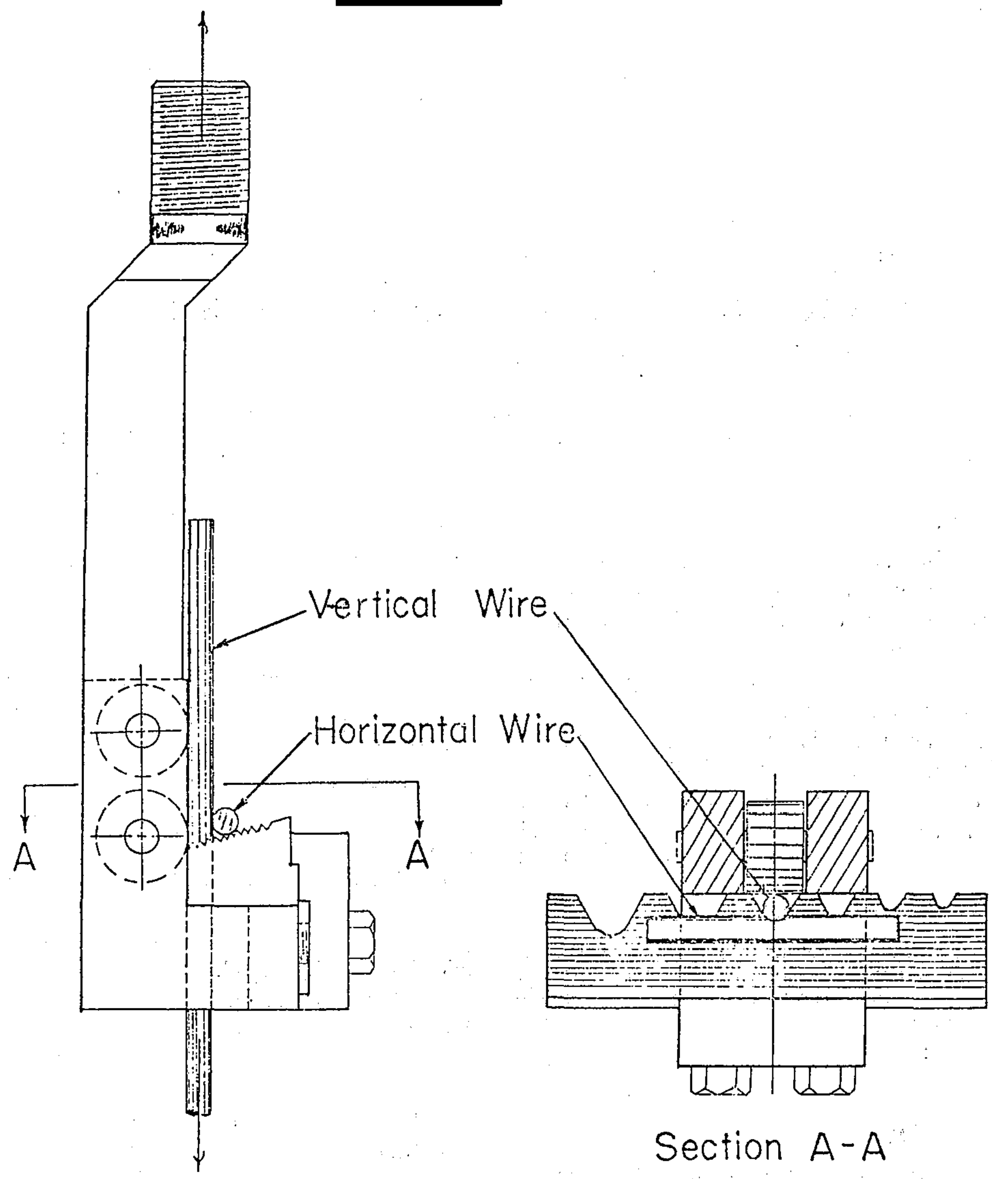


FIG. 1 Welded Wire Fabric Weld Tester.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A500: Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 500 – 78**

Standard Specification for

COLD-FORMED WELDED AND SEAMLESS CARBON STEEL STRUCTURAL TUBING IN ROUNDS AND SHAPES[1]

This Standard is issued under the fixed designation A 500; 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.

1. Scope

1.1 This specification covers cold-formed welded and seamless carbon steel round, square, rectangular, or special shape structural tubing for welded, riveted, or bolted construction of bridges and buildings, and for general structural purposes.

1.2 This tubing is produced in welded sizes with a maximum periphery of 64 in. (1626 mm) and a maximum wall of 0.500 in. (12.70 mm), and in seamless with a maximum periphery of 32 in. (813 mm) and a maximum wall of 0.500 in.

NOTE 1—Products manufactured to this standard may not be suitable for those applications such as dynamically loaded elements in welded structures, etc., where low-temperature notch-toughness properties may be important. For such applications the manufacturer should be consulted.

NOTE 2—The values stated in U.S. customary units are to be regarded as the standard.

2. Ordering Information

2.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately.

2.1.1 Quantity (feet or number of lengths),

2.1.2 Name of material (cold-formed tubing),

2.1.3 Method of manufacture (seamless or welded),

2.1.4 Grade (Table 1 and 2),

2.1.5 Size

2.1.6 Length (specific or random, see 12.1.3 or 12.2.3),

2.1.7 End condition (see 16.3),

2.1.8 Burr removal (see 16.3),

2.1.9 Certification (see 16.4),

2.1.10 Specification number,

2.1.11 End use, and

2.1.12 Special requirements.

3. Process

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

4. Manufacture

4.1 The tubing shall be made by a seamless or welding process.

4.2 Welded tubing shall be made from flat-rolled steel by an automatic welding process producing a longitudinal weld with no addition of filler metal. The longitudinal butt joint of welded tubing shall be welded across its thickness in such a manner that the structural design strength of the tubing section is assured.

4.2.1 Structural tubing welded by electric-resistance methods is normally furnished without removal of inside flash.

4.3 The tubing may be stress relieved or annealed as is considered necessary by the manufacturer to conform to the requirements of this specification.

5. Heat Analysis

5.1 An analysis of each heat of open-hearth, basic-oxygen, or electric-furnace 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 A01.09 on Pipe.

Current edition approved July 28, 1978. Published September 1978. Originally published as A 500 – 64. Last previous edition A 500 – 77.

ASTM Logo Removed

shall be made by the manufacturer. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1 for heat analysis.

6. Product Analysis

6.1 An analysis may be made by the purchaser from finished tubing manufactured in accordance with this specification, or an analysis may be made from flat-rolled stock of which the welded tubing is manufactured. When product analyses are made, two sample lengths from a lot of each 500 lengths or fraction thereof shall be selected. The specimens for chemical analysis shall be taken from the sample lengths in accordance with ASTM Method E 59, Sampling Steel and Iron for Determination of Chemical Composition.[2] The chemical composition thus determined shall conform to the requirements specified in Table 1 for product analysis.

6.2 In the event the chemical composition of one of the sample lengths does not conform to the requirements shown in Table 1 for product analysis, an analysis of two additional lengths selected from the same lot shall be made, each of which shall conform to the requirements shown in Table 1 for product analysis, or the lot is subject to rejection.

7. Tensile Requirements

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

8. Flattening Test

8.1 The flattening test shall be made on round structural tubing. A flattening test is not required for shaped structural tubing.

8.2 For welded round structural tubing, a specimen at least 4 in. (102 mm) in length shall be flattened cold between parallel plates in three steps, with the weld located at 90 deg from the line of direction of force. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the tubing. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces, except as provided for in 8.5, shall occur until the distance between the plates is less than one half of the original outside diameter of the tubing but is not less than five times the wall thickness of the tubing. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tubing meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

8.3 For seamless round structural tubing 2⅜ in. (60.3 mm) outside diameter and larger, a section not less than 2½ in. (63.5 mm) in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility no cracks or breaks on the inside or outside surfaces, except as provided for in 8.5, shall occur until the distance between the plates is less than the value of "H" calculated by the following equation:

$$H = (1 + e)t/(e + t/D)$$

where:

H = distance between flattening plates, in.,
e = deformation per unit length (constant for a given grade of steel, 0.09 for Grade A, 0.07 for Grade B, and 0.06 for Grade C),
t = nominal wall thickness of tubing, in., and
D = actual outside diameter of tubing, in.

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tubing meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

8.4 Surface imperfections not found in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with Section 16.

8.5 When low D-to-t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations,

[2] *Annual Book of ASTM Standards*, Part 12.

cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

9. Test Methods

9.1 The tension specimens required by this specification shall conform to those described in the latest issue of ASTM Methods and Definitions A 370, for the Mechanical Testing of Steel Products, Supplementary Requirements II.[3]

9.2 The tension test specimen shall be taken longitudinally from a section of the finished tubing, at a location at least 90 deg from the weld in the case of welded tubing, and shall not be flattened between gage marks. If desired, the tension tests may be made on the full section of the tubing; otherwise, a longitudinal strip-test specimen as prescribed in Methods A 370 Supplementary Requirements II shall be used. The specimens shall have all burrs removed and shall not contain surface imperfections which would interfere with proper determination of the tensile properties of the metal.

9.3 The yield point shall be determined in accordance with one of the alternative methods described in Methods A 370.

10. Number of Tests

10.1 One tension test as specified in Section 9 shall be made from a length of tubing representing each lot.

10.2 The flattening test, as specified in Section 8 shall be made on one length of round tubing from each lot.

10.3 The term "lot" applies to all tubes of the same nominal size and wall thickness which are produced from the same heat of steel.

11. Retests

11.1 If the results of the mechanical tests representing any lot do not conform to a requirement as specified in Sections 7 and 8, retests may be made on additional tubing of double the original number from the same lot, each of which shall conform to the requirement specified, or the tubing represented by the test is subject to rejection.

11.2 In case of failure on retest to meet the requirements of Sections 7 and 8, the manufacturer may elect to retreat, rework, or otherwise eliminate the condition responsible for failure to meet the specified requirements. Thereafter, the material remaining from the lot originally represented may be tested and shall comply with all requirements of this specification.

12. Permissible Variations in Dimensions

12.1 *Round Structural Tubing*

12.1.1 *Diameter*—The outside diameter shall not vary more than ± 0.5 percent rounded to the nearest 0.005 in. (0.13 mm), of the nominal outside diameter size specified, for nominal outside diameter dimensions 1.900 in. (48.26 mm) and smaller, and plus and minus 0.75 percent rounded to the nearest 0.005 in. of the nominal outside diameter for nominal outside diameter dimensions 2.00 in. and larger. The outside diameter measurements shall be made at positions at least 2 in. (50.8 mm) from either end of the tubing.

12.1.2 *Wall Thickness*—The minimum wall thickness at any point of measurement on the tubing shall be not more than 10 percent less than the nominal wall thickness specified. The maximum wall thickness, excluding the weld seam of welded tubing, shall be not more than 10 percent greater than the nominal wall thickness specified.

12.1.3 *Length*—Structural tubing is normally produced in random mill lengths 5 ft (1.5 m) and over, in multiple lengths, and in specified mill lengths. Refer to Section 2. When specified mill lengths are ordered, the length tolerance shall be in accordance with Table 3.

12.1.4 *Straightness*—The permissible variation for straightness of round structural tubing shall be ⅛ in. times the number of feet (10.4 mm times the number of meters) of total length divided by 5.

12.2 *Square and Rectangular Structural Tubing*

12.2.1 *Outside Dimensions*—The specified dimensions, measured across the flats at positions at least 2 in. (50.8 mm) from either end of the tubing and including an allowance for convexity or concavity, shall not exceed the plus and minus tolerances shown in Table 4.

12.2.2 *Wall Thickness*—The tolerance for wall thickness exclusive of the weld area shall be plus and minus 10 percent of the nominal wall thickness specified. The wall thickness is to be measured at the center of the flat.

[3] *Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, 5, and 10.

12.2.3 *Length*—Square and rectangular structural tubing is normally produced in random mill lengths 5 ft and over, in multiple lengths, and in specified mill lengths. Refer Section 2. When specified mill lengths are ordered for square and rectangular structural tubing, the length tolerances shall be in accordance with Table 5.

12.2.4 *Straightness*—The permissible variation for straightness of square and rectangular structural tubing shall be $\frac{1}{8}$ in. times the number of feet of total length divided by 5.

12.2.5 *Squareness of Sides*—For square or rectangular structural tubing, adjacent sides may deviate from 90 deg by a tolerance of plus or minus 2 deg max.

12.2.6 *Radius of Corners*—For square or rectangular structural tubing, the radius of any outside corner of the section shall not exceed three times the specified wall thickness.

12.2.7 *Twist*—The tolerances for twist or variation with respect to axial alignment of the section, for square and rectangular structural tubing, shall be as shown in Table 6. Twist is measured either by holding down one end of a square or rectangular tube on a flat surface plate with the bottom side of the tube parallel to the surface plate and noting the difference in height above the surface plate of the two corners at the opposite end of the bottom side of the tube or by measuring this difference on the heavier sections by a suitable measuring device. The difference in the height of the corners shall not exceed the values in Table 6. Twist measurements are not to be taken within 2 in. (50 mm) of either end of the product.

13. Special Shape Structural Tubing

13.1 The dimensions and tolerances of special shape structural tubing are available by inquiry and negotiation with the manufacturer.

14. Marking

14.1 Except as noted in 14.2, each length of structural tubing shall be legibly marked to show the following information: manufacturer's name, brand, or trademark; the specification number; and grade letter.

14.2 For structural tubing having a largest dimension of 4 in. (101.6 mm) or less, the information listed in 14.1 may be marked on a tag securely attached to each bundle.

15. Packing, Marking, and Loading

15.1 When specified in the order, contract, etc., packing, marking, and loading shall be in accordance with those procedures recommended by Recommended Practice A 700 for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment.[4]

16. Inspection

16.1 All tubing shall be subject to an inspection at place of manufacture to assure conformance to the requirements of this specification.

16.2 All tubing shall be free from injurious defects and shall have a workmanlike finish. Surface imperfections caused by handling marks, light die or roll marks, or shallow pits are not considered injurious defects, providing the imperfections are removable within the minimum wall permitted. The removal of such surface imperfections is not required. Welded tubing shall be free of protruding metal on the outside surface of the weld seam.

16.3 The ends of structural tubing, unless otherwise specified, shall be finished square cut and the burr held to a minimum. The burr can be removed on the outside diameter, inside diameter, or both, as a supplementary requirement. When burrs are to be removed, it shall be specified on the purchase order.

16.4 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tensile tests shall be furnished.

17. Rejection

17.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

17.2 Tubing found in fabrication or in instal-

[4] *Annual Book of ASTM Standards*, Parts 1, 3, 4, and 5.

lation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such tubing shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

TABLE 1 Chemical Requirements

Element	Composition, %			
	Grades A and B		Grade C	
	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis
Carbon, max	0.26	0.30	0.23	0.27
Manganese, max	...	...	1.35	1.40
Phosphorus, max	0.04	0.05	0.04	0.05
Sulfur, max	0.05	0.063	0.05	0.063
Copper, when copper steel is specified, min	0.20	0.18	0.20	0.18

TABLE 2 Tensile Requirements

Round Structural Tubing			
	Grade A	Grade B	Grade C
Tensile Strength, min, psi (MPa)	45 000 (310)	58 000 (400)	62 000 (427)
Yield Strength, min, psi (MPa)	33 000 (228)	42 000 (290)	46 000 (317)
Elongation in 2 in. (50.8 mm), min, %	25[a]	23[b]	21[c]
Shaped Structural Tubing			
	Grade A	Grade B	Grade C
Tensile Strength, min, psi (MPa)	45 000 (310)	58 000 (400)	62 000 (427)
Yield Strength, min, psi (MPa)	39 000 (269)	46 000 (317)	50 000 (345)
Elongation in 2 in. (50.8 mm), min, %	25[a]	23[b]	21[c]

[a] Applies to specified wall thicknesses 0.120 in. (3.05 mm) and over. For wall thicknesses under 0.120 in., the minimum elongation shall be calculated by the formula: percent elongation in 2 in. = $56t + 17.5$.

[b] Applies to specified wall thicknesses 0.180 in. (4.57 mm) and over. For wall thicknesses under 0.180 in., the minimum elongation shall be calculated by the formula: percent elongation in 2 in. = $61t + 12$.

[c] Applies to specified wall thicknesses 0.120 in. (3.05 mm) and over. For lighter wall thicknesses, elongation shall be by agreement with the manufacturer.

NOTE—The following table gives completed minimum values for longitudinal strip tests:

Wall thickness, in. (mm)	Elongation in 2 in. (50.8 mm), min, %	
	Grade A	Grade B
0.180 (4.57)	...	23
0.165 (4.19)	...	22
0.148 (3.76)	...	21
0.134 (3.40)	...	20
0.120 (3.05)	25	19.5
0.109 (2.77)	23.5	19
0.095 (2.41)	23	18
0.083 (2.11)	22	17
0.065 (1.65)	21	16
0.049 (1.24)	20	15
0.035 (0.89)	19.5	14

ASTM Logo Removed

A 500

TABLE 3 Specified Mill Length Tolerances for Round Structural Tubing

	22 ft (6.7 m) and Under		Over 22 to 44 ft (6.7 to 13.4 m), incl	
	Over	Under	Over	Under
Length tolerance for specified mill length, in. (mm)	½ (12.7)	¼ (6.4)	¾ (19.0)	¼ (6.4)

TABLE 4 Outside Dimension Tolerances for Square and Rectangular Structural Tubing

Largest Outside Dimension, across flats, in. (mm)	Tolerance,[a] plus and minus, in. (mm)
2½ (63.5) and under	0.020 (0.51)
Over 2½ to 3½ (63.5 to 88.9), incl	0.025 (0.64)
Over 3½ to 5½ (88.9 to 139.7), incl	0.030 (0.76)
Over 5½ (139.7)	1 percent

[a] Tolerances include allowance for convexity or concavity. For rectangular sections, the tolerance calculated for the larger flat dimension shall also apply to the smaller flat dimension. This tolerance may be increased 50 percent when applied to the smaller dimension, if the ratio of the cross-sectional dimensions is 1.5 to 3, inclusive, and 100 percent when the ratio exceeds 3.

TABLE 5 Specified Mill Length Tolerances for Square and Rectangular Structural Tubing

	22 ft (6.7 m) and Under		Over 22 ft to 44 ft (6.7 to 13.4 m), incl	
	Over	Under	Over	Under
Length tolerance for specified mill length, in. (mm)	½ (12.7)	¼ (6.4)	¾ (19.0)	¼ (6.4)

TABLE 6 Twist Tolerances for Square and Rectangular Structural Tubing

Specified Dimension of Longest Side, in. (mm)	Maximum Twist in the First 3 ft (1 m) and in each additional 3 ft	
	in.	mm
1½ (38.1) and under	0.050	1.39
Over 1½ to 2½ (38.1 to 63.5), incl	0.062	1.72
Over 2½ to 4 (63.5 to 101.6), incl	0.075	2.09
Over 4 to 6 (101.6 to 152.4), incl	0.087	2.42
Over 6 to 8 (152.4 to 203.2), incl	0.100	2.78
Over 8 (203)	0.112	3.11

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A501: Hot-Formed Welded and Seamless Carbon Steel Structural Tubing

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD ANSI/ASTM A 501 – 76

Standard Specification for
HOT-FORMED WELDED AND SEAMLESS CARBON STEEL STRUCTURAL TUBING[1]

This Standard is issued under the fixed designation A 501; 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.

1. Scope

1.1 This specification covers hot-formed welded and seamless carbon steel square, round, rectangular, or special shape structural tubing for welded, riveted, or bolted construction of bridges and buildings, and for general structural purposes.

1.2 Square and rectangular tubing is furnished in sizes 1 to 10 in. (25.4 to 254 mm) across flat sides with wall thicknesses 0.095 to 1.000 in. (2.41 to 25.40 mm), depending on size; round tubing is furnished in nominal diameters ½ to 24 in. (12.7 to 610 mm), incl, with nominal (average) wall thicknesses 0.109 to 1.000 in. (2.77 to 25.40 mm), depending on size. Tubing having other dimensions may be furnished provided such tubing complies with all other requirements of this specification.

1.3 Tubing may be furnished with hot-dipped galvanized coating.

NOTE—The values stated in U.S. customary units are to be regarded as the standard.

2. Ordering Information

2.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately.

2.1.1 Quantity (feet or number of lengths),

2.1.2 Name of material (hot-formed tubing),

2.1.3 Method of manufacture (seamless or butt welded),

2.1.4 When galvanized coating required (see 14.1),

2.1.5 Size (Section 12),

2.1.6 Length (specific or random, see 13.3),

2.1.7 End condition (see 17.3),

2.1.8 Burr removal (see 17.3),

2.1.9 Certification (see 17.4),

2.1.10 ASTM specification number,

2.1.11 End use, and

2.1.12 Special requirements.

3. Process

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

4. Manufacture

4.1 The tubing shall be made by the seamless or furnace butt welding process (continuous welded) except that tubing made by the electric-resistance-welding process and subsequently reheated throughout its cross section and hot formed by a reducing or shaping process, or both, is also an acceptable process of manufacture.

5. Heat Analysis

5.1 An analysis of each heat of open-hearth, basic-oxygen, or electric-furnace steel shall be made by the manufacturer. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1 for heat analysis.

6. Product Analysis

6.1 An analysis may be made by the purchaser from finished tubing manufactured in accordance with this specification, or an analysis may be made from flat-rolled stock from which the welded tubing is manufactured.

[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 A01.09 on Pipe.

Current edition approved July 30, 1976. Published September 1976. Originally published as A 501 – 64. Last previous edition A 501 – 74.

When product analyses are made, two sample lengths from a lot of each 500 lengths or fraction thereof shall be selected. The specimens for chemical analysis shall be taken from the sample lengths in accordance with the applicable procedures of ASTM Method E 59, Sampling Steel and Iron for Determination of Chemical Composition.[2] The chemical composition thus determined shall conform to the requirements specified in Table 1 for product analysis.

6.2 In the event the chemical composition of one of the sample lengths does not conform to the requirements shown in Table 1 for product analysis, an analysis of two additional lengths selected from the same lot shall be made, each of which shall conform to the requirements shown in Table 1 for product analysis, or the lot is subject to rejection.

7. Tensile Requirements

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

8. Bend Test

8.1 The bend test shall be made on square or rectangular tubing manufactured in accordance with this specification.

8.2 The bend test specimen shall be taken longitudinally from the tubing, and shall represent the full wall thickness of material. The sides of the bend test specimen may have the corners rounded to a maximum radius of ¹⁄₁₆ in. (1.6 mm).

8.3 The bend test specimen shall stand being bent cold through 180 deg, without cracking on the outside of the bent portion, to an inside diameter which shall have a relation to the thickness of the specimen as prescribed in Table 3.

9. Test Method

9.1 The test specimens required by this specification shall conform to those described in the latest issue of ASTM Methods and Definitions, A 370, for Mechanical Testing of Steel Products.[3]

9.2 The tension test specimen shall be taken longitudinally from a section of the finished tubing, at a location at least 90 deg from the weld in the case of welded tubing, and shall not be flattened between gage marks. If desired, the tension test may be made on the full section of the tubing; otherwise, a longitudinal strip-test specimen shall be used as prescribed in Methods A 370 Supplement II. The specimens shall have all burrs removed and shall not contain surface imperfections which would interfere with proper determination of the tensile properties of the metal.

9.3 The yield point shall be determined in accordance with one of the alternatives described in Methods A 370.

10. Number of Tests

10.1 One tension and one bend test, as specified in Sections 7 and 8 shall be made from tubing representing each heat.

11. Retests

11.1 If the results of the mechanical tests representing any heat do not conform to a requirement, as specified in Sections 7 and 8, retests may be made on additional tubing of double the original number from the same heat, each of which shall conform to the requirement specified, or the tubing represented by the test is subject to rejection.

11.2 In case of failure on retest to meet the requirements of Sections 7 and 8, the manufacturer may elect to retreat, rework, or otherwise eliminate the condition responsible for failure to meet the specified requirements. Thereafter, the material remaining from the respective heat originally represented may be tested, and shall comply with all requirements of this specification.

12. Dimensions

12.1 *Square Structural Tubing*—The outside dimensions (across the flats), the weight per foot, and the calculated nominal wall thickness of common sizes of square structural tubing included in this specification are listed in Table 4.

12.2 *Rectangular Structural Tubing*—The outside dimensions (across the flats), the weight per foot, and the calculated nominal

[2] *Annual Book of ASTM Standards*, Part 12.
[3] *Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, and 5, and 10.

wall thickness of common sizes of rectangular structural tubing included in this specification are listed in Table 5.

12.3 *Round Structural Tubing*—The nominal size and outside diameter dimensions, the weight per foot, and the calculated nominal wall thickness of common sizes of round structural tubing included in this specification are listed in Table 6.

12.4 *Special Shape Structural Tubing*—The dimensions and tolerances of special shape structural tubing are available by inquiry and negotiation with the manufacturer.

12.5 *Other Sizes*—Hot-formed welded and seamless structural tubing may be manufactured in accordance with the requirements of this specification to other ordered dimensions not listed in Tables 4, 5, and 6. In this event, the dimensional tolerances shall be consistent with those shown in this specification for similar sizes and type of product.

13. Permissible Variations in Dimensions of Square, Round, Rectangular and Special Shape Structural Tubing

13.1 *Outside Dimensions*—The specified dimensions, measured across the flats at positions at least 2 in. (50.8 mm) from either end of square or rectangular tubing and including an allowance for convexity or concavity, shall not exceed the plus and minus tolerance shown in Table 7. For round hot-formed structural tubing 2 in. and over in nominal size, the outside diameter shall not vary more than ±1 percent from the standard specified. For nominal sizes 1½ in. (38.1 mm) and under the outside diameter shall not vary more than 1/64 in. (0.40 mm) over nor more than 1/32 in. (0.79 mm) under the standard specified.

13.2 *Weight*—The weight of the structural tubing, as specified in Tables 4, 5, and 6, shall not be less than the specified value by more than 3.5 percent.

13.3 *Length*—Structural tubing is commonly produced in random mill lengths of 16 to 22 ft (4.9 to 6.7 m) or 32 to 44 ft (6.7 to 9.8 m) in multiple lengths, and in definite cut lengths. Refer to Section 2. When cut lengths are specified for structural tubing, the length tolerances shall be in accordance with Table 8.

13.4 *Straightness*—The permissible variation for straightness of structural tubing shall be ⅛ in. times the number of feet (10.4 mm times the number of meters) of total length divided by 5.

13.5 *Squareness of Sides*—For square or rectangular structural tubing, adjacent sides may deviate from 90 deg by a tolerance of plus or minus 2 deg max.

13.6 *Radius of Corners*—For square or rectangular structural tubing, the radius of any outside corner of the section shall not exceed three times the specified wall thickness.

13.7 *Twist*—The tolerances for twist or variation with respect to axial alignment of the section, for square and rectangular structural tubing, shall be as shown in Table 9. Twist is measured either by holding down one end of a square or rectangular tube on a flat surface plate with the bottom side of the tube parallel to the surface plate and noting the height that either corner, at the opposite end of the bottom side of the tube, extends above the surface plate, or by use of a suitable measuring device for heavier sections. The difference in the height of the corners shall not exceed the values in Table 9. Twist measurements are not to be taken within 2 in. (50 mm) of either end of the product.

14. Galvanized Coatings

14.1 For structural tubing requiring galvanized coating, such coating shall comply with the requirements contained in the latest revision of ASTM Specification A 120, Pipe, Steel, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless, for Ordinary Uses,[4] with the additional provision that, at the option of the manufacturer, the weight of coating may also be determined from the weight of zinc on the outside surface only.

15. Marking

15.1 Except as noted in 15.2, each length of structural tubing shall be legibly marked by rolling, die-stamping, ink printing, or paint stenciling to show the following information: manufacturer's name, brand, or trademark; size and thickness; and the specification number.

[4] *Annual Book of ASTM Standards*, Part 1.

ASTM Logo Removed

15.2 For structural tubing having the greatest cross sectional dimension less than 2 in. (50.8 mm), the information listed in 15.1 may be marked on a tag securely attached to each bundle.

16. Packaging, Marking, and Loading

16.1 When specified in the order, contract, etc. packaging, marking, and loading shall be in accordance with those procedures recommended by ASTM Recommended Practice A 700, for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment.[5]

17. Inspection

17.1 All tubing shall be subject to an inspection at the place of manufacture to assure conformance with the requirements of this specification.

17.2 The structural tubing shall be free from injurious defects and shall have a commercially smooth finish.

17.2.1 Surface imperfections shall be classed as injurious defects when their depth exceeds 15 percent of the wall thickness as stated in Tables 4, 5, or 6 and when the imperfections materially affect the appearance of the structural member, or when their length (measured in a transverse direction) and depth would materially reduce the total cross sectional area at any location.

17.2.2 Injurious defects having a depth not in excess of 33 1/3 percent of the wall thickness stated in Tables 4, 5, or 6 may be repaired by welding, subject to the following conditions:

17.2.2.1 The defect shall be completely removed by chipping or grinding to sound metal.

17.2.2.2 The repair weld shall be made using suitable coated electrodes.

17.2.2.3 The projecting weld metal shall be removed to produce a workmanlike finish.

17.3 The ends of structural tubing, unless otherwise specified, shall be finished square cut, and the burr held to a minimum. The burr can be removed on the outside diameter, inside diameter, or both, as a supplementary requirement. When burrs are to be removed, it shall be specified in the purchase order.

17.4 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tensile tests shall be furnished.

18. Rejection

18.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

18.2 Tubing found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such tubing shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

[5] *Annual Book of ASTM Standards*, Parts 1, 3, 4, and 5.

TABLE 1 Chemical Requirements

Element	Composition, percent	
	Heat analysis	Product analysis
Carbon, max	0.26	0.30
Phosphorus, max	0.04	0.05
Sulfur, max	0.05	0.063
Copper, when copper steel is specified, min	0.20	0.18

TABLE 2 Tensile Requirements

Tensile strength, min, psi (MPa)	58 000 (400)
Yield point, min, psi (MPa)	36 000 (248)
Elongation in 2 in. (50.8 mm) min, percent[a]	23
Elongation in 8 in. (203 mm) min, percent[a]	20[b]

[a] Elongation may be determined in a gage length of either 2 in. or 8 in. at the manufacturer's option.

[b] For material under 5/16 in. in thickness, a deduction from the percentage elongation of 1.25 percent in 8 in. specified in Table 2 shall be made for each decrease of 1/32 in. of the specified thickness under 5/16 in.

ASTM Logo Removed

A 501

TABLE 3 Bend Test Requirements

Thickness of Material, in. (mm)	Ratio of Bend Diameter to Specimen Thickness
¾ in. (19.0) and under	½
Over ¾ in. to 1 in. (19.0 to 25.4), incl	1

TABLE 4 Dimensions of Common Sizes of Square Structural Tubing

Size Given in Outside Dimensions Across Flat Sides, in. (mm)	Weight per Foot, lb (kg/m)		Calculated Nominal Wall Thickness, in. (mm)	
1 by 1	1.09	(1.62)	0.095	(2.41)
(25.4 by 25.4)	1.41	(2.10)	0.133	(3.38)
2 by 2	2.69	(4.00)	0.110	(2.79)
(50.8 by 50.8)	3.04	(4.52)	0.125	(3.18)
	3.65	(5.44)	0.154	(3.91)
	4.31	(6.41)	0.188	(4.78)
2½ by 2½	4.32	(6.43)	0.141	(3.58)
(63.5 by 63.5)	5.59	(8.32)	0.188	(4.78)
	7.10	(10.56)	0.250	(6.35)
3 by 3	5.78	(8.60)	0.156	(3.96)
(76.2 by 76.2)	6.86	(10.21)	0.188	(4.78)
	8.80	(13.09)	0.250	(6.35)
3½ by 3½	6.88	(10.24)	0.156	(3.96)
(88.9 by 88.9)	8.14	(12.11)	0.188	(4.78)
	10.50	(15.62)	0.250	(6.35)
	12.69	(18.88)	0.312	(7.92)
4 by 4	9.31	(13.85)	0.188	(4.78)
(101.6 by 101.6)	12.02	(17.89)	0.250	(6.35)
	14.52	(21.61)	0.312	(7.92)
	16.84	(25.06)	0.375	(9.52)
	20.88	(31.07)	0.500	(12.70)
5 by 5	11.86	(17.65)	0.188	(4.78)
(127.0 by 127.0)	15.42	(22.94)	0.250	(6.35)
	18.77	(27.93)	0.312	(7.92)
	21.94	(32.65)	0.375	(9.52)
	27.68	(41.19)	0.500	(12.70)
6 by 6	14.41	(21.44)	0.188	(4.78)
(152.4 by 152.4)	18.82	(28.00)	0.250	(6.35)
	23.02	(34.25)	0.312	(7.92)
	27.04	(40.28)	0.375	(9.52)
	34.48	(51.31)	0.500	(12.70)
7 by 7	16.85	(25.07)	0.188	(4.78)
(177.8 by 177.8)	22.04	(32.80)	0.250	(6.35)
	26.99	(39.16)	0.312	(7.92)
	31.73	(47.21)	0.375	(9.52)
	40.55	(60.34)	0.500	(12.70)
8 by 8	25.44	(37.85)	0.250	(6.35)
(203.2 by 203.2)	31.24	(46.49)	0.312	(7.92)
	36.83	(54.80)	0.375	(9.52)
	47.35	(70.46)	0.500	(12.70)
	56.98	(84.79)	0.625	(15.88)
	65.73	(97.81)	0.750	(19.05)
10 by 10	32.23	(47.96)	0.250	(6.35)
(254.0 by 254.0)	39.74	(59.13)	0.312	(7.92)
	47.03	(69.98)	0.375	(9.52)
	60.95	(90.69)	0.500	(12.70)
	73.98	(110.08)	0.625	(15.88)
	86.13	(128.16)	0.750	(19.05)
	107.79	(160.39)	1.000	(25.40)

ASTM Logo Removed

TABLE 5 Dimensions of Common Sizes of Rectangular Structural Tubing

Size Given in Outside Dimensions Across Flat Sides, in. (mm)	Weight per Foot, lb (kg/m)	Calculated Nominal Wall Thickness, in. (mm)
3 by 2 (76.2 by 50.8)	4.32 (6.43)	0.141 (3.58)
	5.59 (8.32)	0.188 (4.78)
	7.10 (10.56)	0.250 (6.35)
4 by 2 (101.6 by 50.8)	5.78 (8.60)	0.156 (3.96)
	6.86 (10.21)	0.188 (4.78)
	8.80 (13.09)	0.250 (6.35)
4 by 3 (101.6 by 76.2)	6.88 (10.24)	0.156 (3.96)
	8.14 (12.11)	0.188 (4.78)
	10.50 (15.62)	0.250 (6.35)
	12.69 (18.88)	0.312 (7.92)
5 by 3 (127.0 by 76.2)	9.31 (13.85)	0.188 (4.78)
	12.02 (17.89)	0.250 (6.35)
	14.52 (21.61)	0.312 (7.92)
	16.84 (25.06)	0.375 (9.52)
6 by 3 (152.4 by 76.2)	10.58 (15.74)	0.188 (4.78)
	13.72 (20.42)	0.250 (6.35)
	16.65 (24.78)	0.312 (7.92)
	19.39 (28.85)	0.375 (9.52)
6 by 4 (152.4 by 101.6)	11.86 (17.65)	0.188 (4.78)
	15.42 (22.94)	0.250 (6.35)
	18.77 (27.93)	0.312 (7.92)
	21.94 (32.65)	0.375 (9.52)
	27.68 (41.19)	0.500 (12.70)
7 by 5 (177.8 by 127.0)	14.41 (21.44)	0.188 (4.78)
	18.82 (28.00)	0.250 (6,35)
	23.02 (34.25)	0.312 (7.92)
	27.04 (40.28)	0.375 (9.52)
	34.48 (51.31)	0.500 (12.70)
8 by 4 (203.2 by 101.6)	14.41 (21.44)	0.188 (4.78)
	18.82 (28.00)	0.250 (6.35)
	23.02 (34.25)	0.312 (7.92)
	27.04 (40.28)	0.375 (9.52)
	34.48 (51.31)	0.500 (12.70)
8 by 6 (203.2 by 152.4)	16.85 (25.07)	0.188 (4.78)
	22.04 (32.80)	0.250 (6.35)
	26.99 (39.16)	0.312 (7.92)
	31.73 (47.21)	0.375 (9.52)
	40.55 (60.34)	0.500 (12.70)
10 by 6 (254.0 by 152.4)	25.44 (37.85)	0.250 (6.35)
	31.24 (46.49)	0.312 (7.92)
	36.83 (54.80)	0.375 (9.52)
	47.35 (70.46)	0.500 (12.70)

TABLE 6 Dimensions of Common Sizes of Round Structural Tubing

Nominal Size, in.	Outside Diameter, in. (mm)	Weight Per Foot, lb (kg/m)	Calculated Nominal Wall Thickness, in. (mm)
½	0.840 (21.3)	0.85 (1.26)	0.109 (2.77)
	0.840 (21.3)	1.09 (1.62)	0.147 (3.73)
¾	1.050 (26.7)	1.13 (1.68)	0.113 (2.87)
	1.050 (26.7)	1.47 (2.19)	0.154 (3.91)
1	1.315 (33.4)	1.34 (1.99)	0.104 (2.64)
	1.315 (33.4)	1.68 (2.50)	0.133 (3.38)
	1.315 (33.4)	2.17 (3.23)	0.179 (4.55)
1¼	1.660 (42.2)	1.81 (2.69)	0.110 (2.79)
	1.660 (42.2)	2.27 (3.38)	0.140 (3.56)
	1.660 (42.2)	3.00 (4.47)	0.191 (4.85)
1½	1.900 (48.3)	2.17 (3.23)	0.114 (2.90)
	1.900 (48.3)	2.72 (4.05)	0.145 (3.68)
	1.900 (48.3)	3.63 (5.41)	0.200 (5.08)
2	2.375 (60.3)	2.92 (4.34)	0.121 (3.07)
	2.375 (60.3)	3.65 (5.44)	0.154 (3.91)
	2.375 (60.3)	5.02 (7.48)	0.218 (5.54)
2½	2.875 (73.0)	4.53 (6.75)	0.156 (3.96)
	2.875 (73.0)	5.40 (8.04)	0.188 (4.78)
	2.875 (73.0)	5.79 (8.62)	0.203 (5.16)
	2.875 (73.0)	7.66 (11.41)	0.276 (7.01)
3	3.500 (88.9)	5.58 (8.30)	0.156 (3.96)
	3.500 (88.9)	6.63 (9.87)	0.188 (4.78)
	3.500 (88.9)	7.58 (11.29)	0.216 (5.49)
	3.500 (88.9)	10.25 (15.27)	0.300 (7.62)
3½	4.000 (101.6)	6.40 (9.53)	0.156 (3.96)
	4.000 (101.6)	7.63 (11.35)	0.188 (4.78)
	4.000 (101.6)	9.11 (13.57)	0.226 (5.74)
	4.000 (101.6)	12.51 (18.61)	0.318 (8.08)
4	4.500 (114.3)	7.25 (10.79)	0.156 (3.96)
	4.500 (114.3)	8.64 (12.86)	0.188 (4.78)
	4.500 (114.3)	10.00 (14.88)	0.219 (5.56)
	4.500 (114.3)	10.79 (16.06)	0.237 (6.02)
	4.500 (114.3)	14.98 (22.29)	0.337 (8.56)
5	5.563 (141.3)	14.62 (21.75)	0.258 (6.55)
	5.563 (141.3)	20.78 (30.92)	0.375 (9.53)
	5.563 (141.3)	38.55 (57.36)	0.750 (19.05)
6	6.625 (168.3)	18.97 (28.23)	0.280 (7.11)
	6.625 (168.3)	28.57 (42.51)	0.432 (10.97)
	6.625 (168.3)	53.16 (79.10)	0.864 (21.95)
8	8.625 (219.1)	28.55 (42.48)	0.322 (8.18)
	8.625 (219.1)	43.39 (64.56)	0.500 (12.70)
	8.625 (219.1)	72.42 (107.76)	0.875 (22.23)
10	10.750 (273.0)	40.48 (60.23)	0.365 (9.27)
	10.750 (273.0)	54.74 (81.45)	0.500 (12.70)
	10.750 (273.0)	104.13 (154.95)	1.000 (25.40)
12	12.750 (323.8)	49.56 (73.75)	0.375 (9.53)
	12.750 (323.8)	65.42 (97.34)	0.500 (12.70)
	12.750 (323.8)	125.49 (186.73)	1.000 (25.40)
14	14.000 (355.6)	54.57 (81.20)	0.375 (9.53)
	14.000 (355.6)	72.09 (107.27)	0.500 (12.70)
16	16.000 (406.4)	62.58 (93.12)	0.375 (9.53)
	16.000 (406.4)	82.77 (123.16)	0.500 (12.70)
18	18.000 (457.2)	70.59 (105.04)	0.375 (9.53)
	18.000 (457.2)	93.45 (139.05)	0.500 (12.70)
20	20.000 (508.0)	78.60 (116.96)	0.375 (9.53)
	20.000 (508.0)	104.13 (154.91)	0.500 (12.70)
24	24.000 (609.6)	94.02 (140.79)	0.375 (9.53)
	24.000 (609.6)	125.49 (186.73)	0.500 (12.70)

TABLE 7 Outside Dimension Tolerances for Square, Rectangular, and Special Shape Structural Tubing

Largest Outside Dimension, Across Flats, in. (mm)	Tolerance,[a] plus and minus, in. (mm)
2½ (63.5) and under	0.020 (0.51)
Over 2½ to 3½ (63.5 to 88.9), incl	0.025 (0.64)
Over 3½ to 5½ (88.9 to 139.7), incl	0.030 (0.76)
Over 5½ (139.7)	1 percent

[a] The respective outside dimension tolerances include the allowances for convexity and concavity.

TABLE 8 Cut Length Tolerances for Structural Tubing

	22 ft (6.7 m) and Under		Over 22 to 44 ft (6.7 to 13.4 m), incl	
	Over	Under	Over	Under
Length tolerance for specified cut lengths, in. (mm)	½ (12.7)	¼ (6.4)	¾ (19.0)	¼ (6.4)

TABLE 9 Twist Tolerances for Square, Rectangular, or Special Shape Structural Tubing

Specified Dimension of Longest Outer Side, in. (mm)	Maximum Twist in the First 3 ft (1 m) and in each additional 3 ft	
	in.	mm
1½ (38.1) and under	0.050	1.39
Over 1½ to 2½ (38.1 to 63.5), incl	0.062	1.72
Over 2½ and 4 (63.5 to 101.6), incl	0.075	2.09
Over 4 to 6 (101.6 to 152.4), incl	0.087	2.42
Over 6 to 8 (152.4 to 203.2), incl	0.100	2.78
Over 8 (203)	0.112	3.11

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A502: Steel Structural Rivets

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 502 – 76**

American Association State Highway and Transportation Officials Standard
AASHTO No.: M 228

Standard Specification for
STEEL STRUCTURAL RIVETS[1]

This Standard is issued under the fixed designation A 502; 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.

1. Scope

1.1 This specification covers three grades of steel rivets in diameters from ½ to 1½ in. (13 to 38 mm), incl, for structural fabricating purposes. Grade 1 is a carbon steel rivet for general purposes. Grade 2 is a carbon-manganese steel rivet suitable, with proper riveting technique, for use with high-strength carbon and high-strength low alloy structural steels. Grade 3 is similar to Grade 2 with enhanced atmospheric corrosion resistance approximately four times that of carbon steel without copper.

NOTE 1—Grade 1 rivets correspond to those formerly made from steel conforming to Specification A 141 for Structural Rivet Steel,[2] and Grade 2 rivets correspond to those formerly made from steel conforming to Specification A 195 for High-Strength Structural Rivet Steel.[2] Grade 3 rivets correspond to those made from steel conforming to Specification A 588 for High-Strength Low-Alloy Structural Steel with 50 000 psi Minimum Yield Point to 4 in. Thick.[3]

1.2 Rivets conforming to this specification may be made by either the hot- or cold-heading process. It is expected that these rivets ordinarily will be hot driven.

NOTE 2—The values stated in inch-pound units are to be regarded as the standard.

2. Process

2.1 The steel for rivets shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

3. Chemical Requirements

3.1 The rivets shall conform to the heat and product analysis requirements for chemical composition given in Table 1.

3.2 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

4. Test Specimens

4.1 Rivets used for testing shall be heat treated in the following manner prior to testing:

4.1.1 *Grade 1*—Normalize by air cooling from above the transformation range.

4.1.2 *Grade 2*—Anneal by heating to 1450°F (790°C), holding for 30 min at temperature and cooling in the furnace.

4.1.3 *Grade 3*—Heat treatment of test samples is not a requirement; however, at the option of the manufacturer, normalizing of test samples is permitted.

5. Mechanical Requirements

5.1 The rivets shall conform to the hardness requirements shown in Table 2. Hardness shall be measured on a transverse section through the shank of the rivet at a point one quarter of the nominal diameter from the axis of the rivet. This transverse section shall be taken at a distance from the end of the rivet which is equal to the diameter of the rivet. Except as noted below, either the Brinell or the Rockwell hardness test may be used. Test procedure shall conform to Methods and Definitions A 370, for Mechanical Testing of Steel Products.[4] Brinell hardness shall be measured at only one point. Rockwell hard-

---

[1] This specification is under the jurisdiction of ASTM Committee F-16 on Fasteners.
Current edition approved July 30, 1976. Published October 1976. Originally published as A 502 – 64. Last previous edition A 502 – 75.

[2] Discontinued; see *1966 Book of ASTM Standards*, Part 4.

[3] *Annual Book of ASTM Standards*, Part 4.

[4] *Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, 5, and 10.

ness shall be measured at three points, equally spaced about the axis of the rivet, and the hardness shall be taken as the arithmetic average of the three measurements. When use of the Brinell hardness test is prohibited by proximity to the periphery of the section, measurement of hardness shall be made by the Rockwell hardness test.

6. Dimensions

6.1 Dimensions of rivets, unless otherwise specified, shall conform to those of one of the head types provided in American National Standard B18.4 for Large Rivets (½ Inch Nominal Diameter and Larger).[5]

7. Marking

7.1 Rivet heads shall be marked as follows to identify the grade, and shall also be marked to identify the manufacturer. Marking may be either raised or depressed at the option of the manufacturer.

Grade	Grade Marking
1	none required[a]
2	2
3	3

[a] The numeral 1 may be used at the manufacturer's option.

8. Number of Tests and Retests Applicable for Mechanical (Hardness) Testing and Chemical Analysis

8.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

8.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

8.3 Additional tests of individual shipments of rivets are not ordinarily required but when such additional tests are specified on the purchase order, a lot for the purpose of selecting test samples shall consist of all rivets in the shipment which have the following common characteristics:

8.3.1 One type of head,

8.3.2 One nominal diameter, and

8.3.3 One nominal length.

8.4 From each lot, the number of tests for each requirement shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and under	1
801 to 8 000	2
8 001 to 22 000	3
Over 22 000	5

8.5 If any test specimen shows defective preparation it may be discarded and another specimen substituted.

8.6 Should any specimen fail to meet the requirements of its specified test, double the number of specimens from the same lot shall be tested for the property in which failure was found and all the additional specimens shall meet the specification requirements.

9. Quality Level for Visual Soundness

9.1 *Inspection*—Acceptable quality level (Note 3) for rivets shall be as given in Table 3.

NOTE 3—The acceptable quality level (AQL) provides standards for visual soundness inspection. The standards used here are those of a recommended practice for large solid rivets formulated by the Industrial Fasteners Institute, June, 1965. That practice is based on Military Standard MIL-STD-105D for Sampling Procedures and Tables for Inspection by Attributes. Table 3 provides levels of quality for various attributes or characteristics and these are given numerical value in Table 4.

9.2 The AQL sampling and inspection shall be conducted in accordance with the sample size, acceptance, and rejection values given in Table 4.

10. Inspection

10.1 If the testing described in 8.3 is required by the purchaser, it shall be specified in the inquiry and contract or order.

10.2 The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this

[5] Available from American National Standards Institute, 1430 Broadway, New York, N. Y. 10018.

ASTM Logo Removed

specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

11. Rejection

11.1 Rejections based on requirements specified herein shall be reported to the manufacturer within 30 days after receipt of material by the purchaser.

TABLE 1 Chemical Requirements

	Grade 1		Grade 2		Grade 3[b]			
					Class A		Class B	
	Heat Analysis, %	Product Analysis,[a] %	Heat Analysis, %	Product Analysis, %	Heat Analysis, %	Product Analysis, %	Heat Analysis, %	Product Analysis, %
Carbon	0.13–0.25	0.11–0.27	0.19–0.30	0.16–0.33	0.10–0.19	0.09–0.20	0.20 max	0.21 max
Manganese	0.30–0.90	0.27–0.93	1.20–1.65	1.14–1.71	0.90–1.25	0.86–1.24	0.75–1.25	0.71–1.29
Phosphorus, max								
acid	0.06	0.070	0.06	0.070	. . .	. . .	. . .	. . .
basic	0.04	0.048	0.04	0.048	0.04	0.045	0.04	0.045
Sulfur, max	0.05	0.058	0.05	0.058	0.05	0.055	0.05	0.055
Silicon	. . .	. . .	0.10–0.30	0.08–0.32	0.15–0.30	0.13–0.32	0.15–0.30	0.13–0.32
Nickel	. . .	. . .	. . .	. . .	. . .	. . .	0.25–0.50	0.22–0.53
Chromium	. . .	. . .	. . .	. . .	0.40–0.65	0.37–0.68	0.40–0.70	0.37–0.73
Copper	. . .	. . .	. . .	. . .	0.25–0.40	0.22–0.43	0.20–0.40	0.17–0.43
Copper, when copper bearing steel is specified, min	0.20	0.18	0.20	0.18	. . .	. . .	. . .	. . .
Vanadium	. . .	. . .	. . .	. . .	0.02–0.10	0.01–0.11	0.01–0.10	0.11 max

[a] Product analysis is not applicable to rivets made from rimmed steel or merchant quality bars.
[b] A and B are classes of material used for Grade 3 rivets. Selection of a class shall be at the option of the rivet manufacturer.

TABLE 2 Hardness Requirements

	Grade 1		Grade 2		Grade 3[a]	
	Min	Max	Min	Max	Min	Max
Rockwell, B	55	72	76	85	76	93
Brinell, 500-kgf (4900-N), 10-mm ball	103	126	137	163	137	197

[a] In order to meet the atmospheric corrosion or hardness requirements or both, various combinations of alloying elements will be required. Maximum limits may be specified for the number and amount of alloy elements by mutual agreement between purchaser and producer at the time of ordering.

TABLE 3 Levels of Quality

Defect	Acceptable Quality Level
Crack or burst[a]	10.0
Duds (incompleted rivet or foreign material)	1.0

[a] Crack and burst are two names for the same thing. Each designates an abrupt interruption of the periphery of a rivet head by separation of the metal. Such interruptions do not adversely affect structural strength, corrosion resistance, or other functional requirements of the rivet, but are unsightly if they are large. For this reason, a rivet with a crack or burst having an opening at the periphery of the head which is wider than 0.020 in. plus 0.05 times the rivet diameter is considered defective.

TABLE 4 Numerical Values for Levels of Quality

Lot Size	Sample Size	Acceptable Quality Level 1.0 Acceptance[a]	1.0 Rejection[b]	10.0 Acceptance[a]	10.0 Rejection[b]
0 to 50	8	0	1	2	3
51 to 90	13	0	1	3	4
91 to 150	20	0	1	5	6
151 to 280	32	1	2	7	8
281 to 500	50	1	2	10	11
501 to 1200	80	2	3	14	15
1201 to 3200	125	3	4	21	22
3201 to 10 000	200	5	6	21	22
10 001 to 35 000	315	7	8	21	22
35 001 to 150 000	500	10	11	21	22
150 001 to 500 000	800	14	15	21	22
over 500 000	1250	21	22	21	22

[a] Defectives in sample permitted for acceptance of lot.
[b] Defectives in sample requiring rejection of lot.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A514: High-Yield Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding24 CFR 200, Subpart S

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD ANSI/ASTM A 514 – 77

American Association State Highway and Transportation Officials Standard AASHTO No.: M 244

Standard Specification for HIGH-YIELD-STRENGTH, QUENCHED AND TEMPERED ALLOY STEEL PLATE, SUITABLE FOR WELDING[1]

This Standard is issued under the fixed designation A 514; 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.

1. Scope

1.1 This specification covers quenched and tempered alloy steel plates of structural quality in thicknesses of 6 in. (152 mm) and under intended primarily for use in welded bridges and other structures.

NOTE 1—All grades are not available in a maximum thickness of 6 in. See Table 1 for thicknesses available in each grade.

1.2 Welding technique is of fundamental importance and must not adversely affect the properties of the plate, especially in the heat affected zone. It is presupposed that welding procedures will be suitable for the materials being welded.

NOTE 2—The values stated in inch-pound units are to be regarded as the standard.

2. General Requirements for Delivery

2.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of ASTM Specification A 6, for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use.[2]

3. Process

3.1 The steel shall be made by one of the following processes: open-hearth, basic-oxygen, or electric-furnace. Additional refining by vacuum-arc-remelt (VAR) or electroslag-remelt (ESR) is permitted.

3.2 The steel shall be fully killed, fine grain (ASTM No. 5 or finer) as determined in accordance with ASTM Methods E 112, for Estimating the Average Grain Size of Metals,[3] specifically, Plate IV.

4. Heat Treatment

4.1 The material shall be heat treated by the manufacturer to conform to the tensile and hardness requirements of Table 2 by heating to not less than 1650°F (900°C), quenching in water or oil and tempering at not less than 1150°F (620°C). The heat-treating temperatures shall be reported on the test certificates.

5. Chemical Requirements

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

5.2 The steel shall conform on product analysis to the requirements as prescribed in Table 1, subject to the product analysis tolerances in Specification A 6.

6. Tensile Requirements

6.1 The material as represented by the tension test specimens shall conform to the tensile properties prescribed in Table 2.

6.2 A deduction of 1.25 % from the percentage of elongation specified in Table 2 shall be made for each decrease of $^1/_{32}$ in. (0.80 mm) of the specified thickness under $^5/_{16}$ in. (8.0 mm). This deduction in elongation shall not exceed 3 %.

---

[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 24, 1977. Published August 1977. Originally published as A 514 – 64. Last previous edition A 514 – 75.

[2] *Annual Book of ASTM Standards,* Part 4.

[3] *Annual Book of ASTM Standards,* Part 11.

7. Brinell Hardness Requirements

7.1 For plates 3/8 in. (9.5 mm) and under in thickness, a Brinell hardness test may be used instead of tension testing each plate, in which case a tension test shall be made from a corner of each of two plates per lot. A lot shall consist of plates from the same heat and thickness, same prior condition and scheduled heat treatment and shall not exceed 15 tons (13.6 Mg) in weight. A Brinell hardness test shall be made on each plate not tension tested and shall meet the requirements shown in Table 2.

8. Test Specimens

8.1 When possible, all test specimens shall be cut from the plate in its heat-treated condition as shipped. If it is necessary to prepare test specimens from separate pieces, these pieces shall be full thickness, and all pieces shall be similarly and simultaneously heat treated with the material. All such separate pieces shall be of such size that the prepared test specimens are free of any variation in properties due to edge effects.

8.2 The purchaser shall specify on the purchase order any additional thermal treatments which shall be given to the test specimens in addition to the heat treatment specified in Section 4. (This is intended to simulate thermal treatments which subsequently may be done by the fabricator.)

9. Number of Tests

9.1 Except as described in 7.1, one tension test shall be taken from a corner of each plate as heat treated. Plates wider than 24 in. (610 mm) shall be tested in the transverse direction and are subject to the modifications for elongation and reduction of area contained in footnote *C* of Table 2.

9.2 One grain size test (see 3.2) shall be made from each heat.

10. Retest

10.1 Plates subjected to Brinell hardness tests and which fail to meet the hardness requirements, at the manufacturer's option, may be subjected to tension testing and shall be accepted if the results conform to the requirements of Table 2.

10.2 The manufacturer may reheat-treat plates that fail to meet the mechanical property requirements of this specification. All mechanical property tests shall be repeated when material is resubmitted for inspection.

11. Marking

11.1 Each plate shall be legibly marked with the ASTM specification number and type letter in addition to the standard markings in accordance with Specification A 6.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply when specified in the order or contract.

S1. When specified, the inspector shall examine every plate surface by visual and dimensional means, and for shipment preparation, in order to satisfy himself that the material conforms to the requirements of this specification.

S2. When specified, flatness tolerances closer than Table 16 of Specification A 6 are available and should be negotiated with the manufacturer.

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

S14. Bend Test.

TABLE 1 Chemical Requirements (Heat Analysis)

	Grade A, %	Grade B, %	Grade C, %	Grade D, %	Grade E, %	Grade F, %	Grade G, %	Grade H, %	Grade J, %	Grade K, %	Grade L, %	Grade M, %	Grade N, %	Grade P, %	Grade Q, %
Maximum Thickness, in. (mm)	1¼ (32.0)	1¼ (32.0)	1¼ (32.0)	1¼ (32.0)	6 (152)	4 (102)	2 (51.0)	2 (51.0)	1¼ (32)	2 (51.0)	2 (51.0)	2 (51.0)	¾ (19.0)	6 (152)	6 (152)
Carbon	0.15–0.21	0.12–0.21	0.10–0.20	0.13–0.20	0.12–0.20	0.10–0.20	0.15–0.21	0.12–0.21	0.12–0.21	0.10–0.20	0.13–0.20	0.12–0.21	0.15–0.21	0.12–0.21	0.14–0.21
Manganese	0.80–1.10	0.70–1.00	1.10–1.50	0.40–0.70	0.40–0.70	0.60–1.00	0.80–1.10	0.95–1.30	0.45–0.70	1.10–1.50	0.40–0.70	0.45–0.70	0.80–1.10	0.45–0.70	0.95–1.30
Phosphorus, max	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Sulfur, max	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Silicon	0.40–0.80	0.20–0.35	0.15–0.30	0.20–0.35	0.20–0.35	0.15–0.35	0.50–0.90	0.20–0.35	0.20–0.35	0.15–0.30	0.20–0.35	0.20–0.35	0.40–0.90	0.20–0.35	0.15–0.35
Nickel	...	...	...	...	...	0.70–1.00	...	0.30–0.70	...	...	...	1.20–1.50	...	1.20–1.50	1.20–1.50
Chromium	0.50–0.80	0.40–0.65	...	0.85–1.20	1.40–2.00	0.40–0.65	0.50–0.90	0.40–0.65	...	...	1.15–1.65	...	0.50–0.80	0.85–1.20	1.00–1.50
Molybdenum	0.18–0.28	0.15–0.25	0.20–0.30	0.15–0.25	0.40–0.60	0.40–0.60	0.40–0.60	0.20–0.30	0.50–0.65	0.45–0.55	0.25–0.40	0.45–0.60	0.25– max	0.45–0.60	0.40–0.60
Vanadium	...	0.03–0.08	...	[A]	[A]	0.03–0.08	...	0.03–0.08	...	...	[A]	...	...	...	0.03–0.08
Titanium	...	0.01–0.03	...	0.04–0.10	0.04–0.10	...	...	...	...	...	0.04–0.10	...	...	...	...
Zirconium	0.05–0.15[B]	...	...	...	...	...	0.05–0.15[B]	...	...	...	...	...	0.05–0.15[B]	...	...
Copper	...	...	...	0.20–0.40	0.20–0.40	0.15–0.50	...	...	...	...	0.20–0.40	...	...	...	...
Boron	0.0025 max	0.0005–0.005	0.001–0.005	0.0015–0.005	0.0015–0.005	0.0005–0.006	0.0025– max	0.0005–0.005	0.001–0.005	0.001–0.005	0.0015–0.005	0.001–0.005	0.0005–0.0025	0.001–0.005	...

[A] May be substituted for part or all of titanium content on a one for one basis.
[B] Zirconium may be replaced by cerium. When cerium is added, the cerium/sulfur ratio should be approximately 1.5 to 1, based upon heat analysis.

ASTM Logo Removed

A 514

TABLE 2 Tensile and Hardness Requirements

NOTE 1—On plates wider than 24 in. (610 mm), the test specimen shall be taken in the transverse direction. (See Section 9 and Specification A 6.)

NOTE 2—Either the full thickness rectangular specimen shown in Fig. 4 of ASTM Methods and Definitions A 370 for Mechanical Testing of Steel Products,[4] or the 1/2-in. (12.5-mm) diameter specimen shown in Fig. 5 of Methods A 370 may be used for plates over 3/4 to 1 1/2 in. (19 to 40 mm) in thickness.

Thickness, in.	Ultimate Tensile Strength, ksi (MPa)	Yield Strength[A] min, ksi (MPa)	Elongation in 2 in. or 50 mm,[B,C,E] min, %	Reduction of Area[B,C], min, %	Brinell Hardness[D] Number
To 3/4, incl	110 to 130 (760 to 895)	100 (690)	18	40[E]	235 to 293
Over 3/4 to 2 1/2, incl	110 to 130 (760 to 895)	100 (690)	18	40[E], 50[F]	...
Over 2 1/2 to 6, incl	100 to 130 (690 to 895)	90 (620)	16	50[F]	...

[A] Measured at 0.2 % offset or 0.5 % extension under load as described in Section 13 of Methods A 370.

[B] Elongation and reduction of area not required to be determined for floor plates.

[C] For plates tested in the transverse direction, the elongation minimum percent is reduced by 2 % and the reduction of area minimum requirement is reduced by 5 %.

[D] See Section 7.

[E] When measured on the Fig. 4 (Methods A 370) 1 1/2-in. (40-mm) wide specimen (see Note 2 above), the elongation is determined in a 2-in. or 50-mm gage length which includes the fracture and shows the greatest elongation.

[F] When measured on the Fig. 5 (Methods A 370) 1/2-in. (12.5-mm) round specimen (see Note 2 above).

[4] *Annual Book of ASTM Standards,* Parts 1, 2, 3, 4, 5, and 10.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A516: Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate and Lower-Temperature Service

CFR Section(s): 49 CFR 178.337-2(b)(2)(i)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: A 516/A 516M – 90 (Reapproved 1996)$^{\epsilon 1}$

Used in USDOE-NE Standards

Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service[1]

This standard is issued under the fixed designation A 516/A 516M; 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.

ϵ^1 NOTE—Editorial corrections were made to this standard in August 1999.

1. Scope

1.1 This specification[2] covers carbon steel plates intended primarily for service in welded pressure vessels where improved notch toughness is important.

1.2 Plates under this specification are available in four grades having different strength levels as follows:

Grade U.S. [SI]	Tensile Strength, ksi [MPa]
55 [380]	55–75 [380–515]
60 [415]	60–80 [415–550]
65 [450]	65–85 [450–585]
70 [485]	70–90 [485–620]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade U.S. [SI]	Maximum Thickness, in. [mm]
55 [380]	12 [305]
60 [415]	8 [205]
65 [450]	8 [205]
70 [485]	8 [205]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately 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 Documents

2.1 *ASTM Standards:*

A 20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

---

[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 A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved Dec. 28, 1990. Published May 1991. Originally published as A 516 – 64. Last previous edition A 516/A 516M – 86.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-516/SA-516M in Section II of that Code.

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

Copyright © ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, United States.

5. Heat Treatment

5.1 Plates 1.50 in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 1.50 in. [40 mm] in thickness shall be normalized.

5.3 When notch-toughness tests are required on plates 1½ in. [40 mm] and under in thickness, the plates shall be normalized unless otherwise specified by the purchaser.

5.4 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible for improvement of the toughness, provided the plates are subsequently tempered in the temperature range 1100 to 1300°F [595 to 705°C].

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

TABLE 1 Chemical Requirements

Elements	Composition, %			
	Grade 55 [Grade 380]	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max[A]:				
1/2 in. [12.5 mm] and under	0.18	0.21	0.24	0.27
Over 1/2 in. to 2 in. [12.5 to 50 mm], incl	0.20	0.23	0.26	0.28
Over 2 in. to 4 in. [50 to 100 mm], incl	0.22	0.25	0.28	0.30
Over 4 to 8 in. [100 to 200 mm], incl	0.24	0.27	0.29	0.31
Over 8 in. [200 mm]	0.26	0.27	0.29	0.31
Manganese:				
1/2 in. [12.5 mm] and under:				
Heat analysis[B]	0.60–0.90	0.60–0.90	0.85–1.20	0.85–1.20
Product analysis[B]	0.55–0.98	0.55–0.98	0.79–1.30	0.79–1.30
Over 1/2 in. [12.5 mm]:				
Heat analysis	0.60–1.20	0.85–1.20	0.85–1.20	0.85–1.20
Product analysis	0.55–1.30	0.79–1.30	0.79–1.30	0.79–1.30
Phosphorus, max[A]	0.035	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45

[A] Applies to both heat and product analyses.
[B] Grade 60 plates 1/2 in. [12.5 mm] and under in thickness may have 0.85–1.20 % manganese on heat analysis, and 0.79–1.30 % manganese on product analysis.

TABLE 2 Tensile Requirements

	Grade			
	55 [380]	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	55–75 [380–515]	60–80 [415–550]	65–85 [450–585]	70–90 [485–620]
Yield strength, min,[A] ksi [MPa]	30 [205]	32 [220]	35 [240]	38 [260]
Elongation in 8 in. [200 mm], min, %[B]	23	21	19	17
Elongation in 2 in. [50 mm], min, %[B]	27	25	23	21

[A]Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[B]See Specification A 20/A20M for elongation adjustment.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in ASTM Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

This standard is copyrighted by ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (http://www.astm.org).

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A570: Hot-Rolled Carbon Steel Sheet and Strip, Structural Quality

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 570 – 79**

Standard Specification for
HOT-ROLLED CARBON STEEL SHEET AND STRIP, STRUCTURAL QUALITY[1]

This Standard is issued under the fixed designation A 570; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers hot-rolled carbon steel sheet and strip of structural quality in cut lengths or coils. This material is intended for structural purposes where mechanical test values are required, and is available in a maximum thickness of 0.2299 in. (5.8 mm) except as limited by Specification A 568.

1.1.2 The following grades are covered in this specification:

	Mechanical Properties	
Grade	Yield Point, min, psi (MPa)	Tensile Strength, min, psi (MPa)
30	30 000 (210)	49 000 (340)
33	33 000 (230)	52 000 (360)
36	36 000 (250)	53 000 (365)
40	40 000 (280)	55 000 (380)
45	45 000 (310)	60 000 (410)
50	50 000 (340)	65 000 (450)

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standard:*

A 568, Specification for Steel, Carbon and High-Strength Low-Alloy Hot-Rolled Sheet, Hot-Rolled Strip, and Cold-Rolled Sheet, General Requirements[2]

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 568, unless otherwise provided herein.

4. Ordering Information

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

4.1.1 ASTM specification number and date of issue, and grade,

4.1.2 Copper-bearing steel (if required),

4.1.3 Special requirements (if required),

4.1.4 Name of material (hot-rolled sheets or strip),

4.1.5 Condition (Material to this specification is furnished in the hot-rolled condition. Pickled (or blast cleaned) should be specified if required. Material so ordered will be oiled unless ordered dry),

4.1.6 Dimensions, including type of edges,

4.1.7 Coil size requirements, and

4.1.8 Cast or heat (formerly ladle) analysis or test report (request, if required).

NOTE 2—A typical ordering description is as follows: ASTM A 570, Grade 36, Hot-Rolled Sheets, 0.075 by 36 cut edge by 96 in.

5. Chemical Requirements

5.1 The cast or heat analysis of the steel shall conform to the requirements prescribed in Table 1.

6. Physical Requirements

6.1 *Tensile Properties*—The material as

---

[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 A01.19 on Sheet Steel and Steel Sheets.

Current edition approved Aug. 31, 1979. Published October 1979. Originally published as A 570 – 66 T. Last previous edition A 570 – 78.

[2] *Annual Book of ASTM Standards*, Part 3.

represented by the test specimens shall conform to the requirements as to tensile properties prescribed in Table 2.

6.2 *Bending Properties*—The bend test specimens shall stand being bent at room temperature in any direction through 180 deg without cracking on the outside of the bent portion to an inside diameter which shall have a relation to the thickness of the specimen as prescribed in Table 3.

7. Test Specimens

7.1 Tension test specimens shall be taken longitudinally.

8. Number of Tests

8.1 Two tension tests and two bend tests shall be made from each heat or from each lot of 50 tons (45 Mg). When the amount of finished material from a heat or lot is less than 50 tons, only one tension test and one bend test shall be made. When material rolled from one heat differs 0.050 in. (1.27 mm) or more in thickness, one tension test and one bend test shall be made from both the thickest and thinnest material rolled regardless of the weight represented.

8.2 *Retests*—If one test fails, two more tests shall be run from the same lot, in which case both tests shall conform to the requirements prescribed in this specification; otherwise, the lot under test shall stand rejected.

9. Packaging

9.1 *Coil Size*—Small coils result from the cutting of full-size coils for center test purposes. These small coils are acceptable under this specification.

TABLE 1 Chemical Requirements

Element	Composition, %	
	Grades 30, 33, 36, and 40	Grades 45 and 50
Carbon, max	0.25	0.25
Manganese, max	0.90	1.35
Phosphorus, max	0.04	0.04
Sulfur, max	0.05	0.05
Copper, when copper is specified, min	0.20	0.20

TABLE 2 Tensile Requirements

	Grade 30	Grade 33	Grade 36	Grade 40	Grade 45	Grade 50
Tensile strength, min, psi (MPa)	49 000 (340)	52 000 (360)	53 000 (365)	55 000 (380)	60 000 (410)	65 000 (450)
Yield point, min, psi (MPa)	30 000 (210)	33 000 (230)	36 000 (250)	40 000 (280)	45 000 (310)	50 000 (340)
Elongation in 2 in. (50 mm), min, %, for thicknesses:						
0.2299 to 0.0972 in. (5.84 to 2.46 mm), incl	25.0	23.0	22.0	21.0	19.0	17.0
0.0971 to 0.0636 in. (2.45 to 1.62 mm), incl	24.0	22.0	21.0	20.0	18.0	16.0
0.0635 to 0.0255 in. (1.61 to 0.65 mm), incl	21.0	18.0	17.0	15.0	13.0	11.0
Elongation in 8 in. (200 mm), min, %, for thicknesses:						
0.2299 to 0.0972 in. (5.84 to 2.46 mm), incl	19.0	18.0	17.0	16.0	14.0	12.0
0.0971 to 0.0892 in. (2.45 to 2.26 mm), incl	17.0	16.0	15.0	14.0	12.0	10.0

TABLE 3 Bend Test Requirements

Grade	Ratio of Bend Diameter to Thickness of Specimen
30	1
33	1½
36	1½
40	2
45	2½
50	3

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A572: High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD ANSI/ASTM A 572 – 79

American Association State Highway and Transportation Officials Standard
AASHTO No.: M 223

Standard Specification for

HIGH-STRENGTH LOW-ALLOY COLUMBIUM-VANADIUM STEELS OF STRUCTURAL QUALITY[1]

This Standard is issued under the fixed designation A 572; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers four grades of high-strength low-alloy structural steel shapes, plates, sheet piling, and bars. Grades 42 and 50 are intended for riveted, bolted, or welded construction of bridges, buildings, and other structures. Grades 60 and 65 are intended for riveted or bolted construction of bridges, and for riveted, bolted, or welded construction in other applications. When the steel is used in welded construction, welding procedure shall be suitable for the steel and the intended service.

1.2 For welded bridge construction notch toughness is an important requirement. For this or other applications where notch-toughness requirements are indicated, they shall be negotiated between the purchaser and the producer.

1.3 The use of columbium, vanadium, and nitrogen, or combinations thereof, within the limitations noted in Section 5, shall be at the option of the producer unless otherwise specified. Where designation of one of these elements or combination of elements is desired, reference is made to Supplementary Requirement S1 in which these elements and their common combinations are listed as to type. When such a designation is desired, both the grade and type must be specified.

1.4 The maximum thicknesses available in the grades and products covered by this specification are shown in Table 1.

NOTE—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standard:*

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

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 6.

4. Process

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

5. Chemical Requirements

5.1 The heat analysis shall conform to the requirements prescribed in Table 2 and in 5.3.

5.2 The steel shall conform on product analysis to the requirements prescribed in Table 2 and 5.3 subject to the product analysis tolerances in Specification A 6.

5.3 Alloy content shall be in accordance with one of the following types:

---

[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.

Current edition approved Nov. 5, 1979. Published January 1980. Originally published as A 572 – 66. Last previous edition A 572 – 78.

[2] *Annual Book of ASTM Standards*, Part 4.

ASTM Logo Removed

Elements	Heat Analysis, %
Type 1—Columbium[a]	0.005–0.05[b]
Type 2—Vanadium	0.01–0.15
Type 3—Columbium[a] (0.05 max, %) plus vanadium[c]	0.02–0.15
Type 4—Nitrogen[d] (with vanadium)	0.015 max

[a] Columbium when added either singly or in combination with vanadium shall be restricted to the following unless killed steel is furnished:

Grades	Maximum Plate and Bar Thicknesses, in. (mm)	Structural Shape Size Groupings (Specification A 6, Table A)
42 and 50	3/4 (19)	Groups 1 and 2
60 and 65	1/2 (13)	Group 1

[b] Product analysis limits = 0.004–0.060 %.

[c] Product analysis limits = 0.01 to 0.16 when columbium and vanadium are used in combination.

[d] Nitrogen (0.015 max %) when added as a supplement to vanadium shall be reported, and the minimum ratio of vanadium to nitrogen shall be 4 to 1.

6. Mechanical Requirements

6.1 *Tensile Properties:*

6.1.1 The material as represented by the test specimens shall conform to the tensile properties given in Table 3.

6.1.2 For material under 5/16 in. (7.5 mm) in thickness or diameter, a deduction from the percentage of elongation in 8 in. (200 mm), specified in Table 3, of 1.25 % shall be made for each decrease of 1/32 in. (0.8 mm) of the specified thickness or diameter below 5/16 in.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply when specified in the order or contract:

S1. Types

S1.1 When a purchaser prefers to designate the specific elements (columbium, vanadium, nitrogen, or combinations thereof), one of the types listed below shall be specified. The type in addition to the grade must be shown on the order.

Type 1—Columbium

Type 2—Vanadium

Type 3—Columbium and vanadium

Type 4—Vanadium and nitrogen

S1.2 The composition limits of Section 5 shall apply for any of these types.

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

S14. Bend Test.

S18. Maximum Tensile Strength.

TABLE 1 Maximum Product Thickness

Grade	Yield Point, min		Maximum Thickness or Size			
			Plates and Bars		Structural Shapes Groups[b]	Sheet Piling
	psi	MPa	in.	mm		
42[a]	42 000	290	6	152.4	all	all
50[a]	50 000	345	2	50.8	all	all
60[a]	60 000	415	1 1/4	31.8	1 and 2	not available
65	65 000	450	1 1/4	31.8	1	not available

[a] In the above tabulation, Grades 42, 50, and 60 are the yield point levels most closely approximating a geometric progression pattern between 36 000 psi, min, yield point steels covered by Specification A 36, for Structural Steel[2] and 100 000 psi, min, yield strength steels covered by Specification A 514, for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding.[2]

[b] See Specification A 6.

TABLE 2 Chemical Requirements[a]
(Heat Analysis)

Diameter Thickness, or Distance Between Parallel Faces, in. (mm)	Grade	Carbon, max, %	Manganese,[b] max, %	Phosphorus, max, %	Sulfur, max, %	Silicon[c]: Plates to 1½-in. (38.1-mm) Thick, Shapes to 426 lb/ft (634 kg/m), Sheet Piling, and Bars[d] max, %	Silicon[c]: Plates Over 1½-in. (38.1 mm) Thick and Shapes Over 426 lb/ft (634 kg/m) range, %
6 (152)	42	0.21	1.35	0.04	0.05	0.40	0.15–0.40
2 (51)	50	0.23	1.35	0.04	0.05	0.40	0.15–0.40
1¼ (31.8)	60	0.26	1.35	0.04	0.05	0.40	. . .
>½–1¼ (12.7–31.8)	65	0.23	1.65	0.04	0.05	0.40	. . .
≤½ (12.7)[e]	65	0.26	1.35	0.04	0.05	0.40	. . .

[a] Copper when specified shall have a minimum content of 0.20 % by heat analysis (0.18 % product analysis).

[b] Manganese, minimum by heat analysis of 0.80 % (0.75 % product analysis) shall be required for all plates over ⅜ in. (9.5 mm) in thickness; a minimum of 0.50 % (0.45 % product analysis) shall be required for plates ⅜ in. and less in thickness, and for all other products. The manganese to carbon ratio shall not be less than 2 to 1.

[c] Silicon content in excess of 0.40 % by heat analysis must be negotiated.

[d] Bars over 1½ in. (38.1 mm) in diameter, thickness, or distance between parallel faces, shall be made by a killed steel practice.

[e] An alternative chemical requirement with a maximum carbon of 0.21 % and a maximum manganese of 1.65 % is permissible with the balance of the elements as shown in Table 2.

TABLE 3 Tensile Requirements[a]

Grade	Yield Point, min psi	Yield Point, min MPa	Tensile Strength, min psi	Tensile Strength, min MPa	Minimum Elongation,[b,c,d] % in 8 in. or 200 mm	Minimum Elongation,[b,c,d] % in 2 in. or 50 mm
42	42 000	290	60 000	415	20	24
50	50 000	345	65 000	450	18	21
60	60 000	415	75 000	520	16	18
65	65 000	450	80 000	550	15	17

[a] For plates wider than 24 in. (610 mm), the test specimen is taken in the transverse direction. See 11.2 of Specification A 6.

[b] Elongation not required to be determined for floor plate.

[c] For wide flange shapes over 426 lb/ft elongation in 2 in. (50 mm) of 19 % minimum applies.

[d] For plates wider than 24 in. (610 mm), the elongation requirement is reduced two percentage points for Grades 42 and 50, and three percentage points for Grades 60 and 65.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A588: High-Strength Low-Alloy Structural Steel with 50 ksi Minimum Yield Point to 4 inches Thick

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 588 – 79a**

American Association State Highway and Transportation Officials Standard
AASHTO No.: M 222

Standard Specification for
HIGH-STRENGTH LOW-ALLOY STRUCTURAL STEEL WITH 50 000 psi MINIMUM YIELD POINT TO 4 in. THICK[1]

This standard is issued under the fixed designation A 588; 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.

1. Scope

1.1 This specification covers high-strength low-alloy structural steel shapes, plates, and bars for welded, riveted, or bolted construction but intended primarily for use in welded bridges and buildings where savings in weight or added durability are important. The atmospheric corrosion resistance of this steel is approximately two times that of carbon structural steel with copper (Note 1). Welding technique is of fundamental importance, and it is presupposed that welding procedure will be suitable for the steel and the intended service. This specification is limited to material up to 8 in. (203.2 mm) inclusive in thickness.

NOTE 1—Two times carbon structural steel with copper is equivalent to four times carbon structural steel without copper (Cu 0.02 max).

NOTE 2—The values stated in inch-pound units are to be regarded as the standard.

2. General Requirements for Delivery

2.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of ASTM Specification A 6, for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use.[2]

3. Process

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

3.2 The steel shall be made to fine grain practice.

4. Chemical Requirements

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

4.2 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6.

4.3 When required, the manufacturer shall supply evidence of corrosion resistance satisfactory to the purchaser.

5. Tensile Requirements

5.1 The material as represented by the test specimens shall conform to the requirements for tensile properties prescribed in Table 2.

5.2 For material under 5⁄16 in. (7.9 mm) in thickness or diameter, as represented by the test specimen, a deduction of 1.25 percentage points from the percentage of elongation in 8 in. or 200 mm specified in Table 2 shall be made for each decrease of 1⁄32 in. (0.8 mm) of the specified thickness or diameter below 5⁄16 in. (7.9 mm).

---

[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 July 27 and Nov. 5, 1979. Published January 1980. Originally published as A 588 – 68. Last previous edition A 588 – 77a.

[2] *Annual Book of ASTM Standards*, Part 4.

SUPPLEMENTARY REQUIREMENTS

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

ASTM Logo Removed

S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S5. Charpy V-Notch Impact Test,
S6. Drop Weight Test,
S8. Ultrasonic Examination,
S14. Bend Test,
S15. Reduction of Area, and
S18. Maximum Tensile Strength.

TABLE 1 Chemical Requirements (Heat Analysis)

Element	Composition, %								
	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G	Grade H	Grade J
Carbon	0.19 max	0.20 max	0.15 max	0.10–0.20	0.15 max	0.10–0.20	0.20 max	0.20 max	0.20 max
Manganese	0.80–1.25	0.75–1.25	0.80–1.35	0.75–1.25	1.20 max	0.50–1.00	1.20 max	1.25 max	0.60–1.00
Phosphorus	0.04 max	0.04 max	0.04 max	0.04 max	0.04 max	0.04 max	0.04 max	0.035 max	0.04 max
Sulfur	0.05 max	0.05 max	0.05 max	0.05 max	0.05 max	0.05 max	0.05 max	0.040 max	0.05 max
Silicon	0.30–0.65	0.15–0.30	0.15–0.30	0.50–0.90	0.30 max	0.30 max	0.25–0.70	0.25–0.75	0.30–0.50
Nickel	0.40 max	0.50 max	0.25–0.50	...	0.75–1.25	0.40–1.10	0.80 max	0.30–0.60	0.50–0.70
Chromium	0.40–0.65	0.40–0.70	0.30–0.50	0.50–0.90	...	0.30 max	0.50–1.00	0.10–0.25	...
Molybdenum	...	...	...	...	0.08–0.25	0.10–0.20	0.10 max	0.15 max	...
Copper	0.25–0.40	0.20–0.40	0.20–0.50	0.30 max	0.50–0.80	0.30–1.00	0.30–0.50	0.20–0.35	0.30 min
Vanadium	0.02–0.10	0.01–0.10	0.01–0.10	...	0.05 max	0.01–0.10	...	0.02–0.10	...
Zirconium	...	...	...	0.05–0.15	...	...	...	...	...
Columbium	...	...	...	0.04 max	...	...	...	...	...
Titanium	...	...	...	...	...	...	0.07 max	0.005–0.030	0.03–0.05

TABLE 2 Tensile Requirements[a]

	Plates and Bars			Structural Shapes
	For Thicknesses 4 in. and Under (101.6 mm)	For Thicknesses Over 4 in. to 5 in. incl (101.6 to 127.0 mm)	For Thicknesses Over 5 in. to 8 in. incl (127.0 to 203.2 mm)	All Groups[f]
Tensile strength, min, psi (MPa)	70 000 (485)	67 000 (460)	63 000 (435)	70 000 (485)
Yield point, min, psi (MPa)	50 000 (345)	46 000 (315)	42 000 (290)	50 000 (345)
Elongation in 8 in. or 200 mm, min, %	18[b,c,d]	...	...	18[b]
Elongation in 2 in. or 50 mm, min, %	21[c,d]	21[c,d]	21[c,d]	21[e]

[a] For plates wider than 24 in. (610 mm), the test specimen is taken in the transverse direction. See 11.2 of Specification A 6.
[b] See 5.2.
[c] Elongation not required to be determined for floor plate.
[d] For plates wider than 24 in. (610 mm), the elongation requirement is reduced two percentage points.
[e] For wide flange shapes over 426 lb/ft elongation in 2 in. of 18 % minimum applies.
[f] See Specification A 6.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A611: Steel, Cold-rolled Sheet, Carbon, Structural

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 611 – 72 (Reapproved 1979)**

Standard Specification for

STEEL, COLD-ROLLED SHEET, CARBON, STRUCTURAL[1]

This Standard is issued under the fixed designation A 611; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers cold-rolled carbon structural steel sheet, in cut lengths or coils. It includes five strength levels designated as Grade A with yield point 25 000 psi (170 MPa) minimum; Grade B with 30 000 psi (210 MPa) minimum; Grade C with 33 000 psi (230 MPa) minimum; Grade D with 40 000 psi (280 MPa) minimum; and Grade E with 80 000 psi (550 MPa) minimum.

1.2 Grades A, B, C, and D have moderate ductility whereas Grade E is a full-hard product with no specified minimum elongation.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standard:*

A 568 Specification for Steel, Carbon and High-Strength Low-Alloy, Hot-Rolled Sheet, Hot-Rolled Strip, and Cold-Rolled Sheet, General Requirements.[2]

3. Definitions

3.1 *structural steel sheet*—sheet produced to tensile property values as specified or required.

4. General Requirements for Delivery

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 568.

5. Ordering Information

5.1 Orders for material under this specification shall include the following information, as required, to describe the material adequately.

5.1.1 ASTM specification number and date of issue and grade,

5.1.2 Copper-bearing steel (if required),

5.1.3 Special requirements (if required),

5.1.4 Name of material (cold-rolled sheet), structural quality,

5.1.5 Finish; matte (dull) finish will be supplied unless otherwise ordered,

5.1.6 Condition (oiled or dry),

5.1.7 Dimensions,

5.1.8 Coil size requirements, and

5.1.9 Cast or heat (formerly ladle) analysis and test report (request, if required).

NOTE 2—A typical ordering description is as follows: ASTM A 611, date, Grade C, Cold-Rolled Oiled Sheet, Structural Quality, 0.035 by 36 by 96 in. (0.89 by 914 by 2438 mm) for Roof Deck.

6. Chemical Requirements

6.1 The cast or heat analysis of the steel shall conform to the requirements prescribed in Table 1.

---

[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 A01.19 on Sheet Steel and Steel Sheets.
Current edition approved April 3, 1972. Published June 1972. Originally published as A 611 - 70. Last previous edition A 611 - 70.

[2] *Annual Book of ASTM Standards*, Part 3.

7. Mechanical Requirements

7.1 *Tension Tests:*

7.1.1 *Requirements*—The material as represented by the test specimens shall conform to the mechanical requirements prescribed in Table 2.

7.1.2 *Number of Tests*—Two tension tests shall be made from each heat or from each lot of 50 tons (45 Mg). When the amount of finished material from a heat or lot is less than 50 tons, only one tension test shall be made. When material rolled from one heat differs 0.050 in. (1.27 mm) or more in thickness, one tension test shall be made from both the thickest and thinnest material rolled regardless of the weight represented.

7.1.3 *Test Specimen Orientation*—Test specimens shall be taken longitudinally.

7.2 *Bend Test:*

7.2.1 *Requirements*—The bend test specimens shall stand being bent at room temperature in any direction through 180 deg without cracking on the outside of the bent portion to an inside diameter which shall have a relation to the thickness of the specimen as prescribed in Table 3.

7.2.2 *Number of Tests*—Two bend tests shall be made from each heat or from each lot of 50 tons (45 Mg). When the amount of finished material from a heat or lot is less than 50 tons, only one bend test shall be made. When material rolled from one heat differs 0.050 in. (1.27 mm) or more in thickness, one bend test shall be made from both the thickest and thinnest material rolled regardless of the weight represented.

7.2.3 *Retests*—If one test fails, two more tests shall be run from the same lot, in which case both tests shall conform to the requirements prescribed in this specification; otherwise, the lot under test shall stand rejected.

8. Finish and Condition

8.1 *Surface Finish*—Unless otherwise specified the sheet shall have a matte (dull) finish.

8.2 *Oiling*—The sheet shall be furnished oiled or dry, as specified.

9. Certification and Reports

9.1 When requested, the manufacturer shall furnish copies of a test report showing the results of the ladle or cast analysis and mechanical property tests made to determine compliance with this specification. The report shall include the purchase order number; ASTM designation number; and heat or lot number correlating the test results with the material represented.

10. Packaging

10.1 *Coil Size*—Small coils result from the cutting of full-size coils for center test purposes. These small coils are acceptable under this specification.

TABLE 1 Chemical Requirements

Element	Composition, %	
	Grades A, B, C, E	Grade D
Carbon, max	0.20	0.20
Manganese, max	0.60	0.90
Phosphorus, max	0.04	0.04
Sulfur, max	0.04	0.04
Copper, when copper steel is specified, min	0.20	0.20

TABLE 2 Mechanical Requirements

Grade	Yield Point, min		Tensile Strength, min		Elongation in 2 in. or 50 mm, min, %
	psi	MPa	psi	MPa	
A	25 000	170	42 000	290	26
B	30 000	210‡	45 000	310	24
C	33 000	230	48 000	330	22
D	40 000	280‡	52 000	360	20
E	80 000[A]	550	82 000	570	...

[A] On this full-hard product, the yield point approaches the tensile strength and since there is no halt in the gage or drop in the beam, the yield point shall be taken as the stress at 0.5 % elongation, under load.

‡ Editorially changed.

TABLE 3 Bend Test Requirements

Grade	Ratio of the Bend Diameter to Thickness of the Specimen
A	0
B	1
C	1 $^1/_2$
D	2
E	bend test not applicable

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A615: Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD ANSI/ASTM A 615 – 79

American Association State Highway and Transportation Officials Standard
AASHTO No.: M 31

Standard Specification for DEFORMED AND PLAIN BILLET-STEEL BARS FOR CONCRETE REINFORCEMENT[1]

This standard is issued under the fixed designation A 615; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers deformed and plain billet-steel concrete-reinforcement bars. A deformed bar is defined as a bar that is intended for use as reinforcement in reinforced concrete construction. The surface of the bar is provided with lugs or protrusions (herein-after called *deformations*) which inhibit longitudinal movement of the bar relative to the concrete which surrounds the bar in such construction and conform to the provisions of this specification. The standard sizes and dimensions of deformed bars and their number designations shall be those listed in Table 1.

1.1.1 A supplementary requirement (S1) of an optional nature is provided. It shall apply only when specified by the purchaser.

1.2 Bars are of two minimum yield levels: namely, 40 000 psi and 60 000 psi, designated as Grade 40 and Grade 60, respectively.

1.3 Hot-rolled plain rounds, in sizes up to and including 2 in. in diameter in coils or cut lengths, when specified for dowels, spirals and structural ties or supports shall be furnished under this specification in Grade 40 and Grade 60 (Note 1). For bending properties, test provisions of the nearest nominal diameter deformed bar size shall apply. Those requirements providing for deformations and marking shall not be applicable.

1.4 The weldability of the steel is not part of this specification.

NOTE 1—The weight for plain rounds smaller than 3/8 in. in diameter shall be computed on the basis of the size in Specification A 510.

NOTE 2—A complete metric companion to Specification A 615 has been developed—A 615M; therefore, no metric equivalents are presented in this specification.

2. Applicable Documents

2.1 *ASTM Standards*:

A 370 Methods and Definitions for Mechanical Testing of Steel Products[2]

A 510 Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel[3]

A 700 Recommended Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[4]

2.2 *Military Standards*:

MIL-STD-129 Marking for Shipment and Storage[5]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[5]

2.3 *Federal Standard*:

---

[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 A01.05 on Steel Reinforcement.

Current edition approved Sept. 17, 1979. Published November 1979. Originally published as A 615 – 68. Last previous edition A 615 – 78.

[2] *Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, 5, and 10.

[3] *Annual Book of ASTM Standards*, Part 3.

[4] *Annual Book of ASTM Standards*, Parts 1, 3, 4, and 5.

[5] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120.

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[5]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity (weight or length),

3.1.2 Name of material (deformed and plain billet-steel bars for concrete reinforcement),

3.1.3 Size and length,

3.1.4 Deformed or plain,

3.1.5 Grade,

3.1.6 Packaging (see Section 16),

3.1.7 Supplementary requirements (if desired), and

3.1.8 ASTM designation and date of issue.

NOTE 3—A typical ordering description is as follows: 8000-linear ft, deformed and plain billet-steel bars for concrete reinforcement, No. 8, 30 ft 0 in. long, deformed, Grade 60, in secured lifts, including Supplementary Requirement S1, to ASTM A 615 dated ____.

4. Material and Manufacture

4.1 The bars shall be rolled from properly identified heats of mold cast or strand cast steel using the open-hearth, basic-oxygen, or electric-furnace process.

5. Chemical Requirements

5.1 An analysis of each heat of steel shall be made by the manufacturer from test samples taken preferably during the pouring of the heats. The percentages of carbon, manganese, phosphorus, and sulfur, shall be determined. The phosphorus content thus determined shall not exceed 0.05 %.

5.2 The chemical composition thus determined shall be reported on request to the purchaser or his representative.

5.3 An analysis may be made by the purchaser from finished bars. The phosphorus content thus determined shall not exceed that specified in 5.1 by more than 25 %.

6. Requirements for Deformations

6.1 Deformations shall be spaced along the bar at substantially uniform distances. The deformations on opposite sides of the bar shall be similar in size and shape.

6.2 The deformations shall be placed with respect to the axis of the bar so that the included angle is not less than 45 deg. Where the line of deformations forms an included angle with the axis of the bar of from 45 to 70 deg inclusive, the deformations shall alternately reverse in direction on each side, or those on one side shall be reversed in direction from those on the opposite side. Where the line of deformation is over 70 deg, a reversal in direction is not required.

6.3 The average spacing or distance between deformations on each side of the bar shall not exceed seven tenths of the nominal diameter of the bar.

6.4 The overall length of deformations shall be such that the gap between the ends of the deformations on opposite sides of the bar shall not exceed 12½ % of the nominal perimeter of the bar. Where the ends terminate in a longitudinal rib, the width of the longitudinal rib shall be considered the gap. Where more than two longitudinal ribs are involved, the total width of all longitudinal ribs shall not exceed 25 % of the nominal perimeter of the bar; furthermore, the summation of gaps shall not exceed 25 % of the nominal perimeter of the bar. The nominal perimeter of the bar shall be 3.14 times the nominal diameter.

6.5 The spacing, height, and gap of deformations shall conform to the requirements prescribed in Table 1.

7. Measurements of Deformations

7.1 The average spacing of deformations shall be determined by dividing a measured length of the bar specimen by the number of individual deformations and fractional parts of deformations on any one side of the bar specimen. A measured length of the bar specimen shall be considered the distance from a point on a deformation to a corresponding point on any other deformation on the same side of the bar. Spacing measurements shall not be made over a bar area containing bar marking symbols involving letters or numbers.

7.2 The average height of deformations shall be determined from measurements made on not less than two typical deformations. Determinations shall be based on three measurements per deformation, one at the center of the overall length and the other two at the quarter points of the overall length.

7.3 Insufficient height, insufficient circumferential coverage, or excessive spacing of deformations shall not constitute cause for rejection unless it has been clearly established by determinations on each lot (Note 4) tested that typical deformation height, gap, or spacing do not conform to the minimum requirements prescribed in Section 6. No rejection may be made on the basis of measurements if fewer than ten adjacent deformations on each side of the bar are measured.

NOTE 4—A lot is defined as all the bars of one bar number and pattern of deformation contained in an individual shipping release or shipping order.

8. Tensile Requirements

8.1 The material, as represented by the test specimens, shall conform to the requirements for tensile properties prescribed in Table 2.

8.2 The yield point or yield strength shall be determined by one of the following methods:

8.2.1 The yield point shall be determined by drop of the beam or halt in the gage of the testing machine.

8.2.2 Where the steel tested does not have a well-defined yield point, the yield strength shall be determined by one of the methods indicated in 8.2.2.1 and 8.2.2.2.

8.2.2.1 Extension under load using dividers with an 8-in. gage length. The extension under load shall be 0.04 in., and shall be determined by scribing on the specimen an 8-in. gage length, pivoting from a prick punch mark. The yield load shall be recorded when the total gage length under load becomes 8.04 in. as measured by the dividers.

8.2.2.2 Extension under load using an autographic diagram method or an extensometer as described in 13.1.2 to 13.1.3 of Methods and Definitions A 370. However, the extension under load shall be 0.005 in./in. of gage length (0.5 %).

8.3 The percentage of elongation shall be as prescribed in Table 2.

9. Bending Requirements

9.1 The bend-test specimen shall stand being bent around a pin without cracking on the outside of the bent portion. The requirements for degree of bending and sizes of pins are prescribed in Table 3.

9.2 The bend test shall be made on specimens of sufficient length to ensure free bending and with apparatus which provides:

9.2.1 Continuous and uniform application of force throughout the duration of the bending operation.

9.2.2 Unrestricted movement of the specimen at points of contact with the apparatus and bending around a pin free to rotate, or bending about a central pin on a simple span with end supports free to rotate.

9.2.3 Close wrapping of the specimen around the pin during the bending operation.

9.3 Other methods of bend testing may be used, but failures due to such methods shall not constitute a basis for rejection.

9.4 Bars of size Nos. 14 and 18 shall not be subject to bend test requirements unless ordered in accordance with supplemental requirement of this specification.

10. Test Specimens

10.1 Tension test specimens shall be the full section of the bar as rolled except Nos. 11, 14 and 18 reinforcing bars in Grade 60 which, at the option of the manufacturer, may be tested by one of the reduced section type of tests indicated in 10.1.1.

10.1.1. Reduced section specimens shall be machined from the bar to a diameter of 1.128 in. (1 in.^{2} cross section) over a length of not less than 9 in., with fillets at the ends of the turned-down section having a radius of ½ in. and using an 8-in. gage length. The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 % larger in diameter than the center (controlling dimension).

10.2 The unit stress determinations on full-size specimens shall be based on the nominal bar area. For reduced section specimens the yield strength and tensile strength results shall be corrected by the ratio of as-rolled bar weight to nominal bar weight.

10.3 The bend-test specimens shall be the full section of the bar as rolled.

11. Number of Tests

11.1 For bar sizes No. 3 to 11, inclusive, one tension test and one bend test shall be made of the largest size rolled from each heat. If, however, material from one heat differs by three or more designation numbers, one tension and one bend test shall be made from both the highest and lowest designation number of the deformed bars rolled.

11.2 In the case of Nos. 14 and 18 bars, one tension test shall be made of each size rolled from each heat.

12. Retests

12.1 If any tensile property of any tension test specimen is less than that specified, and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

12.2 If the results of an original tension specimen are less than specification but within 2000 psi of the required tensile strength, within 1000 psi of the required yield point, or within 2 percentage units of the minimum required elongation, a retest shall be permitted on one random specimen from the heat or lot. If the results of this test specimen meet the specified requirements, the heat or lot shall be accepted.

12.3 If a bend test fails, a retest shall be permitted on one random specimen from the heat or lot. If this test specimen meets the specified requirements, the heat or lot shall be accepted. The retest shall be performed on the test specimen that is at air temperature but not less than 60°F.

12.4 If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

12.5 If any test specimen develops flaws, it may be discarded and another specimen of the same size bar from the same heat substituted.

13. Permissible Variation in Weight

13.1 The permissible variation shall not exceed 6 % under nominal weight, except for bars smaller than ⅜ in. plain round, the permissible variation in weight shall be computed upon the basis of the permissible variation in diameter in Specification A 510. Reinforcing bars are evaluated on the basis of nominal weights. In no case shall the overweight of any bar be the cause for rejection.

14. Finish

14.1 The bars shall be free of injurious defects and shall have a workmanlike finish.

14.2 Rust, seams, surface irregularities, or mill scale shall not be cause for rejection, provided the weight, dimensions, cross-sectional area, and tensile properties of a hand wire brushed test specimen are not less than the requirements of this specification.

15. Marking

15.1 When loaded for mill shipment, bars shall be properly separated and tagged with the manufacturer's heat or test identification number.

15.2 Each producer shall identify the symbols of his marking system.

15.3 All bars produced to this specification, except plain round bars which shall be tagged for grade, shall be identified by a distinguishing set of marks legibly rolled into the surface of one side of the bar to denote in the following order:

15.3.1 *Point of Origin*—Letter or symbol established as the producer's mill designation.

15.3.2 *Size Designation*—Arabic number corresponding to bar designation number of Table 1.

15.3.3 *Type of Steel*—Letter *N* indicating that the bar was produced to this specification.

15.3.4 *Minimum Yield Designation*—For Grade 60 bars, either the number *60* or a single continuous longitudinal line through at least 5 spaces offset from the center of the bar side. (No marking designation for Grade 40 bars.)

16. Packaging

16.1 When specified in the purchase order, packaging shall be in accordance with the procedures in Recommended Practices A 700.

16.2 *For Government Procurement Only*—When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

17. Inspection

17.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection, shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

17.2 *For Government Procurement Only*—Except as otherwise specified in the contract, the contractor is responsible for the performance of all inspection and test requirements specified herein and may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at the time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification, where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

18. Rejection

18.1 Unless otherwise specified, any rejection based on tests made in accordance with 5.3, shall be reported to the manufacturer within 5 working days from the receipt of samples by the purchaser.

18.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

18.3 Substitution of bars produced to Supplementary Requirement S1 (marked S) for bars ordered to the basic Specification (marked N) shall not be cause for rejection.

19. Rehearing

19.1 Samples tested in accordance with 5.3 that represent rejected material shall be preserved for 2 weeks from the date rejection is reported to the manufacturer. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TABLE 1 Deformed Bar Designation Numbers, Nominal Weights, Nominal Dimensions and Deformation Requirements

		Nominal Dimensions[a]			Deformation Requirements, in.		
Bar Designation No.[b]	Nominal Weight, lb/ft	Diameter, in.	Cross-Sectional Area, in.^{2}	Perimeter, in.	Maximum Average Spacing	Minimum Average Height	Maximum Gap (Chord of 12½ % of Nominal Perimeter)
3	0.376	0.375	0.11	1.178	0.262	0.015	0.143
4	0.668	0.500	0.20	1.571	0.350	0.020	0.191
5	1.043	0.625	0.31	1.963	0.437	0.028	0.239
6	1.502	0.750	0.44	2.356	0.525	0.038	0.286
7	2.044	0.875	0.60	2.749	0.612	0.044	0.334
8	2.670	1.000	0.79	3.142	0.700	0.050	0.383
9	3.400	1.128	1.00	3.544	0.790	0.056	0.431
10	4.303	1.270	1.27	3.990	0.889	0.064	0.487
11	5.313	1.410	1.56	4.430	0.987	0.071	0.540
14	7.65	1.693	2.25	5.32	1.185	0.085	0.648
18	13.60	2.257	4.00	7.09	1.58	0.102	0.864

[a] The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight per foot as the deformed bar.

[b] Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars.

ASTM Logo Removed

TABLE 2 Tensile Requirements

	Grade 40[a]	Grade 60
Tensile strength, min, psi	70 000	90 000
Yield strength, min, psi	40 000	60 000
Elongation in 8 in., min, %:		
Bar No.		
3	11	9
4, 5, 6	12	9
7	11	8
8	10	8
9	9	7
10	8	7
11	7	7
14, 18	...	7

[a] Grade 40 bars are furnished only in sizes 3 through 11. Sizes 7 through 11 may not be readily available; manufacturers should be consulted to verify availability.

TABLE 3 Bend Test Requirements

Bar Designation No.	Pin Diameter for[a] Bend Tests d = nominal diameter of specimen	
	Grade 40	Grade 60
3, 4, 5	4*d*	4*d*
6	5*d*	5*d*
7, 8	5*d*	6*d*
9, 10, 11	5*d*	8*d*

[a] Test bends 180 deg unless noted otherwise.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified in the purchase order or contract.

S1. For material ordered to this supplementary requirement, articles 9.1, 9.3, 10.1, 10.1.1, 11.2, and 15.3.3 are replaced by the following (all requirements S1.1 through S1.5 shall apply):

S1.1 (*replaces 9.1 and 9.3*) The bend-test specimen shall stand being bent, when at ambient temperature but in no case less than 60°F around a pin without cracking on the outside of the bent portion. The requirements for degree of bending and sizes of pins are prescribed in Table S1.

S1.2 (*replaces 10.1 and 10.1.1*) Tension test specimens shall be the full section of the bar as rolled.

S1.3 (*replaces 11.2*) In the case of Nos. 14 and 18 bars, one tension test and one bend test shall be made of each size rolled from each heat.

S1.4 If a bend test fails for reasons other than mechanical reasons or flaws in the specimen as described in 12.4 and 12.5, a retest shall be permitted on two random specimens from the same heat or lot. If the results of both test specimens meet the specified requirements, the heat or lot shall be accepted.

S1.5 (*replaces 15.3.3*) Bars furnished to this supplement shall be designated for type of steel by the symbol S.

TABLE S1 Bend Test Requirements (Supplementary)

Bar Designation No.	Pin Diameter for Bend Tests[a] d = nominal diameter of specimen	
	Grade 40	Grade 60
3, 4, 5	3½*d*	3½*d*
6, 7, 8	5*d*	5*d*
9, 10, 11	5*d*	7*d*
14, 18 (90 deg)	...	9*d*

[a] Test bends 180 deg unless noted otherwise.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A616: Rail-Steel Deformed and Plain Bars for Concrete Reinforcement

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD ANSI/ASTM A 616 – 79

American Association State Highway and Transportation Officials Standard
AASHTO No.: M 42

Standard Specification for RAIL-STEEL DEFORMED AND PLAIN BARS FOR CONCRETE REINFORCEMENT[1]

This standard is issued under the fixed designation A 616; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers deformed and plain rail steel concrete reinforcement bars. A deformed bar is defined as a bar that is intended for use as reinforcement in reinforced concrete construction. The surface of the bar is provided with lugs or protrusions (hereinafter called *deformations*) which inhibit longitudinal movement of the bars relative to the concrete which surrounds the bars in such construction and conform to the provisions of this specification. The standard sizes and dimensions of deformed bars and their number designations shall be those listed in Table 1.

1.2 Bars are of two minimum yield levels: namely, 50 000 psi (345 MPa) and 60 000 psi (415 MPa), designated as Grade 50 and Grade 60, respectively.

1.3 Plain rounds, in sizes up to and including 2 in. (50.8 mm) in diameter, in coils or cut lengths, when specified for dowels, spirals and structural ties or supports shall be furnished under this specification in Grade 50 and Grade 60. For bending properties test provisions of the nearest smaller nominal diameter deformed bar size shall apply. Those requirements providing for deformations and marking shall not be applicable.

1.4 The weldability of the steel is not part of this specification.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards*:

A 370 Methods and Definitions for Mechanical Testing of Steel Products[2]

A 700 Recommended Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[3]

2.2 *Military Standards*:

MIL-STD-129 Marking for Shipment and Storage[4]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[4]

2.3 *Federal Standard*:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[4]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity (weight or length),

3.1.2 Name of material (rail-steel deformed and plain bars for concrete reinforcement),

3.1.3 Size and length,

3.1.4 Deformed or plain,

3.1.5 Grade,

3.1.6 Packaging (see Section 14), and

3.1.7 ASTM designation and date of issue.

---

[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 A01.05 on Steel Reinforcement Bars.

Current edition approved July 27, 1979. Published September 1979. Originally published as A 616 – 68. Last previous edition A 616 – 76.

[2] *Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, 5, and 10.

[3] *Annual Book of ASTM Standards*, Parts 1, 3, 4, and 5.

[4] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120.

NOTE 2—A typical ordering design is as follows: 8000 linear ft rail-steel deformed and plain bars for concrete reinforcement, No. 8, 40 ft 0 in. long, deformed, Grade 60, in secured lifts, to ASTM A 616 dated ——.

4. Material and Manufacture

4.1 The bars shall be rolled from standard section Tee rails. No other materials such as those known by the terms *rerolled*, *rail-steel equivalent*, and *rail-steel quality* shall be substituted.

5. Requirements for Deformations

5.1 Deformations shall be spaced along the bar at substantially uniform distances. The deformations on opposite sides of the bar shall be similar in size and shape.

5.2 The deformations shall be placed with respect to the axis of the bar so that the included angle is not less than 45 deg. Where the line of deformations forms an included angle with the axis of the bar of from 45 to 70 deg inclusive, the deformations shall alternately reverse in direction on each side, or those on one side shall be reversed in direction from those on the opposite side. Where the line of deformation is over 70 deg, a reversal in direction is not required.

5.3 The average spacing or distance between deformations on each side of the bar shall not exceed seven tenths of the nominal diameter of the bar.

5.4 The overall length of deformations shall be such that the gap between the ends of the deformations on opposite sides of the bar shall not exceed 12½ % of the nominal perimeter of the bar. Where the ends terminate in a longitudinal rib, the width of longitudinal rib shall be considered the gap. Where more than two longitudinal ribs are involved, the total width of all longitudinal ribs shall not exceed 25 % of the nominal perimeter of the bar; furthermore, the summation of gaps shall not exceed 25 % of the nominal perimeter of the bar. The nominal perimeter of the bar shall be 3.14 times the nominal diameter.

5.5 The spacing, height and gap of deformations shall conform to the requirements prescribed in Table 1.

6. Measurements of Deformations

6.1 The average spacing of deformations shall be determined by dividing a measured length of the bar specimen by the number of individual deformations and fractional parts of deformations on any one side of the bar specimen. A measured length of the bar specimen shall be considered the distance from a point on a deformation to a corresponding point on any other deformation on the same side of the bar. Spacing measurements shall not be made over a bar area containing bar marking symbols involving letters or numbers.

6.2 The average height of deformations shall be determined from measurements made on not less than two typical deformations. Determinations shall be based on three measurements per deformation, one at the center of the over-all length and the other two at the quarter points of the overall length.

6.3 Insufficient height, insufficient circumferential coverage, or excessive spacing of deformations shall not constitute cause for rejection unless it has been clearly established by determinations on each lot (Note 3) tested that typical deformation height, gap or spacing do not conform to the minimum requirements prescribed in Section 5. No rejection may be made on the basis of measurements if fewer than ten adjacent deformations on each side of the bar are measured.

NOTE 3—A lot is defined as all the bars of one bar number and pattern of deformation contained in an individual shipping release or shipping order.

7. Tensile Requirements

7.1 *Grade 50 and Grade 60*—The material as represented by the test specimens shall conform to the requirements for tensile properties prescribed in Table 2.

7.2 The yield point or yield strength shall be determined by one of the following methods:

7.2.1 The yield point shall be determined by drop of the beam or halt in the gage of the testing machine.

7.2.2 When the steel tested does not have a well-defined yield point, the yield strength shall be tested by one of the methods indicated in 7.2.2.1 or 7.2.2.2.

7.2.2.1 Extension under load using dividers with an 8-in. (203.2-mm) gage length. The extension under load shall be 0.04 in. (1.02 mm) and shall be determined by scribing on the specimen an 8-in. gage length, pivoting from a prick punch mark. The yield load shall be recorded when the total gage length under load becomes 8.04 in. (204.2 mm) as measured by the dividers.

7.2.2.2 Extension under load using an autographic diagram method or an extensometer as described in 13.1.2 to 13.1.3 of Methods and Definitions A 370. However, the extension under load shall be 0.005 in./in. of gage length (0.5 %) for Grade 60.

7.3 The percentage of elongation shall be as prescribed in Table 2.

8. Bending Requirements

8.1 The bend test specimen shall stand being bent, when at ambient temperature but in no case less than 60°F (16°C), around a pin without cracking on the outside of the bent portion. The requirements for degree of bending and sizes of pins are prescribed in Table 3.

8.2 The bend test shall be made on specimens of sufficient length to ensure free bending and with apparatus which provides:

8.2.1 Continuous and uniform application of force throughout the duration of the bending operation.

8.2.2 Unrestricted movement of the specimen at points of contact with the apparatus and bending around a pin free to rotate, or bending about a central pin on a simple span with end supports free to rotate.

8.2.3 Close wrapping of the specimen around the pin during the bending operation.

8.3 Other methods of bend testing may be used, but failure due to such methods shall not constitute a basis for rejection.

9. Test Specimens

9.1 Tension test specimens shall be full section of the bar as rolled.

9.2 The unit stress determinations on full-size specimens shall be based on the nominal bar area.

9.3 The bend test specimens shall be the full section of the bar as rolled.

9.3.1 Bend tests are not required on bars fabricated by the producer.

10. Number of Tests

10.1 For bar sizes No. 3 to No. 11 inclusive, one tension test and one bend test shall be made of each bar size rolled from each lot of 10 tons (9072 kg) or fraction thereof rolled from rails varying not more than 10 lb/yd of nominal weight.

10.2 If any test specimen develops flaws, it may be discarded and another specimen of the same size bar from the same lot of 10 tons or fraction thereof substituted.

10.3 If any tensile property of the test specimen is less than that specified in Section 7 and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

11. Permissible Variations in Weight

11.1 The permissible variations shall not exceed 6 % under nominal weight. Reinforcing bars are evaluated on the basis of nominal weights. In no case shall overweight of any bar be the cause for rejection.

12. Finish

12.1 The bars shall be free from injurious defects and shall have a workmanlike finish.

12.2 Rust, seams, surface irregularities, or mill scale shall not be cause for rejection provided the weight, dimensions, cross-sectional area and tensile properties of a hand wire brushed test specimen are not less than the requirements of this specification.

13. Marking

13.1 When loaded for mill shipment, bars shall be properly separated and tagged with the manufacturer's test identification number.

13.2 Each producer shall identify the symbols of his marking system.

13.3 All bars produced to this specification, except plain round bars, which shall be tagged for grade, shall be identified by a distinguishing set of marks legibly rolled into the surface of one side of the bar to denote in the following order:

13.3.1 *Point of Origin*—Letter or symbol established as the producer's mill designation.

13.3.2 *Size Designation*—Arabic number corresponding to bar designation number of Table 1.

13.3.3 *Type of Steel*—A rail symbol indicating that the bar was produced from rail steel.

13.3.4 *Minimum Yield Designation*—For Grade 60 bars, either the number *60* or a single continuous longitudinal line through at least five spaces offset from the center of the bar side.

14. Packaging

14.1 When specified in the purchase order, packaging shall be in accordance with the procedures in Recommended Practices A 700.

14.2 *For Government Procurement Only*—When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

15. Inspection

15.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

15.2 *For Government Procurement Only*—Except as otherwise specified in the contract, the contractor is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at the time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

16. Rejection

16.1 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

TABLE 1 Deformed Bar Designation Numbers, Nominal Weights, Nominal Dimensions and Deformation Requirements

Inch-Pound Units

Bar Designation No.[B]	Nominal Weight, lb/ft	Nominal Dimensions[A] Diameter, in.	Nominal Dimensions[A] Cross-Sectional Area, in.^{2}	Nominal Dimensions[A] Perimeter, in.	Deformation Requirements, in. Maximum Average Spacing	Deformation Requirements, in. Minimum Average Height	Deformation Requirements, in. Maximum Gap (Chord of 12½ per-cent of Nominal Perimeter)
3	0.376	0.375	0.11	1.178	0.262	0.015	0.143
4	0.668	0.500	0.20	1.571	0.350	0.020	0.191
5	1.043	0.625	0.31	1.963	0.437	0.028	0.239
6	1.502	0.750	0.44	2.356	0.525	0.038	0.286
7	2.044	0.875	0.60	2.749	0.612	0.044	0.334
8	2.670	1.000	0.79	3.142	0.700	0.050	0.383
9	3.400	1.128	1.00	3.544	0.790	0.056	0.431
10	4.303	1.270	1.27	3.990	0.889	0.064	0.487
11	5.313	1.410	1.56	4.430	0.987	0.071	0.540

SI Units

Bar Designation No.[B]	Nominal Weight, kg/m	Nominal Dimensions[A] Diameter, mm	Nominal Dimensions[A] Cross Sectional Area, cm^2	Nominal Dimensions[A] Perimeter, mm	Deformation Requirements, mm Maximum Average Spacing	Deformation Requirements, mm Minimum Average Height	Deformation Requirements, mm Maximum Gap (Chord of 12½ per-cent of Nominal Perimeter)
3	0.560	9.52	0.71	29.9	6.7	0.38	3.5
4	0.994	12.70	1.29	39.9	8.9	0.51	4.9
5	1.552	15.88	2.00	49.9	11.1	0.71	6.1
6	2.235	19.05	2.84	59.8	13.3	0.96	7.3
7	3.042	22.22	3.87	69.8	15.5	1.11	8.5
8	3.973	25.40	5.10	79.8	17.8	1.27	9.7
9	5.059	28.65	6.45	90.0	20.1	1.42	10.9
10	6.403	32.26	8.19	101.4	22.6	1.62	11.4
11	7.906	35.81	10.06	112.5	25.1	1.80	13.6

[A] The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight per foot as the deformed bar.

[B] Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars.

TABLE 2 Tensile Requirements

	Grade 50	Grade 60
Tensile strength, min, psi (MPa)	80 000 (550)	90 000 (620)
Yield strength, min, psi (MPa)	50 000 (345)	60 000 (415)
Elongations in 8 in. or 203 mm, min, %:		
Bar No.		
3	6	6
4, 5, 6	7	6
7	6	5
8	5	4.5
9, 10, 11	5	4.5

TABLE 3 Bend Test Requirements

Bar Designation No.	Pin Diameter for[A] Bend Tests d = nominal diameter of specimen	
	Grade 50	Grade 60
3, 4, 5, 6	6*d*	6*d*
7, 8	6*d*	6*d*
9, 10	8*d*	8*d*
11	8*d* (90 deg)	8*d* (90 deg)

[A] Test bends 180 deg unless noted otherwise.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A617: Axle-Steel Deformed and Plain Bars for Concrete Reinforcement

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD ANSI/ASTM A 617 – 79

American Association State Highway and Transportation Officials Standard
AASHTO No.: M 53

Standard Specification for
AXLE-STEEL DEFORMED AND PLAIN BARS FOR CONCRETE REINFORCEMENT[1]

This standard is issued under the fixed designation A 617; 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.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards

1. Scope

1.1 This specification covers deformed and plain axle steel concrete reinforcement bars. A deformed bar is defined as a bar that is intended for use as reinforcement in reinforced concrete construction. The surface of the bar is provided with lugs or protrusions (hereinafter called *deformations*) which inhibit longitudinal movement of the bar relative to the concrete which surrounds the bar in such construction and conform to the provisions of this specification. The standard sizes and dimensions of deformed bars and their number designations shall be those listed in Table 1.

1.2 Bars are of two minimum yield levels: namely, 40 000 psi (275 MPa) and 60 000 psi (415 MPa), designated as Grade 40 and Grade 60, respectively.

1.3 Plain rounds, in sizes up to and including 2 in. (50.8 mm) in diameter, in coils or cut lengths, when specified for dowels, spirals and structural ties or supports shall be furnished under this specification in Grade 40 and Grade 60. For bending properties test provisions of the nearest smaller nominal diameter deformed bar size shall apply. Those requirements providing for deformations and marking shall not be applicable.

1.4 The weldability of the steel is not part of this specification.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards*:

A 370 Methods and Definitions for Mechanical Testing of Steel Products[2]

A 700 Recommended Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[3]

2.2 *Military Standards*:

MIL-STD-129 Marking for Shipment and Storage[4]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[4]

2.3 *Federal Standard*:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[4]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity (weight or length),

3.1.2 Name of material (axle-steel deformed and plain bars for concrete reinforcement),

3.1.3 Size and length,

3.1.4 Deformed or plain,

3.1.5 Grade,

3.1.6 Packaging (see Section 15), and

3.1.7 ASTM designation and date of issue.

---

[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 A01.05 on Steel Reinforcement Bars.

Current edition approved July 27, 1979. Published November 1979. Originally published as A 617 – 68. Last previous edition A 617 – 76.

[2] *Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, 5, and 10.

[3] *Annual Book of ASTM Standards*, Parts 1, 3, 4, and 5.

[4] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120.

NOTE 2—A typical ordering description is as follows: 8000 linear ft axle-steel deformed and plain bars for concrete reinforcement, No. 8, 40 ft 0 in. long, deformed, Grade 60, in secured lifts, to ASTM A 617 dated ——.

4. Material and Manufacture

4.1 The bars shall be rolled from carbon steel axles for cars and locomotive tenders in the following standard journal sizes. No other axles or material shall be used.

	Standard Journal Sizes, in. (mm)
Carbon steel axles	4¼ by 8 (108.0 by 203.2)
	5 by 9 (127.0 by 228.6)
	5½ by 10 (139.7 by 254.0)
	6 by 11 (152.4 by 279.4)

5. Carbon Determination

5.1 The manufacturer shall make a determination for the carbon content of each axle received by him for manufacture into reinforcement bars. Based on these carbon determinations, all steel axles shall be stocked for subsequent rolling in separated lots by carbon range. The ranges of carbon shall be determined by the manufacturer as those best suited to meet the mechanical requirements.

5.2 When requested by the purchaser, the manufacturer shall report the carbon range for each lot of bars furnished.

6. Requirements of Deformations

6.1 Deformations shall be spaced along the bar at substantially uniform distances. The deformations on opposite sides of the bar shall be similar in size and shape.

6.2 The deformations shall be placed with respect to the axis of the bar so that the included angle is not less than 45 deg. Where the line of deformations forms an included angle with the axis of the bar of from 45 to 70 deg inclusive, the deformations shall alternately reverse in direction on each side, or those on one side shall be reversed in direction from those on the opposite side. Where the line of deformation is over 70 deg, a reversal in direction is not required.

6.3 The average spacing or distance between deformations on each side of the bar shall not exceed seven tenths of the nominal diameter of the bar.

6.4 The over-all length of deformations shall be such that the gap between the ends of the deformations on opposite sides of the bar shall not exceed 12½ % of the nominal perimeter of the bar. Where the ends terminate in a longitudinal rib, the width of the longitudinal rib shall be considered the gap. Where more than two longitudinal ribs are involved, the total width of all longitudinal ribs shall not exceed 25 % of the nominal perimeter of the bar; furthermore, the summation of gaps shall not exceed 25 % of the nominal perimeter of the bar. The nominal perimeter of the bar shall be 3.14 times the nominal diameter.

6.5 The spacing, height and gap of deformations shall conform to the requirements prescribed in Table 1.

7. Measurements of Deformations

7.1 The average spacing of deformations shall be determined by dividing a measured length of the bar specimen by the number of individual deformations and fractional parts of deformations on any one side of the bar specimen. A measured length of the bar specimen shall be considered the distance from a point on a deformation to a corresponding point on any other deformation on the same side of the bar. Spacing measurements shall not be made over a bar area containing bar marking symbols involving letters or numbers.

7.2 The average height of deformations shall be determined from measurements made on not less than two typical deformations. Determinations shall be based on three measurements per deformation, one at the center of the overall length and the other two at the quarter points of the overall length.

7.3 Insufficient height, insufficient circumferential coverage, or excessive spacing of deformations shall not constitute cause for rejection unless it has been clearly established by determinations on each lot (Note 3) tested that typical deformation height, gap, or spacing do not conform to the minimum requirements prescribed in Section 6. No rejection may be made on the basis of measurements if fewer than ten adjacent deformations on each side of the bar are measured.

NOTE 3—A lot is defined as all the bars of one bar number and pattern of deformations contained in an individual shipping release or shipping order.

8. Tensile Requirements

8.1 *Grade 40 and Grade 60*—The material as represented by the test specimens shall conform to the requirements for tensile properties prescribed in Table 2.

8.2 The yield point or yield strength shall be determined by one of the following methods:

8.2.1 The yield point shall be determined by drop of the beam or halt in the gage of the testing machine.

8.2.2 When the steel tested does not have a well-defined yield point, the yield strength shall be tested by one of the methods indicated in 8.2.2.1 or 8.2.2.2.

8.2.2.1 Extension under load using dividers with an 8-in. (203.2-mm) gage length. The extension under load shall be 0.04 in. (1.02-mm) and shall be determined by scribing on the specimen an 8-in. gage length, pivoting from a prick punch mark. The yield load shall be recorded when the total gage length under load becomes 8.04 in. (204.2 mm) as measured by the dividers.

8.2.2.2 Extension under load using an autographic diagram method or an extensometer as described in 13.1.2 to 13.1.3 incl, of Methods and Definitions A 370. However, the extension under load shall be 0.005 in./in. of gage length (0.5 %) for Grade 60.

8.3 The percentage of elongation shall be as prescribed in Table 2.

9. Bending Requirements

9.1 The bend test specimen shall stand being bent, when at ambient temperature, but in no case less than 60°F (16°C) around a pin without cracking on the outside of the bent portion. The requirements for degree of bending and sizes of pins are prescribed in Table 3.

9.2 The bend test shall be made on specimens of sufficient length to ensure free bending and with apparatus which provides:

9.2.1 Continuous and uniform application of force throughout the duration of the bending operation.

9.2.2 Unrestricted movement of the specimen at points of contact with the apparatus and bending around a pin free to rotate, or bending about a central pin on a simple span with end supports free to rotate.

9.2.2 Close wrapping of the specimen around the pin during the bending operation.

9.3 Other methods of bend testing may be used, but failures due to such methods shall not constitute a basis for rejection.

10. Test Specimens

10.1 Tension test specimens shall be the full section of bar as rolled.

10.2 The unit stress determinations on full-size specimens shall be based on the nominal bar area.

10.3 The bend test specimens shall be the full section of the bar as rolled.

11. Number of tests

11.1 For bar sizes No. 3 to No. 11 inclusive, one tension test and one bend test shall be made from each lot (Note 3) of 10 tons (9072 kg) or fraction thereof, rolled from each lot of axles assorted in groups as specified in Section 5.

11.2 If any test specimen develops flaws, it may be discarded and another specimen from the same lot of 10 tons or fraction thereof substituted.

11.3 If any tensile property of the test specimen is less than that specified in Section 7 and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

12. Permissible Variations in Weights

12.1 The permissible variations shall not exceed 6 % under nominal weight. Reinforcing bars are evaluated on the basis of nominal weights. In no case shall overweight of any bar be the cause for rejection.

13. Finish

13.1 The bars shall be free of injurious defects and shall have a workmanlike finish.

13.2 Rust, seams, surface irregularities, or mill scale shall not be cause for rejection, provided the weight, dimensions, cross sectional area, and tensile properties of a hand wire brushed test are not less than the requirements of this specification.

14. Marking

14.1 When loaded for mill shipment, bars shall be properly separated and tagged with the manufacturer's test identification number.

14.2 Each manufacturer shall identify the symbols of his marking system.

14.3 All bars produced to this specification, except plain round bars which shall be tagged for grade, shall be identified by a distinguishing set of marks legibly rolled into the surface of one side of the bar to denote in the following order:

14.3.1 *Point of Origin*—Letter or symbol established as the manufacturer's mill designation.

14.3.2 *Size Designation*—Arabic number corresponding to Bar Designation Number of Table 1.

14.3.3 *Type of Steel*—Letter *A* indicating that the bar was produced from axle steel.

14.3.4 *Minimum Yield Designation*—For Grade 60 bars, either the number *60* or a single continuous longitudinal line through at least 5 spaces offset from the center of the bar side.

14.4 *For Government Procurement Only*—When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

15. Packaging

15.1 When specified in the purchase order, packaging shall be in accordance with the procedures in Recommended Practices A 700.

16. Inspection

16.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the puchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

16.2 *For Government Procurement Only*—Except as otherwise specified in the contract, the contractor is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at the time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

17. Rejection

17.1 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

TABLE 1 Deformed Bar Designation Numbers, Nominal Weights, Nominal Dimensions and Deformation Requirements

Inch-Pound Units

Bar Designation No.[B]	Nominal Weight, lb/ft	Nominal Dimensions[A]			Deformation Requirements, in.		
		Diameter, in.	Cross-Sectional Area, in.²	Perimeter, in.	Maximum Average Spacing	Minimum Average Height	Maximum Gap (Chord of 12½ % of Nominal Perimeter)
3	0.376	0.375	0.11	1.178	0.262	0.015	0.143
4	0.668	0.500	0.20	1.571	0.350	0.020	0.191
5	1.043	0.625	0.31	1.963	0.437	0.028	0.239
6	1.502	0.750	0.44	2.356	0.525	0.038	0.286
7	2.044	0.875	0.60	2.749	0.612	0.044	0.334
8	2.670	1.000	0.79	3.142	0.700	0.050	0.383
9	3.400	1.128	1.00	3.544	0.790	0.056	0.431
10	4.303	1.270	1.27	3.990	0.889	0.064	0.487
11	5.313	1.410	1.56	4.430	0.987	0.071	0.540

SI Units

Bar Designation No.[B]	Nominal Weight, kg/m	Nominal Dimensions[A]			Deformation Requirements, mm		
		Diameter, mm	Cross-Sectional Area, cm²	Perimeter, mm	Maximum Average Spacing	Minimum Average Height	Maximum Gap (Chord of 12½ % of Nominal Perimeter)
3	0.560	9.52	0.71	29.9	6.7	0.38	3.5
4	0.994	12.70	1.29	39.9	8.9	0.51	4.9
5	1.552	15.88	2.00	49.9	11.1	0.71	6.1
6	2.235	19.05	2.84	59.8	13.3	0.96	7.3
7	3.042	22.22	3.87	69.8	15.5	1.11	8.5
8	3.973	25.40	5.10	79.8	17.8	1.27	9.7
9	5.059	28.65	6.45	90.0	20.1	1.42	10.9
10	6.430	32.26	8.19	101.4	22.6	1.62	11.4
11	7.906	35.81	10.06	112.5	25.1	1.80	13.6

[A] The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight per foot as the deformed bar.

[B] Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars.

TABLE 2 Tensile Requirements

	Grade 40[A]	Grade 60
Tensile strength, min, psi (MPa)	70 000 (480)	90 000 (620)
Yield strength, psi (MPa)	40 000 (275)	60 000 (415)
Elongation in 8 in. or 203 mm, min, %:		
Bar No.		
3	11	8
4, 5, 6	12	8
7	11	8
8	10	7
9	9	7
10	8	7
11	7	7

[A] Sizes 7 through 11 may not be readily available; manufacturers should be consulted to verify availability.

TABLE 3 **Bend Test Requirements**

Bar Designation No.	Pin Diameter for Bend Tests 180 deg d = nominal diameter of specimen	
	Grade 40	Grade 60
3, 4, 5	4*d*	4*d*
6	5*d*	5*d*
7, 8	5*d*	6*d*
9, 10, 11	5*d*	8*d*

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM A633: Standard Specification for Normalized High-Strength Low Alloy Structural Steel

CFR Section(s): 49 CFR 178.338-2(a)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

AMERICAN NATIONAL STANDARD **ANSI/ASTM A 633 – 79a**

Standard Specification for

NORMALIZED HIGH-STRENGTH LOW-ALLOY STRUCTURAL STEEL[1]

This Standard is issued under the fixed designation A 633; 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.

1. Scope

1.1 This specification covers normalized high-strength low-alloy structural steel plates, shapes, and bars for welded, riveted, or bolted construction.

1.2 This material is particularly suited for service at low ambient temperatures of −50°F (−45°C) and higher where notch toughness better than that expected in as-rolled material of a comparable strength level is desired.

1.3 Four grades, designated Grades A, C, D, and E (essentially former Specification A 633 without a grade designation) are covered by this specification. Grade A provides a minimum yield point of 42 ksi (290 MPa) in thicknesses through 4 in. (102 mm), inclusive. Grades C and D provide a minimum yield point of 50 ksi (345 MPa) in thicknesses up to 2.50 in. (64 mm), inclusive and 46.0 ksi (315 MPa) in thicknesses over 2.50 in. to 4.0 in., inclusive. Grade E provides a minimum yield point of 60 ksi (415 MPa) in thicknesses up to 4.0 in., inclusive and 55 ksi (380 MPa) in thicknesses over 4 in. to 6 in. (152 mm), inclusive.

1.4 Current practice normally limits plates furnished under this specification to the maximum thicknesses shown in 1.3. The individual manufacturer should be consulted on size limitations for other product forms.

NOTE—The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards:*

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

E 112 Estimating the Average Grain Size of Metals[3]

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 6. These include the requirements for analysis, test preparation, method of test, permissible variations in dimensions and weight, quality, repair, marking, inspection, retests, rejection, packaging and loading, etc.

4. Ordering Information

4.1 The inquiry and order shall indicate the following:

4.1.1 Quantity (weight or number of pieces),

4.1.2 Name of material,

4.1.3 Dimensions or size designation,

4.1.4 ASTM designation, date of issue, and grade,

4.1.5 Condition (heat treatment requirements for material or test coupons, see 6.2), and

4.1.6 Supplementary requirements, if any.

5. Manufacture

5.1 *Melting Process:*

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

---

[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.

Current edition approved July 27 and August 31, 1979. Published October 1979. Originally published as A 633 – 70. Last previous edition A 633 – 78.

[2] *Annual Book of ASTM Standards,* Part 4.

[3] *Annual Book of ASTM Standards,* Part 11.

5.1.2 The steel shall be made to a fine grain practice (see 8.1).

6. Heat Treatment

6.1 The material shall be normalized by heating to a suitable temperature which produces an austenitic structure, but not exceeding 1700°F (925°C), holding a sufficient time to attain uniform heat throughout the material and cooling in air.

6.1.1 Grade E material over 3 in. (76 mm) in thickness shall be double normalized.

6.2 If the purchaser elects to perform the required heat treatment, the material shall be accepted on the basis of mill tests made from test coupons heat treated in accordance with the purchase order requirements. If the test coupon heat-treatment requirements are not indicated on the purchase order, the manufacturer shall heat treat the test coupons under conditions he considers appropriate. The manufacturer shall inform the purchaser of the heat-treatment procedure followed in heat treating the test coupons at the mill.

7. Chemical Requirements

7.1 The heat analysis shall conform to the chemical composition requirements listed in Table 1.

7.2 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6.

8. Metallurgical Structure

8.1 *Austenitic Grain Size*—The steel shall have a carburized austenitic grain size of 5 or finer as determined on one test per heat in accordance with Methods E 112, Plate IV, using the McQuaid-Ehn Test.

8.2 The provisions of 8.1 need not apply when notch toughness requirements are specified per Supplementary Requirement S1.

9. Mechanical Requirements

9.1 *Tension Tests*—The material as represented by the test specimens shall conform to the requirements listed in Table 2.

SUPPLEMENTARY REQUIREMENTS

S1. Notch Toughness Test

S1.1 Notch toughness tests may be specified in accordance with ASTM Specification A 673, for Sampling Procedure for Impact Testing of Structural Steel.[2]

S2. Copper-Bearing Steel

S2.1 In addition to the chemical composition requirements in Table 1, the steel shall have 0.20% minimum copper on heat analysis. Product analysis for copper shall be subject to the tolerances of Specification A 6.

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

S14. Bend Test.

ASTM Logo Removed **A 633**

TABLE 1 Chemical Requirements

Element	Grade A, %	Grade C, %	Grade D, %	Grade E, %
Carbon, max	0.18	0.20	0.20	0.22
Manganese:				
1½ in. (38.1 mm) and under in thickness	1.00–1.35	1.15–1.50[b]	0.70–1.35	1.15–1.50
Over 1½ in. to 4 in. (102 mm), incl	1.00–1.35	1.15–1.50[b]	1.00–1.60	1.15–1.50
Over 4 in. to 6 in. (152 mm), incl	...	...	...	1.15–1.50
Phosphorus, max	0.04	0.04	0.04	0.04
Sulfur, max	0.05	0.05	0.05	0.05
Silicon	0.15–0.50	0.15–0.50	0.15–0.50	0.15–0.50
Vanadium	...	...	...	0.04–0.11
Columbium	0.05 max	0.01–0.05	...	[a]
Nitrogen	...	...	...	0.01–0.03
Copper, max	...	...	0.35	...
Nickel, max	...	...	0.25	...
Chromium, max	...	...	0.25	...
Molybdenum, max	...	...	0.08	...

[a] Columbium may be present in the amount of 0.01–0.05 %.

[b] For Grade C manganese content may be increased to 1.60 % maximum provided the carbon content does not exceed 0.18 %.

[c] For Grade E the minimum total aluminum content shall be 0.018 %, or the vanadium nitrogen ratio shall be 4:1 minimum.

TABLE 2 Tensile Requirements[a]

	Grade A	Grades C and D	Grade E
Yield point, min, ksi (MPa):			
2.5 in. (89 mm) and under	42 (290)	50 (345)	60 (415)
Over 2.5 in. to 4 in. (102 mm), incl	42 (290)	46 (315)	60 (415)
Over 4 in. to 6 in. (152 mm), incl	...	...	55 (380)
Tensile strength, ksi (MPa):			
2.5 in. and under	63 to 83 (430 to 570)	70 to 90 (480 to 620)	80 to 100 (550 to 690)
Over 2.5 in. to 4 in., incl	63 to 83 (430 to 570)	65 to 85 (450 to 590)	80 to 100 (550 to 690)
Over 4 in. to 6 in., incl	...	...	75 to 95 (520 to 660)
Elongation in 8 in. or 200 mm, min, %[b,c]	18	18	18
Elongation in 2 in. or 50 mm, min, %[c]	23	23	23

[a] For plates wider than 24 in. (610 mm), the test specimen is taken in the transverse direction. See 11.2 of Specification A 6.

[b] For material under 5⁄16 in. (8 mm) in thickness, a deduction of 1.25 percentage points shall be made for each decrease of 1⁄32 in. (0.8 mm) in thickness under 5⁄16 in.

[c] For plates wider than 24 in. (610 mm), the elongation requirement is reduced two percentage points.

APPENDIX

X1. CHARPY V-NOTCH IMPACT TEST

X1.1 The values shown in Table X1 are included only as information as to the guarantees which are generally available. Mandatory conformance to any of the values listed is a matter for agreement between the purchaser and the manufacturer.

TABLE X1 Charpy V-Notch Impact Test Minimum Energy Values (Average of Three Specimens)

Test Temperature, °F (°C)	Longitudinal Specimens, ft·lbf (J)	Transverse Specimens, ft·lbf (J)
−75 (−59)	15 (20)	15 (20)
−60 (−51)	20 (27)	15 (20)
−50 (−46)	25 (34)	20 (27)
−40 (−40)	25 (34)	20 (27)
−30 (−34)	30 (41)	25 (34)
0 (−18)	40 (54)	30 (41)
32 (0)	45 (61)	30 (41)
75 (24)	50 (68)	30 (41)

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM B21: Standard Specification for Naval Brass Rod, Bar, and Shapes

CFR Section(s): 46 CFR 56.60-2

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: B 21 – 83b

Standard Specification for Naval Brass Rod, Bar, and Shapes[1]

This standard is issued under the fixed designation B 21; 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 specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers naval brass rod, bar, and shapes. The following five alloys are covered:

Copper Alloy UNS No.[A]	Previously Used Designation
C46200	Alloy D
C46400	Alloy A
C47940	...
C48200	Alloy B
C48500	Alloy C

[A] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix can be used to accommodate composition variations of the base alloy.

NOTE 1—Material for hot forging is covered by Specification B 124.

NOTE 2—A complete metric companion to Specification B21 has been developed—B 21M; therefore, no metric equivalents are presented in this specification.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

B 124 Specification for Copper and Copper-Alloy Forging Rod, Bar, and Shapes[2]

B 154 Method of Mercurous Nitrate Test for Copper and Copper Alloys[2]

B 249 Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, and Shapes[2]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[2]

E 8 Methods of Tension Testing of Metallic Materials[3]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Copper Alloy UNS No. (Section 1.1),

3.1.2 Temper (Section 6),

3.1.3 Form: cross section such as round, hexagonal, square, etc. (9.2 and 9.3)

3.1.4 Diameter or distance between parallel surfaces (9.2),

3.1.5 Length (9.4),

3.1.6 Edge contours (9.6),

3.1.7 Piston finish rod or shafting, if required (Section 11),

3.1.8 Weight: total for each size,

3.1.9 ASTM designation and year of issue,

3.1.10 Certification, if required (see Specification B 249, Section 13), and

3.1.11 Mill test report, if required (see Specification B 249, Section 14).

3.2 When material is purchased for agencies of the U. S. Government, this shall be specified in the contract or purchase order, and the material shall conform to the Supplementary Requirements as defined in the current issue of Specification B 249.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirement of the current edition of Specification B 249.

5. Chemical Composition

5.1 The material shall conform to the chemical requirements of Table 1.

5.2 These specification limits do not preclude the possible presence of other unnamed elements. However, analysis shall regularly be made only for the minor elements listed in the table, plus all major elements except one. The major element that is not analyzed shall be determined by difference between the sum of those elements analyzed and 100 %. By agreement between manufacturer and purchaser, analysis may be required and limits established for elements not specified.

6. Temper

6.1 Tempers available under this specification and as prescribed in Practice B 601 are as follows:

Temper Designation	
Standard	Former
M30	as-hot extruded
O50	light anneal
O60	soft anneal
H50	extruded and drawn
H60	cold heading, forming
H02	half hard
H04	hard
H50	extruded and drawn

[1] This specification is under the jurisdiction of the ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rods, Bars, and Shapes.

Current edition approved Nov. 28, 1983. Published February 1984. Originally published as B 21 – 18 T. Last previous edition B 21 – 83a.

[2] *Annual Book of ASTM Standards*, Vol 02.01.

[3] *Annual Book of ASTM Standards*, Vols 02.01 and 03.01.

[4] *Annual Book of ASTM Standards*, Vols 01.01 and 02.01.

ASTM Logo Removed [redacted] **B 21**

TABLE 1 Chemical Requirements

Element, %	Copper Alloy UNS No.				
	C46200	C46400	C48200	C48500	C47940
Copper	62.0–65.0	59.0–62.0	59.0–62.0	59.0–62.0	63.0–66.0
Tin	0.50–1.0	0.50–1.0	0.50–1.0	0.50–1.0	1.2–2.0
Lead	0.20 max	0.20 max	0.40–1.0	1.3–2.2	1.0–2.0
Zinc	remainder	remainder	remainder	remainder	remainder
Iron	0.15 max	0.15 max	0.15 max	0.15 max	0.10–1.0
Nickel	. . .	. . .	. . .	. . .	0.10–0.50

TABLE 2 Tensile Requirements

Temper Designation		Diameter or Distance Between Parallel Surfaces, in.	Tensile Strength, min, ksi[A]	Yield Strength at 0.5 % Extension Under Load, min, ksi[A]	Elongation in 4 × Diameter of Thickness of Specimen, min, %[B]
Standard	Former				
		Copper Alloy UNS No C46200			
M30	as-hot extruded	all forms, all sizes	50	20	30
O60	soft anneal	rods and bars, all sizes	48	16	30
H60	cold heading	rods, all sizes	48	18	22
H02 or O50	half-hard or light anneal	rods and bars:	58	27	22
		0.500 and under	56	27	25
		over 0.500 to 1.000, incl	54	26	25
		over 1.000 to 2.000, incl	52	25	27
		over 2.000 to 3.000, incl	50	22	30
		over 3.000 to 4.000, incl	50	20	30
		over 4.000			
H04	hard	rods and bars:			
		0.500 and under	64	40	13
		over 0.500 to 1.000, incl	62	38	13
		over 1.000 to 2.000, incl	58	34	18
		Copper Alloy UNS No. C46400			
M30	as-hot extruded	all forms, all sizes	52	20	30
O60	soft anneal	rods and bars:			
		1.000 and under	54	20	30
		over 1.000 to 2.000, incl	52	20	30
		over 2.000	50	20	30
		shapes, all sizes	52	20	30
H50	extruded and drawn[C]	shapes, all sizes	58	25	20
H02 or O50	half-hard or light anneal	rods and bars:			
		0.500 and under	60	27	22
		over 0.500 to 1.000, incl	60	27	25
		over 1.000 to 2.000, incl	58	26	25
		over 2.000 to 3.000, incl	54	25	25
		over 3.000 to 4.000, incl	54	22	27
		over 4.000	54	22	30
H04	hard	rods and bars:			
		1.000 and under	67	45	13
		over 1.000 to 2.000, incl	62	37	18
		Copper Alloy UNS No. C47940			
M30	as extruded	all forms, all sizes	50	20	30
O60	soft anneal	rods and bars, all sizes	48	20	30
H50	extruded and drawn	shapes, all sizes	56	25	20
O50 or H02	half hard or light anneal	rods and bars:	58	30	18
		0.500 and under	56	30	20
		over 0.500 to 1,000, incl	54	25	22
		over 1.000 to 2.000, incl	50	25	25
		over 2.000			
H04	hard	rods and bars:			
		0.500 and under	70	55	10
		over 0.500 to 1.000, incl	65	52	13
		over 1.000 to 2.000, incl	62	45	15

TABLE 2 *Continued*

Temper Designation: Standard	Temper Designation: Former	Diameter or Distance Between Parallel Surfaces, in.	Tensile Strength, min, ksi[A]	Yield Strength at 0.5 % Extension Under Load min, ksi[A]	Elongation in 4 × Diameter of Thickness of Specimen, min, %[B]	
		Copper Alloy UNS Nos. C48200 and C48500			C48200	C48500
M30	as-hot extruded	all forms, all sizes	52	20	25	20
O60	soft anneal	rods and bars:				
		1.000 and under	54	20	25	20
		over 1.000 to 2.000, incl	52	20	25	20
		over 2.000	50	20	25	20
		shapes, all sizes	52	20	25	20
H50	extruded and drawn[C]	shapes, all sizes	58	25	15	15
H02 or O50	half-hard or light anneal	rods and bars:	60	27	18	12
		1.000 and under	58	26	20	20
		over 1.000 to 2.000, incl	54	25	20	20
		over 2.000 to 3.000, incl	54	22	20	20
		over 3.000 to 4.000, incl	54	22	25	20
		over 4.000				
H04	hard	rods and bars:				
		1.000 and under	67	45	11	10
		over 1.000 to 2.000, incl	62	37	15	13

[A] ksi = 1000 psi.
[B] In any case, a minimum gage length of 1 in. shall be used.
[C] Shapes, extruded and drawn, do not apply to hollow shapes.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

8. Mercurous Nitrate Test

NOTE 3: **Caution**—Mercury is a definite health hazard, and therefore equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.

8.1 The test specimens, cut at least 6 in. in length, shall be totally immersed for 30 min in the standard mercurous nitrate solution prescribed in Method B 154. There shall be no cracks in the specimen when examined immediately after it is removed from the solution, rinsed and wiped.

NOTE 4—Bars that have been properly straightened or sprung will have internal stresses so broken up as not to be in danger of splitting or cracking. The mercurous nitrate test is designed to determine whether the internal stresses have been properly broken up and rendered safe.

9. Dimensions and Permissible Variations

9.1 The dimensions and tolerances for material covered by this specification shall be as prescribed in the current edition of Specification B 249, with particular reference to Section 5 and the following tables of that specification:

9.2 *Diameter or Distance Between Parallel Surfaces:*

9.2.1 *Rod: Round, Hexagonal, Octagonal*—See 5.2, Table 1.

9.2.2 *Rod, M30 (As-Hot Extruded)*—See 5.2, Table 4.

9.2.3 *Piston-Finish Rod*—See 5.2, Table 3.

9.2.4 *Bar: Rectangular and Square*—See 5.2, Tables 8 and 10.

9.2.5 *Bar, M30 (As-Hot Extruded)*—See 5.2, Table 4.

9.3 *Shapes*—The dimensional tolerances for shapes shall be as agreed upon by the supplier and the purchaser, and shall be specified in the order.

9.4 *Length of Rod, Bar, and Shapes*—See 5.3, Tables 12 and 13.

9.5 *Straightness:*

9.5.1 *Rod and Bar*—See 5.4.1, Table 15.

9.5.2 *Shafting Rod*—See 5.4.2, Table 16.

9.5.3 M30 (as-hot extruded) rod, bar, and shapes shall be commercially straight.

9.6 *Edge Contours*—See 5.5.

10. Test Specimens

10.1 In the tension test all material shall be pulled in full size when practicable. Full-size or machined test specimens shall be as specified in Methods E 8. Whenever tension test results are obtained from both full-size and from machined test specimens and they differ, the results obtained from full-size test specimens shall be used to determine conformance to the specification requirements.

NOTE 5—The tension test specimens shall conform to the dimensions prescribed in Section 4 of Methods E 8.

10.2 Mercurous nitrate test specimens shall be of the full size of the material, and without bending, springing, polishing, or any other preparation.

11. Piston-Finish Rod and Shafting

11.1 When so specified in the contract or order, round rods over ½ in. in diameter shall be furnished as piston-finish rods or shafting.

11.2 Piston-finish rods shall have a special surface produced by turning or grinding and shall comply with the special diameter tolerances prescribed in 9.2.3.

11.3 The straightness tolerances for piston-finish rod are subject to agreement between the manufacturer and the purchaser.

ASTM Logo Removed

B 21

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM B85: Standard Specification for Aluminum-Alloy Die Castings

CFR Section(s): 46 CFR 56.60-2

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: B 85 – 84

Standard Specification for Aluminum-Alloy Die Castings[1]

This standard is issued under the fixed designation B 85; 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 specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers aluminum-alloy die castings. Ten alloy compositions are specified, designated as shown in Table 1.

1.2 The values stated in inch-pound units are the standard. The SI values in parentheses are for information only.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of order acceptance form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B 179 Specification for Aluminum Alloys in Ingot Form for Sand Castings, Permanent Mold Castings, and Die Castings[2]

B 275 Practice for Codification of Certain Nonferrous Metals and Alloys, Cast and Wrought[2]

E 8 Methods of Tension Testing of Metallic Materials[3]

E 23 Method for Notched-Bar Impact Testing of Metallic Materials[3]

E 29 Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values[4]

E 34 Method for Chemical Analysis of Aluminum and Aluminum Alloys[5]

E 88 Practice for Sampling Nonferrous Metals and Alloys in Cast Form for Determination of Chemical Composition[5]

E 101 Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[6]

E 227 Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[6]

E 505 Reference Radiographs for Inspection of Aluminum and Magnesium Die Castings[7]

E 527 Practice for Numbering Metals and Alloys (UNS)[3]

2.3 *American National Standards Institute:*

H35.1 Alloy and Temper Designation Systems for Aluminum[2]

2.4 *American Die Casting Institute:*

"E" Series Product Standards for Die Castings[2]

2.5 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[8]

Fed. Std. No. 184 Identification Marking of Aluminum, Magnesium and Titanium[8]

2.6 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage (Military Agencies)[8]

MIL-STD-649 Preparation for Storage and Shipment of Aluminum and Magnesium Products[8]

3. Definitions

3.1 *die casting*—a metal object produced by the introduction of molten metal under substantial pressure into a metal die and characterized by a high degree of fidelity to the die cavity.

4. Ordering Information

4.1 Orders for die castings shall include the following basic information:

4.1.1 This specification number and date,

4.1.2 Quantity and delivery schedule, as required,

4.1.3 Part name and number,

4.1.4 Alloy (Table 1), and

4.1.5 Drawing of die casting, when required, giving all necessary dimensions and showing latest revisions and allowances for machining, if any. Location of ejector pin marks or parting lines shall be at the option of the producer; unless specifically designated on the drawing.

4.2 Additional tests, options and special inspection requirements as provided below should be justified only on the basis of need. These shall be specified in the contract or purchase order, as additional procedures and extended delivery time may be involved.

4.2.1 Chemical analysis (7.1.1),

4.2.2 Quality assurance (Section 6),

4.2.3 Special proof tests or mechanical properties (Section 8),

4.2.4 General quality options for internal soundness or for finish (Section 10),

4.2.5 Source inspection (Section 11),

4.2.6 Certification (Section 12),

---

[1] This specification is under the jurisdiction of ASTM Committee B-6 on Die-Cast Metals and Alloys, and is the direct responsibility of Subcommittee B06.01 on Aluminum Die Castings.
Current edition approved March 30, 1984. Published May 1984. Originally published as B 85 – 31 T. Last previous edition B 85 – 82a.

[2] *Annual Book of ASTM Standards*, Vol 02.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

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

[6] *Annual Book of ASTM Standards*, Vol 03.06.

[7] *Annual Book of ASTM Standards*, Vol 03.03.

[8] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120.

TABLE 1 Chemical Requirements[A, B, C]

Alloy[D]			Composition %									
ANSI	ASTM	UNS	Silicon	Iron	Copper	Manganese	Magnesium	Nickel	Zinc	Tin	Titanium	Other Constituents, Except Aluminum (Total)	Aluminum
360.0	SG100B	A03600	9.0–10.0	2.0	0.6	0.35	0.40–0.6	0.50	0.50	0.15	...	0.25	remainder
A360.0	SG100A	A13600	9.0–10.0	1.3	0.6	0.35	0.40–0.6	0.50	0.50	0.15	...	0.25	remainder
380.0	SC84B	A03800	7.5–9.5	2.0	3.0–4.0	0.50	0.10	0.50	3.0	0.35	...	0.50	remainder
A380.0[E]	SC84A	A13800	7.5–9.5	1.3	3.0–4.0	0.50	0.10	0.50	3.0	0.35	...	0.50	remainder
383.0[E]	SC102A	A03830	9.5–11.5	1.3	2.0–3.0	0.50	0.10	0.30	3.0	0.15	...	0.50	remainder
384.0[E]	SC114A	A03840	10.5–12.0	1.3	3.0–4.5	0.50	0.10	0.50	3.0	0.35	...	0.50	remainder
390.0	SC174A	A03900	16.0–18.0	1.3	4.0–5.0	0.10	0.45–0.65	...	0.10	...	0.20	0.20	remainder
B390.0	SC174B	A23900	16.0–18.0	1.3	4.0–5.0	0.50	0.45–0.65	0.10	1.5	...	0.10	0.20	remainder
392.0	S19	A03920	18.0–20.0	1.5	0.40–0.80	0.20–0.60	0.80–1.20	0.50	0.50	0.30	0.20	0.50	remainder
413.0	S12B	A04130	11.0–13.0	2.0	1.0	0.35	0.10	0.50	0.50	0.15	...	0.25	remainder
A413.0	S12A	A14130	11.0–13.0	1.3	1.0	0.35	0.10	0.50	0.50	0.15	...	0.25	remainder
C443.0	S5C	A34430	4.5–6.0	2.0	0.6	0.35	0.10	0.50	0.50	0.15	...	0.25	remainder
518.0	G8A	A05180	0.35	1.8	0.25	0.35	7.5–8.5	0.15	0.15	0.15	...	0.25	remainder

[A] Analysis shall ordinarily be made only for the elements mentioned in this table. 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 the total of these other elements are not present in excess of specified limits.

[B] For purposes of acceptance and rejection, the observed value or calculated value obtained from analysis should be rounded off to the nearest unit in the last right-hand place of figures, used in expressing the specified limit, in accordance with the rounding procedure prescribed in Section 3 of Recommended Practice E 29.

[C] Limits are in percent maximum unless shown otherwise.

[D] Alloys 360.0, 380.0, 413.0, C443.0 and 518.0 are suitable for the production of die casting by either the hot-chamber or the cold-chamber process. Die castings of alloys A360.0, A380.0, 383,0, 384.0 and A413.0 may be made only in cold-chamber machines.

ASTM designations were established in accordance with Recommended Practice B 275. ANSI designations were established in accordance with ANSI H35.1. UNS designations were established in accordance with Recommended Practice E 527.

[E] With respect to mechanical properties, alloys A380.0, 383.0 and 384.0 are substantially interchangeable.

4.2.7 Marking for identification (Section 14), and

4.2.8 Special packaging (Section 15).

5. Materials

5.1 The aluminum alloys used for the manufacture of die castings shall be such that the die castings produced will conform to the chemical composition requirements of this specification.

6. Quality Assurance

6.1 *Responsibility for Inspection*—When specified in the contract or purchase order, the producer or supplier is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract or order, the producer or supplier may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification. Quality assurance standards shall be agreed upon between the producer or supplier and purchaser at the time a contract or order is placed.

6.2 *Lot Definition*—An inspection lot shall be defined as follows:

6.2.1 An inspection lot shall consist of the production from each die or compound die on each machine for each 24 h during the first week of normal operation and the production for each 48 h thereafter of normal operation. Any significant change in the machine, composition, die or continuity of operation shall be considered as the start of a new lot. Die castings inspected by this method shall be so marked or handled during the finishing operations as not to lose their identity.

6.2.2 Each die casting of a randomly selected sample shall be examined to determine conformance to the requirements with respect to general quality, dimensions, and identification marking. The producer or supplier may use a system of statistical quality control for such examinations.

7. Chemical Requirements

7.1 *Limits*—The die castings shall conform to the requirements as to chemical composition prescribed in Table 1. Conformance shall be determined by the producer by analyzing samples taken at the time castings are made. If the producer has determined the chemical composition of the metal during the course of manufacture, he shall not be required to sample and analyze the finished product.

7.1.1 When a detailed chemical analysis is required with a shipment, it shall be called for in the contract or purchase order.

7.1.2 If the producer's or supplier's method of composition control is acceptable, sampling for chemical analysis may be waived at the discretion of the purchaser.

7.2 *Number of Samples*—When required, samples for determination of chemical composition shall be taken to represent the following:

7.2.1 A sample shall be taken from each of two representative castings selected from each lot defined in 6.2.1.

7.3 *Methods of Sampling*—Samples from die castings for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken from the material by drilling, sawing, milling, turning, or clipping a representative piece or pieces to obtain a weight of prepared sample not less than 75 g. Sampling shall be in accordance with Practice E 88.

7.3.2 By agreement, an appropriate spectrographic sample may be prepared at time of manufacture.

7.3.3 The method of sampling cast products for spectrochemical and other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

7.4 *Method of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Methods E 34), spectrochemical (Method E 101 or E 227), or other methods. In case of dispute, the results secured by Methods E 34 shall be the basis of acceptance.

8. Mechanical Properties and Tests

8.1 Unless specified in the contract or purchase order or specifically guaranteed by the manufacturer, acceptance of die castings under these specifications shall not depend on mechanical properties determined by tension or impact tests. Table X1.1 shows typical mechanical properties. When tension or impact tests are made, the tension test specimen shown in Fig. 18 of Methods E 8 and the impact test specimen shown in Fig. 6 of Methods E 23 shall be used.

8.2 When specified in the contract or purchase order, die castings shall withstand proof tests without failure as defined by agreement between the purchaser and the producer or supplier.

9. Permissible Variations in Dimensions

9.1 Permissible variations in dimensions shall be within the limits specified on the drawings or in the contract or purchase order.

9.1.1 Any dimensions for which a tolerance is not specified shall be in accordance with ADCI Product Standard Series E 1 to E 16 inclusive.

9.2 Dimensional tolerance deviations waived by the purchaser shall be confirmed in writing to the producer or supplier.

10. General Quality

10.1 *Internal Soundness*—When specified, the soundness of die castings shall conform to standards or requirements agreed upon between the producer or supplier and the purchaser. The number and extent of imperfections shall not exceed those specified by the purchaser. The standards or requirements may consist of radiographs in accordance with Method E 505, photographs or sectioned die castings.

10.2 Imperfections inherent in die castings shall not be cause for rejection provided it is demonstrated that the die castings are in accordance with the requirements and standards agreed upon.

10.3 *Workmanship*—Die castings shall be of uniform quality, free of injurious discontinuities that will adversely affect their serviceability.

10.4 *Finish*—When specified in the contract or purchase order the as-cast surface finish required shall conform to standards agreed upon between the purchaser and the producer or supplier, or as prescribed in ADCI Product Standard E 18.

10.5 *Pressure Tightness*—When specified in the contract or purchase order the pressure tightness of die castings shall conform to standards agreed upon between the purchaser and the producer or supplier, or as prescribed in ADCI Product Standard E 17.

11. Source Inspection

11.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the product prior to shipment, such agreement shall be made by the purchaser and producer or supplier as part of the contract or purchase order.

11.2 When such inspection or witness of inspection and testing is agreed upon, the producer or supplier shall afford the purchaser's representative all reasonable facilities to satisfy him that the product meets the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

12. Certification

12.1 The producer or supplier shall, when called for in the contract or purchase order, furnish to the purchaser a certificate of inspection stating that each lot has been sampled, tested, and inspected in accordance with this specification, and has been found to meet the requirements specified.

13. Rejection and Retest

13.1 When one or more samples, depending on the approved sampling plan, fail to meet the requirements of this specification, the represented lot is subject to rejection except as otherwise provided in 13.2.

13.2 Lots rejected for failure to meet the requirements of this specification may be resubmitted for test provided:

13.2.1 The producer has removed the nonconforming material or the producer has reworked the rejected lot as necessary to correct the deficiencies.

13.3 Individual castings that show injurious imperfections during subsequent manufacturing operations may be rejected. The producer or supplier shall be responsible only for replacement of the rejected castings to the purchaser. As much of the rejected original material as possible shall be returned to the producer or supplier.

14. Identification Marking

14.1 When specified in the contract or purchase order, all castings shall be properly marked for identification with the part number, name or brand of the producer, as agreed upon. Government applications shall be marked in accordance with Fed. Std. No. 184.

15. Preparation for Delivery

15.1 *Packaging*—Unless otherwise specified, the die castings shall be packaged to provide adequate protection during normal handling and transportation. Each package shall contain only one type of item unless otherwise agreed upon. The type of packaging and gross weight of containers shall, unless otherwise agreed upon, be at the producer's discretion, provided they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

15.2 *Marking*—Each shipping container shall be legibly marked with the purchase order number, gross and net weights, and the supplier's name or trademark. Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for Military agencies.

15.3 *Preservation*—Material intended for prolonged storage in unheated locations shall be adequately packed and protected to avoid deterioration and damage. When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-649. The applicable levels shall be as specified in the contract or order.

16. Characteristics of Die Casting Alloys

16.1 Table X1.1 shows certain casting and other outstanding characteristics which are usually considered in selecting a die-casting alloy for a specific application. The characteristics are rated from *(1) to (5)*, *(1)* being the best and *(5)* being the least desirable alloy. In applying these ratings, it should be noted that all the alloys have sufficiently good characteristics to be accepted by users and producers of die castings. Hence a rating of *(5)* indicates a commercial alloy, although in certain cases its application may be limited or its manufacture may be restricted to relatively simple castings.

APPENDIXES

(Nonmandatory Information)

X1. CHARACTERISTICS

X1.1 Table X1.1 shows certain casting and other outstanding characteristics which are usually considered in selecting a die casting alloy for a specific application.

TABLE X1.1 Die Casting and Other Characteristics

NOTE—*Rating System*—the various alloys are rated 1 to 5 according to the positive to negative qualities in the listed categories. A rating of 1 gives the best performance, 5 the poorest performance. No one alloy is best in all categories. A rating of 5 in any one or more categories does not rule an alloy out of commercial usefulness if its other attributes are especially favorable. However, ratings of 5 may present manufacturing difficulties.

Alloy				Die Casting Characteristics				Other Characteristics[N]						
ANSI[L]	ASTM[L]	UNS[L]	Approximate Melting Temperature Range, °F	Resistance to Hot Cracking[A]	Pressure Tightness	Die Filling Capacity[B]	Anti-Soldering to the Die[E]	Resistance to Corrosion[D]	Machining[C]	Polishing[F]	Electroplating[G]	Anodizing (Appearance)[H]	Chemical Oxide Coating (Protection)[I]	Strength of Elevated Temperatures[J]
360.0	SG100B	A03600	1035–1105	1	2	3	2	2	3	3	2	3	3	1
A360.0	SG100A	A13600	1035–1105	1	2	3	2	2	3	3	2	3	3	1
380.0	SC84B	A03800	1000–1100	2	2	2	1	4	3	3	1	3	4	3
A380.0	SC84A	A13800	1000–1100	2	2	2	1	4	3	3	1	3	4	3
383.0	SC102A	A03830	960–1080	1	2	1	2	3	2	3	1	3	4	2
384.0	SC114A	A03840	960–1080	2	2	1	2	5	3	3	2	4	5	2
390.0	SC174A	A03900	945–1200	4	4	1	2	3	5	5	3	5	5	3
B390.0	SC174B	A23900	950–1200	4	4	1	2	3	5	5	3	5	5	3
392.0	S19	A03920	1025–1245	4	3	1	2	2	5	5	3	5	5	3
413.0	S12B	A04130	1065–1080	1	1	1	1	2	4	5	3	5	3	3
A413.0	S12A	A14130	1065–1080	1	1	1	1	2	4	5	3	5	3	3
C443.0	S5C	A34430	1065–1170	3	3	4	4	2	5	4	2	2	2	5
518.0	G8A	A05180	995–1150	5	5	5	5	1	1	1	5	1	1	4

[A] Ability of alloy to withstand stresses from contraction while cooling through hot-short or brittle temperature range.
[B] Ability of molten alloy to flow readily in die and fill thin sections.
[C] Ability of molten alloy to flow without sticking to the die surfaces. Ratings given for antisoldering are based on nominal iron compositions of approximately 1.
[D] Based on resistance of alloy in standard type salt spray test.
[E] Composite rating based on ease of cutting, chip characteristics, quality of finish and tool life.
[F] Composite rating based on ease and speed of polishing and quality of finish provided by typical polishing procedure.
[G] Ability of the alloy to take and hold an electroplate applied by present standard methods.
[H] Rated on lightness of color, brightness and uniformity of clear anodized coating applied in sulphuric acid electrolyte. Generally aluminum die castings are unsuitable for light color anodizing where pleasing appearance is required.
[I] Rated on combined resistance of coating and base alloy to corrosion.
[J] Rating based on tensile and yield strengths at temperature up to 500°F (260°C), after prolonged heating at testing temperature.
[K] Die castings are not usually solution heat treated. Low temperature aging treatments may be used for stress relief or dimensional stability. Die castings are not generally gas or arc welded or brazed.
[L] ASTM designations were established in accordance with Recommended Practice B 275. ANSI designations were established in accordance with ANSI H 35.1. UNS designations were established in accordance with Recommended Practice E 527.

X2. MECHANICAL PROPERTIES

X2.1 The data in Table X2.1 do not constitute a part of this specification because the data only indicates mechanical properties that may be expected of test specimens when cast in a separate tensile test bar die and that conform to the chemical composition specified. Different machines and dies continue to be necessary for die castings and test bars. Comparison between static breakdown or proof tests and the mechanical properties of separately die cast test bars will show that test bars made in a different machine in a different die have no correlation with the die casting other than a common chemical composition. It should be thoroughly understood that the data in Table X2.1 represent die-cast test specimens and not specimens cut from commercial die-cast parts. For this reason, it is considered that the only practical method for mechanical property control is proof testing the whole die casting.

TABLE X2.1 Typical Mechanical Properties Test Specimens[A]

Alloy		UNS[B]	Tensile Strength, ksi (MPa)	Yield Strength (0.2 % Offset), ksi (MPa)	Elongation in 2 in. or 50 mm, %	Shear Strength, ksi (MPa)	Fatigue Strength (R. R. Moore Specimen), 500,000,000 cycles, ksi (MPa)
ANSI[A]	ASTM[B]						
360.0	SG100B	A03600	44(300)	25(170)	2.5	28(190)	20(140)
A360.0	SG100A	A13600	46(320)	24(170)	3.5	26(180)	18(120)
380.0	SC84B	A03800	46(320)	23(160)	2.5	28(190)	20(140)
A380.0	SC84A	A13800	47(320)	23(160)	3.5	27(190)	20(140)
383.0	SC102A	A03830	45(310)	22(150)	3.5	...	...
384.0	SC114A	A03840	48(330)	24(170)	2.5	29(200)	20(140)
390.0	SC174A	A03900	40.5(280)	35.0(240)	<1	...	...
B390.0	SC174B	A23900	46.0(320)	36.0(250)	<1	...	...
392.0	S19	A03920	42.0(290)	39.0(270)	<1	...	...
413.0	S12B	A04130	43(300)	21(140)	2.5	25(170)	19(130)
A413.0	S12A	A14130	42(290)	19(130)	3.5	25(170)	19(130)
C443.0	S5C	A34430	33(230)	14(100)	9.0	19(130)	17(120)
518.0	G8A	A05180	45(310)	28(190)	5	29(200)	20(140)

[A] See Appendix X3 for explanation of SI unit MPa.
[B] ASTM designations were established in accordance with Recommend Practice B 275. ANSI designations were established in accordance with ANSI H35.1. UNS designations were established in accordance with Recommended Practice E 527.

X3. METRIC EQUIVALENTS

X3.1 The SI unit for strength properties (MPa) is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM B209: Standard Specification for Aluminum and Aluminum Alloy Sheet and Plate

CFR Section(s): 46 CFR 58.50-5, Table 58.50-5(a)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed [redacted]

Designation: B 209 – 96

Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate[1]

This standard is issued under the fixed designation B 209; 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[2] covers aluminum and aluminum-alloy flat sheet, coiled sheet, and plate, in the alloys (Note 1) and tempers shown in Tables 2 and 3, and in the following finishes:

1.1.1 Plate in all alloys and sheet in heat-treatable alloys: mill finish.

1.1.2 Sheet in nonheat-treatable alloys: mill finish, one-side bright mill finish, standard one-side bright finish, and standard two-sides bright finish.

NOTE 1—Throughout this specification use of the term *alloy* in the general sense includes aluminum as well as aluminum alloy.

NOTE 2—See Specification B 632 for tread plate.

1.2 Alloy and temper designations are in accordance with ANSI H35.1. The equivalent Unified Numbering System alloy designations are those of Table 1 preceded by A9, for example, A91100 for aluminum 1100 in accordance with Practice E 527.

1.3 A complete metric companion to Specification B 209 has been developed—B 209 M; therefore, no metric equivalents are presented in this specification.

1.4 For acceptance criteria for inclusion of new aluminum and aluminum alloys in this specification, see Annex A2.

2. Referenced Documents

2.1 The following documents of the issue in effect on the date of material purchase, unless otherwise noted, form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B 548 Method for Ultrasonic Inspection of Aluminum-Alloy Plate for Pressure Vessels[3]

B 557 Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products[3]

B 594 Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products for Aerospace Applications[3]

B 597 Practice for Heat Treatment of Aluminum Alloys[3]

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products[3]

B 666/B 666M Practice for Identification Marking of Aluminum Products[3]

E 3 Methods of Preparation of Metallographic Specimens[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys[6]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[6]

E 101 Test Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[7]

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[6]

E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials[4]

E 407 Test Methods for Microetching Metals and Alloys[4]

E 527 Practice for Numbering Metals and Alloys (UNS)[8]

E 607 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique, Nitrogen Atmosphere[9]

E 716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis[9]

E 1004 Test Method for Electromagnetic (Eddy-Current) Measurements of Electrical Conductivity[10]

E 1251 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Argon

---

[1] This specification is under the jurisdiction of ASTM Committee B-7 on Light Metals and Alloys, and is the direct responsibility of Subcommittee B07.03 on Aluminum-Alloy Wrought Products.

Current edition approved Aug. 10, 1996. Published September 1996. Originally published as B 209 – 46 T. Last previous edition B 209 – 95.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-209 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 02.02.

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

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 03.05.

[7] Discontinued. See *1995 Annual Book of ASTM Standards*, Vol 03.05.

[8] *Annual Book of ASTM Standards*, Vol 01.01.

[9] *Annual Book of ASTM Standards*, Vol 03.06.

[10] *Annual Book of ASTM Standards*, Vol 03.03.

***A Summary of Changes section appears at the end of this standard.**

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

Atmosphere, Point-to-Plane, Unipolar Self-Initiating Capacitor Discharge[9]

G 47 Test Method for Determining Susceptibility to Stress-Corrosion Cracking of High Strength Aluminum Alloy Products[11]

G 66 Test Method for Visual Assessment of Exfoliation Corrosion Susceptibility of 5XXX Series Aluminum Alloys (Asset Test)[11]

Method of Test for Exfoliation Corrosion Susceptibility in 7XXX Series Copper-Containing Aluminum Alloys (Exco Test) (G34-72)[12]

2.3 *ANSI Standards:*

H35.1 Alloy and Temper Designation Systems for Aluminum[13]

H35.2 Dimensional Tolerances for Aluminum Mill Products[13]

2.4 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[14]

2.5 *Military Specification:*

MIL-H-6088 Heat Treatment of Aluminum Alloys[14]

2.6 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[14]

3. Terminology

3.1 *Definitions:*

3.1.1 *sheet*—a rolled product that is rectangular in cross section with thickness less than 0.250 in. but not less than 0.006 in. and with slit, sheared, or sawed edges.

3.1.2 *alclad sheet*—composite sheet comprised of an aluminum-alloy core having on both surfaces (if on one side only, alclad one-side sheet) a metallurgically bonded aluminum or aluminum-alloy coating that is anodic to the core, thus electrolytically protecting the core against corrosion.

3.1.3 *coiled sheet*—sheet in coils with slit edges.

3.1.4 *flat sheet*—sheet with sheared, slit, or sawed edges, which has been flattened or leveled.

3.1.5 *mill finish sheet*—sheet having a nonuniform finish which may vary from sheet to sheet and within a sheet, and may not be entirely free from stains or oil.

3.1.6 *one-side bright mill finish sheet*—sheet having a moderate degree of brightness on one side, and a mill finish on the other.

3.1.7 *standard one-side bright finish sheet*— sheet having a uniform bright finish on one side, and a mill finish on the other.

3.1.8 *standard two-sides bright finish sheet*— sheet having a uniform bright finish on both sides.

3.1.9 *plate*—a rolled product that is rectangular in cross section with thickness not less than 0.250 in., and with sheared or sawed edges.

3.1.10 *alclad plate*—composite plate comprised of an aluminum-alloy core having on both surfaces (if on one side only, alclad one-side plate) a metallurgically bonded aluminum or aluminum alloy coating that is anodic to the core, thus electrolytically protecting the core against corrosion.

3.1.11 *parent coil or plate*—a coil of sheet or a plate that has been processed to final temper as a single unit and subsequently cut into two or more smaller coils or individual sheets or into smaller plates to provide the required width or length, or both.

3.1.12 *producer*—the primary manufacturer of the material.

3.1.13 *supplier*—includes only the category of jobbers and distributors as distinct from producers.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *capable of*—The term *capable of* as used in this specification means that the test need not be performed by the producer of the material. However, should testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),

4.1.2 Quantity in pieces or pounds,

4.1.3 Alloy (7.1),

4.1.4 Temper (9.1),

4.1.5 Finish for sheet in nonheat-treatable alloys (Section 1),

4.1.6 For sheet, whether flat or coiled,

4.1.7 Dimensions (thickness, width, and length or coil size),

4.1.8 Tensile property limits and dimensional tolerances for sizes not covered in Table 2 or Table 3 of this specification and in ANSI H35.2, respectively.

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:

4.2.1 Whether supply of one of the pairs of tempers where shown in Table 2, H14 or H24, H34 or H24 is specifically excluded (Table 2, footnote *D*),

4.2.2 Whether heat treatment in accordance with Practice B 597 is required (8.2),

4.2.3 Whether bend tests are required (12.1),

4.2.4 Whether testing for stress-corrosion cracking resistance of alloy 2124-T851 is required (13.1),

4.2.5 Whether ultrasonic inspection for aerospace or pressure vessel applications is required (Section 17),

4.2.6 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (18.1),

4.2.7 Whether certification is required (Section 22),

4.2.8 Whether marking for identification is required (20.1), and

4.2.9 Whether Practices B 660 applies and, if so, the levels of preservation, packaging, and packing required (23.121.1).

5. Responsibility for Quality Assurance

5.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test

[11] *Annual Book of ASTM Standards*, Vol 03.02.

[12] The applicable edition in the use of this specification is G34–72—available in the Related Materials section (gray pages) of the *Annual Book of ASTM Standards*, Vol 02.02.

[13] Available in the Related Materials section (gray pages) of the *Annual Book of ASTM Standards*, Vol 02.02.

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

TABLE 1 Chemical Composition Limits[A,B,C]

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Other Elements[D]		Aluminum
									Each	Total[E]	
1060	0.25	0.35	0.05	0.03	0.03	...	0.05	0.03	0.03[F]	...	99.60 min[G]
1100	0.95 Si + Fe		0.05–0.20	0.05	...	...	0.10	...	0.05	0.15	99.00 min[G]
1230[H]	0.70 Si + Fe		0.10	0.05	0.05	...	0.10	0.03	0.03[F]	...	99.30 min[G]
2014	0.50–1.2	0.7	3.9–5.0	0.40–1.2	0.20–0.8	0.10	0.25	0.15	0.05	0.15	remainder
Alclad 2014						2014 clad with 6003					
2024	0.50	0.50	3.8–4.9	0.30–0.9	1.2–1.8	0.10	0.25	0.15	0.05	0.15	remainder
Alclad 2024						2024 clad with 1230					
2124	0.20	0.30	3.8–4.9	0.30–0.9	1.2–1.8	0.10	0.25	0.15	0.05	0.15	remainder
2219	0.20	0.30	5.8–6.8	0.20–0.40	0.02	...	0.10	0.02–0.10	0.05[I]	0.15[I]	remainder
Alclad 2219						2219 clad with 7072					
3003	0.6	0.7	0.05–0.20	1.0–1.5	...	...	0.10	...	0.05	0.15	remainder
Alclad 3003						3003 clad with 7072					
3004	0.30	0.7	0.25	1.0–1.5	0.8–1.3	...	0.25	...	0.05	0.15	remainder
Alclad 3004						3004 clad with 7072					
3005	0.6	0.7	0.30	1.0–1.5	0.20–0.6	0.10	0.25	0.10	0.05	0.15	remainder
3105	0.6	0.7	0.30	0.30–0.8	0.20–0.8	0.20	0.40	0.10	0.05	0.15	remainder
5005	0.30	0.7	0.20	0.20	0.50–1.1	0.10	0.25	...	0.05	0.15	remainder
5010	0.40	0.7	0.25	0.10–0.30	0.20–0.6	0.15	0.30	0.10	0.05	0.15	remainder
5050	0.40	0.7	0.20	0.10	1.1–1.8	0.10	0.25	...	0.05	0.15	remainder
5052	0.25	0.40	0.10	0.10	2.2–2.8	0.15–0.35	0.10	...	0.05	0.15	remainder
5083	0.40	0.40	0.10	0.40–1.0	4.0–4.9	0.05–0.25	0.25	0.15	0.05	0.15	remainder
5086	0.40	0.50	0.10	0.20–0.7	3.5–4.5	0.05–0.25	0.25	0.15	0.05	0.15	remainder
5154	0.25	0.40	0.10	0.10	3.1–3.9	0.15–0.35	0.20	0.20	0.05	0.15	remainder
5252	0.08	0.10	0.10	0.10	2.2–2.8	...	0.05	...	0.03[F]	0.10[F]	remainder
5254	0.45 Si + Fe		0.05	0.01	3.1–3.9	0.15–0.35	0.20	0.05	0.05	0.15	remainder
5454	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.05–0.20	0.25	0.20	0.05	0.15	remainder
5456	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.05–0.20	0.25	0.20	0.05	0.15	remainder
5457	0.08	0.10	0.20	0.15–0.45	0.8–1.2	...	0.05	...	0.03[F]	0.10[F]	remainder
5652	0.40 Si + Fe		0.04	0.01	2.2–2.8	0.15–0.35	0.10	...	0.05	0.15	remainder
5657	0.08	0.10	0.10	0.03	0.6–1.0	...	0.05	...	0.02[J]	0.05[J]	remainder
6003[H]	0.35–1.0	0.6	0.10	0.8	0.8–1.5	0.35	0.20	0.10	0.05	0.15	remainder
6061	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.04–0.35	0.25	0.15	0.05	0.15	remainder
Alclad 6061						6061 clad with 7072					
7008[H]	0.10	0.10	0.05	0.05	0.7–1.4	0.12–0.25	4.5–5.5	0.05	0.05	0.10	remainder
7011[H]	0.15	0.20	0.05	0.10–0.30	1.0–1.6	0.05–0.20	4.0–5.5	0.05	0.05	0.15	remainder
7072[H]	0.7 Si + Fe		0.10	0.10	0.10	...	0.8–1.3	...	0.05	0.15	remainder
7075	0.40	0.50	1.2–2.0	0.30	2.1–2.9	0.18–0.28	5.1–6.1	0.20	0.05	0.15	remainder
Alclad 7075						7075 clad with 7072					
7008 Alclad 7075						7075 clad with 7008					
7011 Alclad 7075						7075 clad with 7011					
7178	0.40	0.50	1.6–2.4	0.30	2.4–3.1	0.18–0.28	6.3–7.3	0.20	0.05	0.15	remainder
Alclad 7178						7178 clad with 7072					

[A] Limits are in weight percent maximum unless shown as a range or stated otherwise.

[B] Analysis shall be made for the elements for which limits are shown in this table.

[C] For purposes of determining conformance to these limits, an observed value or a calculated value attained from analysis shall be rounded to the nearest unit in the last righthand place of figures used in expressing the specified limit, in accordance with the rounding-off method of Practice E 29.

[D] *Others* includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic *Others* elements. Should any analysis by the producer or the purchaser establish that an *Others* element exceeds the limit of *Each* or that the aggregate of several *Others* elements exceeds the limit of *Total*, the material shall be considered nonconforming.

[E] *Other Elements*—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.

[F] Vanadium 0.05 max. The total for other elements does not include vanadium.

[G] The aluminum content shall be calculated by subtracting from 100.00 % the sum of all metallic elements present in amounts of 0.010 % or more each, rounded to the second decimal before determining the sum.

[H] Composition of cladding alloy as applied during the course of manufacture. Samples from finished sheet or plate shall not be required to conform to these limits.

[I] Vanadium 0.05–0.15, zirconium 0.10–0.25. The total for other elements does not include vanadium and zirconium.

[J] Gallium 0.03 max, vanadium 0.05 max. The total for other elements does not include vanadium or gallium.

requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser in the order or at the time of contract signing. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

5.2 *Lot Definition*— An inspection lot shall be defined as follows:

5.2.1 For heat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and thickness traceable to a heat-treat lot or lots, and subjected to inspection at one time.

5.2.2 For nonheat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and thickness subjected to inspection at one time.

6. General Quality

6.1 Unless otherwise specified, the material shall be supplied in the mill finish and shall be uniform as defined by the requirements of this specification and shall be commercially sound. Any requirement not so covered is subject to negotiation between producer and purchaser.

6.2 Each sheet and plate shall be examined to determine conformance to this specification with respect to general quality and identification marking. On approval of the purchaser, however, the producer may use a system of statistical quality control for such examinations.

7. Chemical Composition

7.1 *Limits*—The sheet and plate shall conform to the chemical composition limits specified in Table 1. Conformance shall be determined by the producer by analyzing samples taken at the time the ingots are poured, or samples taken from the finished or semifinished product. If the producer has determined the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product.

NOTE 3—It is standard practice in the United States aluminum industry to determine conformance to the chemical composition limits prior to further processing of ingots into wrought products. Due to the continuous nature of the process, it is not practical to keep a specific ingot analysis identified with a specific quantity of finished material.

7.2 *Number of Samples*—The number of samples taken for determination of chemical composition shall be as follows:

7.2.1 When samples are taken at the time the ingots are poured, at least one sample shall be taken for each group of ingots poured simultaneously from the same source of molten metal.

7.2.2 When samples are taken from the finished or semifinished product, a sample shall be taken to represent each 4000 lb, or fraction thereof, of material in the lot, except that not more than one sample shall be required per piece.

7.3 *Methods of Sampling*—Samples for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken by drilling, sawing, milling, turning, or clipping a representative piece or pieces to obtain a prepared sample of not less than 75 g. Sampling shall be in accordance with Practice E 55.

7.3.2 Sampling for spectrochemical analysis shall be in accordance with Practices E 716. Samples for other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

NOTE 4—It is difficult to obtain a reliable analysis of each of the components of clad materials using material in its finished state. A reasonably accurate determination of the core composition can be made if the cladding is substantially removed prior to analysis. The cladding composition is more difficult to determine because of the relatively thin layer and because of diffusion of core elements to the cladding. The correctness of cladding alloy used can usually be verified by a combination of metallographic examination and spectrochemical analysis of the surface at several widely separated points.

7.4 *Methods of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E 34), or spectrochemical (Test Methods E 101, E 227, E 607, and E 1251) methods. Other methods may be used only when no published ASTM method is available. In case of dispute, the methods of analysis shall be agreed upon between the producer and purchaser.

8. Heat Treatment

8.1 Unless specified in 8.2, producer or supplier heat treatment for the applicable tempers in Table 3 shall be in accordance with MIL-H-6088.

8.2 When specified, heat treatment of applicable tempers in Table 3 shall be in accordance with Practice B 597.

9. Tensile Properties of Material as Supplied

9.1 *Limits*—The sheet and plate shall conform to the requirements for tensile properties as specified in Table 2 and Table 3 for nonheat-treatable and heat-treatable alloys, respectively.

9.1.1 Tensile property limits for sizes not covered in Table 2 or Table 3 shall be as agreed upon between the producer and purchaser and shall be so specified in the contract or purchase order.

9.2 *Number of Samples*—One sample shall be taken from each end of each parent coil, or parent plate, but no more than one sample per 2000 lb of sheet or 4000 lb of plate, or part thereof, in a lot shall be required. Other procedures for selecting samples may be employed if agreed upon between the producer and purchaser.

9.3 *Test Specimens*— Geometry of test specimens and the location in the product from which they are taken shall be as specified in Test Methods B 557.

9.4 *Test Methods*— The tension test shall be made in accordance with Test Methods B 557.

10. Producer Confirmation of Heat-Treat Response

10.1 In addition to the requirements of 9.1, material in the O or F temper of alloys 2014, Alclad 2014, 2024, Alclad 2024, 1½ % Alclad 2024, Alclad one-side 2024, 1½ % Alclad one-side 2024, 6061, and Alclad 6061 shall, upon proper solution heat treatment and natural aging at room temperature, develop the properties specified in Table 3 for T42 temper material. The natural aging period at room temperature shall be not less than 4 days, but samples of material may be tested prior to 4 days aging, and if the material fails to conform to the requirements of T42 temper material, the tests may be repeated after completion of 4 days aging without prejudice.

10.2 Also, material in the O or F temper of alloys 2219, Alclad 2219, 6061, 7075, Alclad 7075, Alclad one-side 7075, 7008 Alclad 7075, 7178, and Alclad 7178 shall, upon proper solution heat treatment and precipitation heat treatment, develop the properties specified in Table 3 for T62 temper material.

10.3 Mill-produced material in the O or F tempers of 7008 Alclad 7075 shall, upon proper solution heat treatment and stabilizing, be capable of attaining the properties specified in Table 3 for the T76 temper.

10.4 *Number of Specimens*—The number of specimens from each lot of O temper material and F temper material to be tested to verify conformance with 10.1-10.3 shall be as specified in 9.2.

11. Heat Treatment and Reheat-Treatment Capability

11.1 Mill-produced material in the O or F temper of alloys 2014, Alclad 2014, 2024, Alclad 2024, 1½ % Alclad 2024, Alclad one-side 2024, 1½ % Alclad one-side 2024, 6061, and Alclad 6061 (without the subsequent imposition of cold work or forming operations) shall, upon proper solution heat treatment and natural aging at room temperature, develop the properties specified in Table 3 for T42 temper material. The natural aging period at room temperature shall be not less than 4 days, but samples of material may be tested prior to 4 days aging, and if the material fails to conform to the requirements of T42 temper material, the tests may be repeated after completion of 4 days aging without prejudice.

11.2 Mill-produced material in the O or F temper of alloys 2219, Alclad 2219, 6061, 7075, Alclad 7075, Alclad one-side 7075, 7008 Alclad 7075, 7178, and Alclad 7178 (without the subsequent imposition of cold work or forming operations) shall, upon proper solution heat treatment and precipitation heat treatment, develop the properties specified in Table 3 for T62 temper material.

11.3 Mill-produced material in the O or F temper of 7008 Alclad 7075 (without the subsequent imposition of cold work or forming operations) shall, upon proper solution heat treatment and stabilizing, be capable of attaining the properties specified in Table 3 for the T76 temper.

11.4 Mill-produced material in the following alloys and tempers shall, after proper resolution heat treatment and natural aging for four days at room temperature, be capable of attaining the properties specified in Table 3 for the T42 temper.

Alloys	Tempers
2014 and Alclad 2014	T3, T4, T451, T6, T651
2024 and Alclad 2024	T3, T4, T351, T81, T851
1½ % Alclad 2024, Alclad One-side 2024 and 1½ % Alclad One-side 2024	T3, T351, T81, T851

NOTE 5—Beginning with the 1974 revision 6061 and Alclad 6061 T4, T451, T6, and T651 were deleted from this paragraph because experience has shown that reheat-treated material may develop large recrystallized grains and may fail to develop the tensile properties shown in Table 3.

11.5 Mill-produced material in the following alloys and tempers shall, after proper resolution heat treatment and precipitation heat treatment, be capable of attaining the properties specified in Table 3 for the T62 temper.

Alloys	Tempers
2219 and Alclad 2219	T31, T351, T81, T851
7075	T6, T651, T73, T7351, T76, T7651
Alclad 7075, 7008 Alclad 7075, 7178, and Alclad 7178	T6, T651, T76, T7651
Alclad One-side 7075	T6, T651

11.6 Mill-produced material in the following alloys and tempers and T42 temper material shall, after proper precipitation heat treatment, be capable of attaining the properties specified in Table 3 for the aged tempers listed below.

Alloy and Temper	Temper after Aging
2014 and Alclad 2014-T3, T4, T42, T451	T6, T6, T respectively
2024, Alclad 2024, 1½ % Alclad 2024, Alclad One-side 2024 and 1½ % Alclad One-side 2024-T3, T351, T361, T42	T81, T851, T861, T62 or T72, respectively
2219 and Alclad 2219-T31, T351, T37	T81, T851, T87, respectively
6061 and Alclad 6061-T4, T451, T42	T6, T651, T62, respectively

12. Bend Properties

12.1 *Limits*—Sheet and plate shall be capable of being bent cold through an angle of 180° around a pin having a diameter equal to *N* times the thickness of the sheet or plate without cracking, the value of *N* being as prescribed in Table 2 for the different alloys, tempers, and thicknesses. The test need not be conducted unless specified on the purchase order.

12.2 *Test Specimens*— When bend tests are made, the specimens for sheet shall be the full thickness of the material, approximately ¾ in. in width, and when practical, at least 6 in. in length. Such specimens may be taken in any direction and their edges may be rounded to a radius of approximately 1⁄16 in. if desired. For sheet less than ¾ in. in width, the specimens should be the full width of the material.

12.3 *Test Methods*— The bend tests shall be made in accordance with Test Method E 290 except as stated otherwise in 12.2.

13. Stress-Corrosion Resistance

13.1 When specified on the purchase order or contract, alloy 2124-T851, 2219-T851, and 2219-T87 plate shall be subjected to the test specified in 13.3 and shall exhibit no evidence of stress-corrosion cracking. One sample shall be taken from each parent plate in each lot and a minimum of three adjacent replicate specimens from this sample shall be tested. The producer shall maintain records of all lot acceptance test results and make them available for examination at the producer's facility.

13.2 Alloy 7075 in the T73-type and T76-type tempers, and alloys Alclad 7075, 7008 Alclad 7075, 7178, and Alclad 7178 in the T76-type tempers, shall be capable of exhibiting no evidence of stress-corrosion cracking when subjected to the test specified in 13.3.

13.2.1 For lot-acceptance purposes, resistance to stress-corrosion cracking for each lot of material shall be established by testing the previously selected tension-test samples to the criteria shown in Table 4.

13.2.2 For surveillance purposes, each month the producer shall perform at least one test for stress-corrosion resistance in accordance with 13.3 on each applicable alloy-temper for each thickness range 0.750 in. and over listed in Table 3, produced that month. Each sample shall be taken from material considered acceptable in accordance with lot-acceptance criteria of Table 4. A minimum of three adjacent replicate specimens shall be taken from each sample and tested. The producer shall maintain records of all lots so tested and make them available for examination at the producer's facility.

13.3 The stress-corrosion cracking test shall be performed on plate 0.750 in. and over in thickness as follows:

13.3.1 Specimens shall be stressed in tension in the short transverse direction with respect to grain flow and held at constant strain. For alloy 2124-T851, the stress levels shall be 50 % of the specified minimum long transverse yield strength. For alloy 2219-T851 and T87, the stress levels shall be 75 % of the specified minimum long transverse yield strength. For T73-type tempers, the stress level shall be 75 % of the specified minimum yield strength and for T76-type it shall be 25 ksi.

13.3.2 The stress-corrosion test shall be made in accordance with Test Method G 47.

13.3.3 There shall be no visual evidence of stress-corrosion cracking in any specimen, except that the retest provisions of 19.2 shall apply.

14. Exfoliation-Corrosion Resistance

14.1 Alloys 5083, 5086, and 5456 in the H116 temper shall be capable of exhibiting no evidence of exfoliation corrosion when subjected to the test described in Test Method G 66.

NOTE 6—Alloys 5083, 5086, and 5456 should not be used for continuous service at temperatures exceeding 150°F because of susceptibility to stress corrosion cracking. In addition, stress corrosion susceptibility is increased by cold forming.

14.1.1 For lot-acceptance purposes, the acceptability of each lot of material in the alloys and temper listed in 14.1 shall be determined by the producer by metallographic examination of one sample per lot selected from midsection at one end of a random sheet or plate. The microstructure of the sample from each production lot shall be compared to that of a producer-established reference photomicrograph of acceptable material in the same thickness range which is characterized by being predominantly free of a continuous grain boundary network of aluminum-magnesium (Mg_2Al_3) precipitate. A reference photomicrograph taken at 500× shall be established for each of the thickness ranges shown in Table 2 in which materials are produced and shall be taken from a sample within that thickness range. A longitudinal section perpendicular to the rolled surface shall be prepared for metallographic examination (see Methods E 3, symbol E in Fig. 1) and shall be microetched for metallographic examination using 40 % phosphoric acid etch for 3 min at 95°F or using etchant No. 6 in accordance with Test Methods E 407, Table 2, for 2 min. The metallographic examination shall be conducted at 500× magnification. If the microstructure shows evidence of aluminum-magnesium precipitate in excess of the producer-established reference photomicrograph of acceptable material, the lot is either rejected or tested for exfoliation-corrosion resistance in accordance with 14.1. The sample for corrosion test should be selected in the same manner specified for metallographic tests and shall be taken from the same sheet or plate used for metallographic test. Specimens prepared from the sample shall be full section thickness, except that for material 0.101 in. or more in thickness, 10 % of the thickness shall be removed, by machining, from one as-rolled surface. Both the machined surface and the remaining as-rolled surface shall be evaluated after exposure to the test solution. Production practices shall not be changed after establishment of the reference micrograph except as provided in 14.1.3.

14.1.2 The producer shall maintain at the producing facility all records relating to the establishment of reference photomicrographs and production practices.

14.1.3 Significant changes in production practices that alter the microstructures of the alloy shall require qualification of the practice in accordance with 14.1.1.

14.2 Alloys 7075, Alclad 7075, 7008 Alclad 7075, 7178, and Alclad 7178, in the T76-type tempers, shall be capable of exhibiting no evidence of exfoliation corrosion equivalent to or in excess of that illustrated by Category B in Fig. 2 of Method of Test for Exfoliation Corrosion Susceptibility in 7XXX Series Copper Containing Aluminum Alloys (Exco Test) (G34-72)[14] when subjected to the test in 14.3.

14.2.1 For lot-acceptance purposes, resistance to exfoliation corrosion for each lot of material in the alloys and tempers listed in 14.2 shall be established by testing the previously selected tension-test samples to the criteria shown in Table 4.

14.2.2 For surveillance purposes, each month the producer shall perform at least one test for exfoliation-corrosion resistance for each alloy for each thickness range listed in Table 3, produced that month. The samples for test shall be selected at random from material considered acceptable in accordance with the lot-acceptance criteria of Table 4. The producer shall maintain records of all surveillance test results and make them available for examination.

14.3 The test for exfoliation-corrosion resistance shall be made in accordance with Method of Test for Exfoliation Corrosion Susceptibility in 7XXX Series Copper Containing Aluminum Alloys (Exco Test) (G34-72)[14] and the following:

14.3.1 The specimens shall be a minimum of 2 in. by 4 in. with the 4-in. dimension in a plane parallel to the direction of final rolling. They shall be full-section thickness specimens of the material except that for material 0.101 in. or more in thickness, 10 % of the thickness shall be removed by machining one surface. The cladding of alclad sheet of any thickness shall be removed by machining the test surface; the cladding on the back side (nontest surface) of the specimen for any thickness of alclad material shall also either be removed or masked off. For machined specimens, the machined surface shall be evaluated by exposure to the test solution.

15. Cladding

15.1 Preparatory to rolling alclad sheet and plate to the specified thickness, the aluminum or aluminum-alloy plates which are bonded to the alloy ingot or slab shall be of the composition shown in Table 1 and shall each have a thickness not less than that shown in Table 5 for the alloy specified.

15.2 When the thickness of the cladding is to be determined on finished material, not less than one transverse sample approximately ¾ in. in length shall be taken from each edge and from the center width of the material. Samples shall be mounted to expose a transverse cross section and shall be polished for examination with a metallurgical microscope. Using 100× magnification, the maximum and minimum cladding thickness on each surface shall be measured in each of five fields approximately 0.1 in. apart for each sample. The average of the ten values (five minima plus five maxima) on each sample surface is the average cladding thickness and shall meet the minimum average and, when applicable, the maximum average specified in Table 5.

16. Dimensional Tolerances

16.1 *Thickness*—The thickness of flat sheet, coiled sheet, and plate shall not vary from that specified by more than the respective permissible variations prescribed in Tables 3.1 and Tables 3.13 of ANSI H35.2. Permissible variations in thickness of plate specified in thicknesses exceeding 6 in. shall be the subject of agreement between the purchaser and the producer or the supplier at the time the order is placed.

16.2 *Length, Width, Lateral Bow, Squareness, and Flatness*—Coiled sheet shall not vary in width or in lateral bow from that specified by more than the permissible variations prescribed in Tables 3.5 and Tables 3.6, respectively, of ANSI H35.2. Flat sheet and plate shall not vary in width, length, lateral bow, squareness, or flatness by more than the permissible variations prescribed in the following tables of ANSI H35.2 except that where the tolerances for sizes ordered are not covered by this standard the permissible variations shall be the subject of agreement between the purchaser and the producer or the supplier at the time the order is placed:

Table No.	Title
3.2	width, sheared flat sheet and plate
3.3	width and length, sawed flat sheet and plate
3.4	length, sheared flat sheet and plate
3.7	lateral bow, flat sheet and plate
3.8	squareness, flat sheet and plate
3.11	flatness, flat sheet
3.12	flatness, sawed or sheared plate

16.3 Dimensional tolerances for sizes not covered in ANSI H35.2 shall be as agreed upon between the producer and purchaser and shall be so specified in the contract or purchase order.

16.4 *Sampling for Inspection*—Examination for dimensional conformance shall be made to ensure conformance to the tolerance specified.

17. Internal Quality

17.1 When specified by the purchaser at the time of placing the order, plate 0.500 in. to 4.500 in. in thickness and up to 2000 lb in maximum weight in alloys 2014, 2024, 2124, 2219, 7075, and 7178, both bare and Alclad where applicable, shall be tested in accordance with Practice B 594 to the discontinuity acceptance limits of Table 6.

17.2 When specified by the purchaser at the time of placing the order, plate 0.500 in. in thickness and greater for ASME pressure vessel applications in alloys 1060, 1100, 3003, Alclad 3003, 3004, Alclad 3004, 5052, 5083, 5086, 5154, 5254, 5454, 5456, 5652, 6061, and Alclad 6061 shall be tested in accordance with Method B 548. In such cases the material will be subject to rejection if the following limits are exceeded unless it is determined by the purchaser that the area of the plate containing significant discontinuities will be removed during the subsequent fabrication process or that the plate may be repaired by welding:

17.2.1 If the longest dimension of the marked area representing a discontinuity causing a complete loss of back reflection (95 % or greater) exceeds 1.0 in.

17.2.2 If the length of the marked area representing a discontinuity causing an isolated ultrasonic indication without a complete loss of back reflection (95 % or greater) exceeds 3.0 in.

17.2.3 If each of two marked areas representing two adjacent discontinuities causing isolated ultrasonic indications without a complete loss of back reflection (95 % or greater) is longer than 1.0 in., and if they are located within 3.0 in. of each other.

18. Source Inspection

18.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the material prior to shipment, such agreement shall be made by the purchaser and producer as part of the purchase contract.

18.2 When such inspection or witness of inspection and testing is agreed upon, the producer shall afford the purchaser's representative all reasonable facilities to satisfy him that the material meets the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

19. Retest and Rejection

19.1 If any material fails to conform to all of the applicable requirements of this specification, the inspection lot shall be rejected.

19.2 When there is evidence that a failed specimen was not representative of the inspection lot and when no other sampling plan is provided or approved by the purchaser through the contract or purchase order, at least two additional specimens shall be selected to replace each test specimen that failed. All specimens so selected for retest shall meet the requirements of the specification or the lot shall be subject to rejection.

19.3 Material in which defects are discovered subsequent to inspection may be rejected.

19.4 If material is rejected by the purchaser, the producer or supplier is responsible only for replacement of material to the purchaser. As much as possible of the rejected material shall be returned to the producer or supplier by the purchaser.

20. Identification Marking of Product

20.1 When specified on the purchase order or contract, all sheet and plate shall be marked in accordance with Practice B 666.

20.2 In addition, alloys in the 2000 and 7000 series in the T3-, T4-, T6-, T7-, and T8-type tempers and, when specified, 6061-T6 and T651 shall be marked with the lot number in at least one location on each piece.

20.3 The requirements specified in 20.1 and 20.2 are minimum; marking systems that involve added information, larger characters, and greater frequencies are acceptable under this specification.

21. Packaging and Package Marking

21.1 The material shall be packaged to provide adequate protection during normal handling and transportation and each package shall contain only one size, alloy, and temper of material unless otherwise agreed. The type of packaging and gross weight of containers shall, unless otherwise agreed, be at the producer's or supplier's discretion, provided that they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

21.2 Each shipping container shall be marked with the purchase order number, material size, specification number, alloy and temper, gross and net weights, and the producer's name or trademark.

21.3 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of Practices B 660. The applicable levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

22. Certification

22.1 The producer or supplier shall, on request, furnish tothe purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification, and has met the requirements.

23. Keywords

23.1 aluminum alloy; aluminum-alloy plate; aluminum-alloy sheet

TABLE 2 Mechanical Property Limits for Nonheat-Treatable Alloy[A],[B]

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
			Aluminum 1060				
O	0.006–0.019	8.0	14.0	2.5	...	15	...
	0.020–0.050	8.0	14.0	2.5	...	22	...
	0.051–3.000	8.0	14.0	2.5	...	25	...
H12[C] or H22[C]	0.017–0.050	11.0	16.0	9.0	...	6	...
	0.051–2.000	11.0	16.0	9.0	...	12	...
H14[C] or H24[C]	0.009–0.019	12.0	17.0	10.0	...	1	...
	0.020–0.050	12.0	17.0	10.0	...	5	..
	0.051–1.000	12.0	17.0	10.0	...	10	...
H16[C] or H26[C]	0.006–0.019	14.0	19.0	11.0	...	1	...
	0.020–0.050	14.0	19.0	11.0	...	4	...
	0.051–0.162	14.0	19.0	11.0	...	5	...
H18[C] or H28[C]	0.006–0.019	16.0	...	12.0	...	1	...
	0.020–0.050	16.0	...	12.0	...	3	...
	0.051–0.128	16.0	...	12.0	...	4	...
H112	0.250–0.499	11.0	...	7.0	...	10	...
	0.500–1.000	10.0	...	5.0	...	20	...
	1.001–3.000	9.0	...	4.0	...	25	...
F	0.250–3.000	...	...	...	...	...	...
			Aluminum 1100				
O	0.006–0.019	11.0	15.5	3.5	...	15	0
	0.020–0.031	11.0	15.5	3.5	...	20	0
	0.032–0.050	11.0	15.5	3.5	...	25	0
	0.051–0.249	11.0	15.5	3.5	...	30	0
	0.250–3.000	11.0	15.5	3.5	...	28	0
H12[C] or H22[C]	0.017–0.019	14.0	19.0	11.0	...	3	0
	0.020–0.031	14.0	19.0	11.0	...	4	0
	0.032–0.050	14.0	19.0	11.0	...	6	0
	0.051–0.113	14.0	19.0	11.0	...	8	0
	0.114–0.499	14.0	19.0	11.0	...	9	0
	0.500–2.000	14.0	19.0	11.0	...	12	0
H14[C] or H24[C]	0.009–0.012	16.0	21.0	14.0	...	1	0
	0.013–0.019	16.0	21.0	14.0	...	2	0
	0.020–0.031	16.0	21.0	14.0	...	3	0
	0.032–0.050	16.0	21.0	14.0	...	4	0
	0.051–0.113	16.0	21.0	14.0	...	5	0
	0.114–0.499	16.0	21.0	14.0	...	6	0
	0.500–1.000	16.0	21.0	14.0	...	10	0
H16[C]	0.006–0.019	19.0	24.0	17.0	...	1	4

ASTM Logo Removed **B 209 – 96**

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
or	0.020–0.031	19.0	24.0	17.0	...	2	4
H26[C]	0.032–0.050	19.0	24.0	17.0	...	3	4
	0.051–0.162	19.0	24.0	17.0	...	4	4
H18[C]	0.006–0.019	22.0	...	...	...	1	...
or	0.020–0.031	22.0	...	...	...	2	...
H28[C]	0.032–0.050	22.0	...	...	...	3	...
	0.051–0.128	22.0	...	...	...	4	...
H112	0.250–0.499	13.0	...	7.0	...	9	...
	0.500–2.000	12.0	...	5.0	...	14	...
	2.001–3.000	11.5	...	4.0	...	20	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 3003				
O	0.006–0.007	14.0	19.0	5.0	...	14	0
	0.008–0.012	14.0	19.0	5.0	...	18	0
	0.013–0.031	14.0	19.0	5.0	...	20	0
	0.032–0.050	14.0	19.0	5.0	...	23	0
	0.051–0.249	14.0	19.0	5.0	...	25	0
	0.250–3.000	14.0	19.0	5.0	...	23	...
H12[C]	0.017–0.019	17.0	23.0	12.0	...	3	0
or	0.020–0.031	17.0	23.0	12.0	...	4	0
H22[C]	0.032–0.050	17.0	23.0	12.0	...	5	0
	0.051–0.113	17.0	23.0	12.0	...	6	0
	0.114–0.161	17.0	23.0	12.0	...	7	0
	0.162–0.249	17.0	23.0	12.0	...	8	0
	0.250–0.499	17.0	23.0	12.0	...	9	...
	0.500–2.000	17.0	23.0	12.0	...	10	...
H14[C]	0.009–0.012	20.0	26.0	17.0	...	1	0
or	0.013–0.019	20.0	26.0	17.0	...	2	0
H24[C]	0.020–0.031	20.0	26.0	17.0	...	3	0
	0.032–0.050	20.0	26.0	17.0	...	4	0
	0.051–0.113	20.0	26.0	17.0	...	5	0
	0.114–0.161	20.0	26.0	17.0	...	6	2
	0.162–0.249	20.0	26.0	17.0	...	7	2
	0.250–0.499	20.0	26.0	17.0	...	8	...
	0.500–1.000	20.0	26.0	17.0	...	10	...
H16[C]	0.006–0.019	24.0	30.0	21.0	...	1	4
or	0.020–0.031	24.0	30.0	21.0	...	2	4
H26[C]	0.032–0.050	24.0	30.0	21.0	...	3	4
	0.051–0.162	24.0	30.0	21.0	...	4	6
H18[C]	0.006–0.019	27.0	...	24.0	...	1	...
or	0.020–0.031	27.0	...	24.0	...	2	...
H28[C]	0.032–0.050	27.0	...	24.0	...	3	...
	0.051–0.128	27.0	...	24.0	...	4	...
H112	0.250–0.499	17.0	...	10.0	...	8	...
	0.500–2.000	15.0	...	6.0	...	12	...
	2.001–3.000	14.5	...	6.0	...	18	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alclad Alloy 3003				
O	0.006–0.007	13.0	18.0	4.5	...	14	...
	0.008–0.012	13.0	18.0	4.5	...	18	...
	0.013–0.031	13.0	18.0	4.5	...	20	...
	0.032–0.050	13.0	18.0	4.5	...	23	...
	0.051–0.249	13.0	18.0	4.5	...	25	...
	0.250–0.499	13.0	18.0	4.5	...	23	...
	0.500–3.000	14.0[E]	19.0[E]	5.0[E]	...	23	...
H12[C]	0.017–0.031	16.0	22.0	11.0	...	4	...
or	0.032–0.050	16.0	22.0	11.0	...	5	...
H22[C]	0.051–0.113	16.0	22.0	11.0	...	6	...
	0.114–0.161	16.0	22.0	11.0	...	7	...
	0.162–0.249	16.0	22.0	11.0	...	8	...

ASTM Logo Removed

B 209 – 96

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
	0.250–0.499	16.0	22.0	11.0	...	9	...
	0.500–2.000	17.0[E]	23.0[E]	12.0[E]	...	10	...
H14[C]	0.009–0.012	19.0	25.0	16.0	...	1	...
or	0.013–0.019	19.0	25.0	16.0	...	2	...
H24[C]	0.020–0.031	19.0	25.0	16.0	...	3	...
	0.032–0.050	19.0	25.0	16.0	...	4	...
	0.051–0.113	19.0	25.0	16.0	...	5	...
	0.114–0.161	19.0	25.0	16.0	...	6	...
	0.162–0.249	19.0	25.0	16.0	...	7	...
	0.250–0.499	19.0	25.0	16.0	...	8	...
	0.500–1.000	20.0[E]	26.0[E]	17.0[E]	...	10	...
H16[C]	0.006–0.019	23.0	29.0	20.0	...	1	...
or	0.020–0.031	23.0	29.0	20.0	...	2	...
H26[C]	0.032–0.050	23.0	29.0	20.0	...	3	...
	0.051–0.162	23.0	29.0	20.0	...	4	...
H18	0.006–0.019	26.0	...	...	...	1	...
	0.020–0.031	26.0	...	...	...	2	...
	0.032–0.050	26.0	...	...	...	3	...
	0.051–0.128	26.0	...	...	...	4	...
H112	0.250–0.499	16.0	...	9.0	...	8	...
	0.500–2.000	15.0[E]	...	6.0[E]	...	12	...
	2.001–3.000	14.5[E]	...	6.0[E]	...	18	...
F[D]	0.250–3.000	...	...	...	...	...	...
				Alloy 3004			
O	0.006–0.007	22.0	29.0	8.5	...	...	...
	0.008–0.019	22.0	29.0	8.5	...	10	0
	0.020–0.031	22.0	29.0	8.5	...	14	0
	0.032–0.050	22.0	29.0	8.5	...	16	0
	0.051–0.249	22.0	29.0	8.5	...	18	0
	0.250–3.000	22.0	29.0	8.5	...	16	...
H32[C]	0.017–0.019	28.0	35.0	21.0	...	1	0
or	0.020–0.031	28.0	35.0	21.0	...	3	1
H22[C]	0.032–0.050	28.0	35.0	21.0	...	4	1
	0.051–0.113	28.0	35.0	21.0	...	5	2
	0.114–2.000	28.0	35.0	21.0	...	6	...
H34[C]	0.009–0.019	32.0	38.0	25.0	...	1	2
or	0.020–0.050	32.0	38.0	25.0	...	3	3
H24[C]	0.051–0.113	32.0	38.0	25.0	...	4	4
	0.114–1.000	32.0	38.0	25.0	...	5	...
H36[C]	0.006–0.007	35.0	41.0	28.0	...	...	...
or	0.008–0.019	35.0	41.0	28.0	...	1	6
H26[C]	0.020–0.031	35.0	41.0	28.0	...	2	6
	0.032–0.050	35.0	41.0	28.0	...	3	6
	0.051–0.162	35.0	41.0	28.0	...	4	8
H38[C]	0.006–0.007	38.0	...	31.0	...	...	...
or	0.008–0.019	38.0	...	31.0	...	1	...
H28[C]	0.020–0.031	38.0	...	31.0	...	2	...
	0.032–0.050	38.0	...	31.0	...	3	...
	0.051–0.128	38.0	...	31.0	...	4	...
H112	0.250–3.000	23.0	...	9.0	...	7	...
F[D]	0.250–3.000	...	...	...	...	...	...
				Alclad Alloy 3004			
O	0.006–0.007	21.0	28.0	8.0	...	...	...
	0.008–0.019	21.0	28.0	8.0	...	10	...
	0.020–0.031	21.0	28.0	8.0	...	14	...
	0.032–0.050	21.0	28.0	8.0	...	16	...
	0.051–0.249	21.0	28.0	8.0	...	18	...
	0.250–0.499	21.0	28.0	8.0	...	16	...
	0.500–3.000	22.0[E]	29.0[E]	8.5[E]	...	16	...

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H32[C]	0.017–0.019	27.0	34.0	20.0	...	1	...
or	0.020–0.031	27.0	34.0	20.0	...	3	...
H22[C]	0.032–0.050	27.0	34.0	20.0	...	4	...
	0.051–0.113	27.0	34.0	20.0	...	5	...
	0.114–0.249	27.0	34.0	20.0	...	6	...
	0.250–0.499	27.0	34.0	20.0	...	6	...
	0.500–2.000	28.0[E]	35.0[E]	21.0[E]	...	6	...
H34[C]	0.009–0.019	31.0	37.0	24.0	...	1	...
or	0.020–0.050	31.0	37.0	24.0	...	3	...
H24[C]	0.051–0.113	31.0	37.0	24.0	...	4	...
	0.114–0.249	31.0	37.0	24.0	...	5	...
	0.250–0.499	31.0	37.0	24.0	...	5	...
	0.500–1.000	32.0[E]	38.0[E]	25.0[E]	...	5	...
H36[C]	0.006–0.007	34.0	40.0	27.0	...	...	...
or	0.008–0.019	34.0	40.0	27.0	...	1	...
H26[C]	0.020–0.031	34.0	40.0	27.0	...	2	...
	0.032–0.050	34.0	40.0	27.0	...	3	...
	0.051–0.162	34.0	40.0	27.0	...	4	...
H38	0.006–0.007	37.0	...	...	...	...	...
	0.008–0.019	37.0	...	...	...	1	...
	0.020–0.031	37.0	...	...	...	2	...
	0.032–0.050	37.0	...	...	...	3	...
	0.051–0.128	37.0	...	...	...	4	...
H112	0.250–0.499	22.0	...	8.5	...	7	...
	0.500–3.000	23.0[E]	...	9.0[E]	...	7	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 3005				
O	0.006–0.007	17.0	24.0	6.5	...	10	...
	0.008–0.012	17.0	24.0	6.5	...	12	...
	0.013–0.019	17.0	24.0	6.5	...	14	...
	0.020–0.031	17.0	24.0	6.5	...	16	...
	0.032–0.050	17.0	24.0	6.5	...	18	...
	0.051–0.249	17.0	24.0	6.5	...	20	...
H12	0.017–0.019	20.0	27.0	17.0	...	1	...
	0.020–0.050	20.0	27.0	17.0	...	2	...
	0.051–0.113	20.0	27.0	17.0	...	3	...
	0.114–0.161	20.0	27.0	17.0	...	4	...
	0.162–0.249	20.0	27.0	17.0	...	5	...
H14	0.009–0.031	24.0	31.0	21.0	...	1	...
	0.032–0.050	24.0	31.0	21.0	...	2	...
	0.051–0.113	24.0	31.0	21.0	...	3	...
	0.114–0.249	24.0	31.0	21.0	...	4	...
H16	0.006–0.031	28.0	35.0	25.0	...	1	...
	0.032–0.113	28.0	35.0	25.0	...	2	...
	0.114–0.162	28.0	35.0	25.0	...	3	...
H18	0.006–0.031	32.0	...	29.0	...	1	...
	0.032–0.128	32.0	...	29.0	...	2	...
H19	0.006–0.012	34.0	...	...	...	...	...
	0.013–0.063	34.0	...	...	...	1	...
H25	0.016–0.019	26.0	34.0	22.0	...	1	...
	0.020–0.031	26.0	34.0	22.0	...	2	...
	0.032–0.050	26.0	34.0	22.0	...	3	...
	0.051–0.080	26.0	34.0	22.0	...	4	...
H27	0.016–0.019	29.5	37.5	25.5	...	1	...
	0.020–0.031	29.5	37.5	25.5	...	2	...
	0.032–0.050	29.5	37.5	25.5	...	3	...
	0.051–0.080	29.5	37.5	25.5	...	4	...

ASTM Logo Removed [redacted] **B 209 – 96**

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H28	0.016–0.019	31.0	...	27.0	...	1	...
	0.020–0.031	31.0	...	27.0	...	2	...
	0.032–0.050	31.0	...	27.0	...	3	...
	0.051–0.080	31.0	...	27.0	...	4	...
H29	0.025–0.031	33.0	...	28.0	...	1	...
	0.032–0.050	33.0	...	28.0	...	2	...
	0.051–0.071	33.0	...	28.0	...	3	...
			Alloy 3105				
O	0.013–0.019	14.0	21.0	5.0	...	16	...
	0.020–0.031	14.0	21.0	5.0	...	18	...
	0.032–0.080	14.0	21.0	5.0	...	20	...
H12	0.017–0.019	19.0	26.0	15.0	...	1	...
	0.020–0.031	19.0	26.0	15.0	...	1	...
	0.032–0.050	19.0	26.0	15.0	...	2	...
	0.051–0.080	19.0	26.0	15.0	...	3	...
H14	0.013–0.019	22.0	29.0	18.0	...	1	...
	0.020–0.031	22.0	29.0	18.0	...	1	...
	0.032–0.050	22.0	29.0	18.0	...	2	...
	0.051–0.080	22.0	29.0	18.0	...	2	...
H16	0.013–0.031	25.0	32.0	21.0	...	1	...
	0.032–0.050	25.0	32.0	21.0	...	2	...
	0.051–0.080	25.0	32.0	21.0	...	2	...
H18	0.013–0.031	28.0	...	24.0	...	1	...
	0.032–0.050	28.0	...	24.0	...	1	...
	0.051–0.080	28.0	...	24.0	...	2	...
H25	0.013–0.019	23.0	...	19.0	...	2	...
	0.020–0.031	23.0	...	19.0	...	3	...
	0.032–0.050	23.0	...	19.0	...	4	...
	0.051–0.080	23.0	...	19.0	...	6	...
			Alloy 5005				
O	0.006–0.007	15.0	21.0	5.0	...	12	...
	0.008–0.012	15.0	21.0	5.0	...	14	...
	0.013–0.019	15.0	21.0	5.0	...	16	...
	0.020–0.031	15.0	21.0	5.0	...	18	...
	0.032–0.050	15.0	21.0	5.0	...	20	...
	0.051–0.113	15.0	21.0	5.0	...	21	...
	0.114–0.249	15.0	21.0	5.0	...	22	...
	0.250–3.000	15.0	21.0	5.0	...	22	...
H12	0.017–0.019	18.0	24.0	14.0	...	2	...
	0.020–0.031	18.0	24.0	14.0	...	3	...
	0.032–0.050	18.0	24.0	14.0	...	4	...
	0.051–0.113	18.0	24.0	14.0	...	6	...
	0.114–0.161	18.0	24.0	14.0	...	7	...
	0.162–0.249	18.0	24.0	14.0	...	8	...
	0.250–0.499	18.0	24.0	14.0	...	9	...
	0.500–2.000	18.0	24.0	14.0	...	10	...
H14	0.009–0.031	21.0	27.0	17.0	...	1	...
	0.032–0.050	21.0	27.0	17.0	...	2	...
	0.051–0.113	21.0	27.0	17.0	...	3	...
	0.114–0.161	21.0	27.0	17.0	...	5	...
	0.162–0.249	21.0	27.0	17.0	...	6	...
	0.250–0.499	21.0	27.0	17.0	...	8	...
	0.500–1.000	21.0	27.0	17.0	...	10	...
H16	0.006–0.031	24.0	30.0	20.0	...	1	...
	0.032–0.050	24.0	30.0	20.0	...	2	...
	0.051–0.162	24.0	30.0	20.0	...	3	...
H18	0.006–0.031	27.0	...	...	...	1	...
	0.032–0.050	27.0	...	...	...	2	...
	0.051–0.128	27.0	...	...	...	3	...

ASTM Logo Removed **B 209 – 96**

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H32[C]	0.017–0.019	17.0	23.0	12.0	...	3	...
or	0.020–0.031	17.0	23.0	12.0	...	4	...
H22[C]	0.032–0.050	17.0	23.0	12.0	...	5	...
	0.051–0.113	17.0	23.0	12.0	...	7	...
	0.114–0.161	17.0	23.0	12.0	...	8	...
	0.162–0.249	17.0	23.0	12.0	...	9	...
	0.250–2.000	17.0	23.0	12.0	...	10	...
H34[C]	0.009–0.012	20.0	26.0	15.0	...	2	...
or	0.013–0.031	20.0	26.0	15.0	...	3	...
H24[C]	0.032–0.050	20.0	26.0	15.0	...	4	...
	0.051–0.113	20.0	26.0	15.0	...	5	...
	0.114–0.161	20.0	26.0	15.0	...	6	...
	0.162–0.249	20.0	26.0	15.0	...	7	...
	0.250–0.499	20.0	26.0	15.0	...	8	...
	0.500–1.000	20.0	26.0	15.0	...	10	...
H36[C]	0.006–0.007	23.0	29.0	18.0	...	1	...
or	0.008–0.019	23.0	29.0	18.0	...	2	...
H26[C]	0.020–0.031	23.0	29.0	18.0	...	3	...
	0.032–0.162	23.0	29.0	18.0	...	4	...
H38	0.006–0.012	26.0	...	...	...	1	...
	0.013–0.019	26.0	...	...	...	2	...
	0.020–0.031	26.0	...	...	...	3	...
	0.032–0.128	26.0	...	...	...	4	...
H112	0.250–0.499	17.0	...	...	...	8	...
	0.500–2.000	15.0	...	...	...	12	...
	2.001–3.000	14.5	...	...	...	18	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 5010				
O	0.010–0.070	15.0	21.0	5.0	...	3	...
H22	0.010–0.070	17.0	23.0	14.0	...	2	...
H24	0.010–0.070	20.0	26.0	17.0	...	1	...
H26	0.010–0.070	23.0	29.0	21.0	...	1	...
H28	0.010–0.070	26.0	...	...	...	...	...
			Alloy 5050				
O	0.006–0.007	18.0	24.0	6.0	...	...	0
	0.008–0.019	18.0	24.0	6.0	...	16	0
	0.020–0.031	18.0	24.0	6.0	...	18	0
	0.032–0.050	18.0	24.0	6.0	...	20	0
	0.051–0.113	18.0	24.0	6.0	...	20	0
	0.114–0.249	18.0	24.0	6.0	...	22	0
	0.250–3.000	18.0	24.0	6.0	...	20	2
H32[C]	0.017–0.050	22.0	28.0	16.0	...	4	1
or	0.051–0.249	22.0	28.0	16.0	...	6	2
H22[C]							
H34[C]	0.009–0.031	25.0	31.0	20.0	...	3	1
or	0.032–0.050	25.0	31.0	20.0	...	4	1
H24[C]	0.051–0.249	25.0	31.0	20.0	...	5	3
H36[C]	0.006–0.019	27.0	33.0	22.0	...	2	3
or	0.020–0.050	27.0	33.0	22.0	...	3	3
H26[C]	0.051–0.162	27.0	33.0	22.0	...	4	4
H38	0.006–0.007	29.0	...	...	...	...	...
	0.008–0.031	29.0	...	...	...	2	...
	0.032–0.050	29.0	...	...	...	3	...
	0.051–0.128	29.0	...	...	...	4	...

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H112	0.250–3.000	20.0	...	8.0	...	12	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 5052				
O	0.006–0.007	25.0	31.0	9.5	...	...	0
	0.008–0.012	25.0	31.0	9.5	...	14	0
	0.013–0.019	25.0	31.0	9.5	...	15	0
	0.020–0.031	25.0	31.0	9.5	...	16	0
	0.032–0.050	25.0	31.0	9.5	...	18	0
	0.051–0.113	25.0	31.0	9.5	...	19	0
	0.114–0.249	25.0	31.0	9.5	...	20	0
	0.250–3.000	25.0	31.0	9.5	...	18	...
H32[C]	0.017–0.019	31.0	38.0	23.0	...	4	0
or	0.020–0.050	31.0	38.0	23.0	...	5	1
H22[C]	0.051–0.113	31.0	38.0	23.0	...	7	2
	0.114–0.249	31.0	38.0	23.0	...	9	3
	0.250–0.499	31.0	38.0	23.0	...	11	...
	0.500–2.000	31.0	38.0	23.0	...	12	...
H34[C]	0.009–0.019	34.0	41.0	26.0	...	3	1
or	0.020–0.050	34.0	41.0	26.0	...	4	2
H24[C]	0.051–0.113	34.0	41.0	26.0	...	6	3
	0.114–0.249	34.0	41.0	26.0	...	7	4
	0.250–1.000	34.0	41.0	26.0	...	10	...
H36[C]	0.006–0.007	37.0	44.0	29.0	...	2	4
or	0.008–0.031	37.0	44.0	29.0	...	3	4
H26[C]	0.032–0.162	37.0	44.0	29.0	...	4	5
H38[C]	0.006–0.007	39.0	...	32.0	...	2	...
or	0.008–0.031	39.0	...	32.0	...	3	...
H28[C]	0.032–0.128	39.0	...	32.0	...	4	...
H112	0.250–0.499	28.0	...	16.0	...	7	...
	0.500–2.000	25.0	...	9.5	...	12	...
	2.001–3.000	25.0	...	9.5	...	16	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 5083				
O	0.051–1.500	40.0	51.0	18.0	29.0	16	...
	1.501–3.000	39.0	50.0	17.0	29.0	16	...
	3.001–4.000	38.0	...	16.0	...	16	...
	4.001–5.000	38.0	...	16.0	...	14	...
	5.001–7.000	37.0	...	15.0	...	14	...
	7.001–8.000	36.0	...	14.0	...	12	...
H321	0.188–1.500	44.0	56.0	31.0	43.0	12	...
	1.501–3.000	41.0	56.0	29.0	43.0	12	...
H112	0.250–1.500	40.0	...	18.0	...	12	...
	1.501–3.000	39.0	...	17.0	...	12	...
H116[F]	0.063–0.499	44.0	...	31.0	...	10	...
	0.500–1.250	44.0	...	31.0	...	12	...
	1.251–1.500	44.0	...	31.0	...	12	...
	1.501–3.000	41.0	...	29.0	...	12	...
F[D]	0.250–8.000	...	...	...	...	...	...
			Alloy 5086				
O	0.020–0.050	35.0	44.0	14.0	...	15	...
	0.051–0.249	35.0	44.0	14.0	...	18	...
	0.250–2.000	35.0	44.0	14.0	...	16	...
H32[C]	0.020–0.050	40.0	47.0	28.0	...	6	...
or	0.051–0.249	40.0	47.0	28.0	...	8	...
H22[C]	0.250–2.000	40.0	47.0	28.0	...	12	...

ASTM Logo Removed **B 209 – 96**

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H34[C]	0.009–0.019	44.0	51.0	34.0	...	4	...
or	0.020–0.050	44.0	51.0	34.0	...	5	...
H24[C]	0.051–0.249	44.0	51.0	34.0	...	6	...
	0.250–1.000	44.0	51.0	34.0	...	10	
H36[C]	0.006–0.019	47.0	54.0	38.0	...	3	...
or	0.020–0.050	47.0	54.0	38.0	...	4	...
H26[C]	0.051–0.162	47.0	54.0	38.0	...	6	...
H38[C] or H28[C]	0.006–0.020	50.0	...	41.0	...	3	...
H112	0.188–0.499	36.0	...	18.0	...	8	...
	0.500–1.000	35.0	...	16.0	...	10	...
	1.001–2.000	35.0	...	14.0	...	14	...
	2.001–3.000	34.0	...	14.0	...	14	...
H116[F]	0.063–0.249	40.0	...	28.0	...	8	...
	0.250–0.499	40.0	...	28.0	...	10	...
	0.500–1.250	40.0	...	28.0	...	10	...
	1.251–2.000	40.0	...	28.0	...	10	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 5154				
O	0.020–0.031	30.0	41.0	11.0	...	12	...
	0.032–0.050	30.0	41.0	11.0	...	14	...
	0.051–0.113	30.0	41.0	11.0	...	16	...
	0.114–3.000	30.0	41.0	11.0	...	18	...
H32[C]	0.020–0.050	36.0	43.0	26.0	...	5	...
or	0.051–0.249	36.0	43.0	26.0	...	8	...
H22[C]	0.250–2.000	36.0	43.0	26.0	...	12	...
H34[C]	0.009–0.050	39.0	46.0	29.0	...	4	...
or	0.051–0.161	39.0	46.0	29.0	...	6	...
H24[C]	0.162–0.249	39.0	46.0	29.0	...	7	...
	0.250–1.000	39.0	46.0	29.0	...	10	...
H36[C]	0.006–0.050	42.0	49.0	32.0	...	3	...
or	0.051–0.113	42.0	49.0	32.0	...	4	...
H26[C]	0.114–0.162	42.0	49.0	32.0	...	5	...
H38[C]	0.006–0.050	45.0	...	35.0	...	3	...
or	0.051–0.113	45.0	...	35.0	...	4	...
H28[C]	0.114–0.128	45.0	...	35.0	...	5	...
H112	0.250–0.499	32.0	...	18.0	...	8	...
	0.500–2.000	30.0	...	11.0	...	11	...
	2.001–3.000	30.0	...	11.0	...	15	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 5252				
H24	0.030–0.090	30.0	38.0	...	...	10	...
H25	0.030–0.090	31.0	39.0	...	...	9	...
H28	0.030–0.090	38.0	...	...	...	3	...
			Alloy 5254				
O	0.051–0.113	30.0	41.0	11.0	...	16	...
	0.114–3.000	30.0	41.0	11.0	...	18	...
H32[C]	0.051–0.249	36.0	43.0	26.0	...	8	...
or	0.250–2.000	36.0	43.0	26.0	...	12	...
H22[C]							
H34[C]	0.051–0.161	39.0	46.0	29.0	...	6	...
or	0.162–0.249	39.0	46.0	29.0	...	7	...
H24[C]	0.250–1.000	39.0	46.0	29.0	...	10	...

ASTM Logo Removed **B 209 – 96**

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H36[C]	0.051–0.113	42.0	49.0	32.0	...	4	...
or	0.114–0.162	42.0	49.0	32.0	...	5	...
H26[C]							
H38[C]	0.051–0.113	45.0	...	35.0	...	4	...
or	0.114–0.128	45.0	...	35.0	...	5	...
H28[C]							
H112	0.250–0.499	32.0	...	18.0	...	8	...
	0.500–2.000	30.0	...	11.0	...	11	...
	2.001–3.000	30.0	...	11.0	...	15	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 5454				
O	0.020–0.031	31.0	41.0	12.0	...	12	...
	0.032–0.050	31.0	41.0	12.0	...	14	...
	0.051–0.113	31.0	41.0	12.0	...	16	...
	0.114–3.000	31.0	41.0	12.0	...	18	...
H32[C]	0.020–0.050	36.0	44.0	26.0	...	5	...
or	0.051–0.249	36.0	44.0	26.0	...	8	...
H22[C]	0.250–2.000	36.0	44.0	26.0	...	12	...
H34[C]	0.020–0.050	39.0	47.0	29.0	...	4	...
or	0.051–0.161	39.0	47.0	29.0	...	6	...
H24[C]	0.162–0.249	39.0	47.0	29.0	...	7	...
	0.250–1.000	39.0	47.0	29.0	...	10	...
H112	0.250–0.499	32.0	...	18.0	...	8	...
	0.500–2.000	31.0	...	12.0	...	11	...
	2.001–3.000	31.0	...	12.0	...	15	...
F[C]	0.250–3.000	...	...	...	...	...	...
			Alloy 5456				
O	0.051–1.500	42.0	53.0	19.0	30.0	16	...
	1.501–3.000	41.0	52.0	18.0	30.0	16	...
	3.001–5.000	40.0	...	17.0	...	14	...
	5.001–7.000	39.0	...	16.0	...	14	...
	7.001–8.000	38.0	...	15.0	...	12	...
H321	0.188–0.499	46.0	59.0	33.0	46.0	12	...
	0.500–1.500	44.0	56.0	31.0	44.0	12	...
	1.501–3.000	41.0	54.0	29.0	43.0	12	...
H112	0.250–1.500	42.0	...	19.0	...	12	...
	1.501–3.000	41.0	...	18.0	...	12	...
H116[F]	0.063–0.499	46.0	...	33.0	...	10	...
	0.500–1.250	46.0	...	33.0	...	12	...
	1.251–1.500	44.0	...	31.0	...	12	...
	1.501–3.000	41.0	...	29.0	...	12	...
	3.001–4.000	40.0	...	25.0	...	12	
F[C]	0.250–8.000	...	...	...	...	...	...
			Alloy 5457				
O	0.030–0.090	16.0	22.0	...	...	20	...
			Alloy 5652				
O	0.051–0.113	25.0	31.0	9.5	...	19	0
	0.114–0.249	25.0	31.0	9.5	...	20	0
	0.250–3.000	25.0	31.0	9.5	...	18	...
H32[D]	0.051–0.113	31.0	38.0	23.0	...	7	2
or	0.114–0.249	31.0	38.0	23.0	...	9	3
H22[D]	0.250–0.499	31.0	38.0	23.0	...	11	...
	0.500–2.000	31.0	38.0	23.0	...	12	...
H34[D]	0.051–0.113	34.0	41.0	26.0	...	6	3

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
or	0.114–0.249	34.0	41.0	26.0	...	7	4
H24[D]	0.250–1.000	34.0	41.0	26.0	...	10	...
H112	0.250–0.499	28.0	...	16.0	...	7	...
	0.500–2.000	25.0	...	9.5	...	12	...
	2.001–3.000	25.0	...	9.5	...	16	...
F[C]	0.250–3.000	...	...	...	...	...	...
				Alloy 5657			
H241[G]	0.030–0.090	18.0	26.0	...	...	13	...
H25	0.030–0.090	20.0	28.0	...	...	8	...
H26	0.030–0.090	22.0	30.0	...	...	7	...
H28	0.030–0.090	25.0	...	...	...	5	...

[A] To determine conformance to this specification each value for tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E 29.

[B] The basis for establishment of mechanical property limits is shown in Annex A1.

[C] Material in either of these tempers (H32 or H22), (H34 or H24), (H36 or H26), (H38 or H28), (H12 or H22), (H14 or H24), (H16 or H26), (H18 or H28), may be supplied at the option of the supplier, unless one is specifically excluded by the contract or purchase order. When ordered as H2x tempers, the maximum tensile strength and minimum yield strength do not apply. When H2x tempers are supplied instead of ordered H1x or H3x tempers, the supplied H2x temper material shall meet the respective H1x or H3x temper tensile property limits.

[D] Tests of F temper plate for tensile properties are not required.

[E] The tension test specimen from plate 0.500 in. and thicker is machined from the core and does not include the cladding alloy.

[F] The -H116 temper designation now also applies to products previously designated -H117.

TABLE 3 Tensile Property Limits for Heat-Treatable Alloys[A,B]

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
				Alloy 2014			
O	0.020–0.124	...	32.0	...	16.0	16	0
	0.125–0.249	...	32.0	...	16.0	16	1
	0.250–0.499	...	32.0	...	16.0	16	2
T3	0.020–0.039	59.0	...	35.0	...	14	3
	0.040–0.124	59.0	...	36.0	...	14	3
	0.125–0.249	59.0	...	36.0	...	14	4
T4[C]	0.020–0.124	59.0	...	35.0	...	14	3
	0.125–0.249	59.0	...	35.0	...	14	4
T42[D]	0.020–0.124	58.0	...	34.0	...	14	3
	0.125–0.249	58.0	...	34.0	...	14	4
	0.250–0.499	58.0	...	34.0	...	14	5
	0.500–1.000	58.0	...	34.0	...	14	...
T451[E]	0.250–1.000	58.0	...	36.0	...	14	...
	1.001–2.000	58.0	...	36.0	...	12	...
	2.001–3.000	57.0	...	36.0	...	8	...
T6, T62[D]	0.020–0.039	64.0	...	57.0	...	6	4
	0.040–0.050	66.0	...	58.0	...	7	5
	0.051–0.124	66.0	...	58.0	...	7	6
	0.125–0.249	66.0	...	58.0	...	7	8
T62[D], T651[E]	0.250–0.499	67.0	...	59.0	...	7	10
	0.500–1.000	67.0	...	59.0	...	6	...
	1.001–2.000	67.0	...	59.0	...	4	...
	2.001–2.500	65.0	...	58.0	...	2	...
	2.501–3.000	63.0	...	57.0	...	2	...
	3.001–4.000	59.0	...	55.0	...	1	...
F[F]	0.250–1.000	...	...	...	...	...	...

ASTM Logo Removed **B 209 – 96**

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
				Alclad Alloy 2014			
O	0.020–0.499	...	30.0	...	14.0	16	...
	0.500–1.000	...	32.0[G]	...	...	10	...
T3	0.020–0.039	54.0	...	33.0	...	14	...
	0.040–0.124	55.0	...	34.0	...	14	...
	0.125–0.249	57.0	...	35.0	...	15	...
T4[C]	0.020–0.124	54.0	...	31.0	...	14	...
	0.125–0.249	55.0	...	32.0	...	14	...
	0.040–0.249	57.0	...	34.0	...	15	...
T42[D]	0.020–0.124	54.0	...	31.0	...	14	...
	0.125–0.249	55.0	...	32.0	...	14	...
	0.250–0.499	57.0	...	34.0	...	15	...
	0.500–1.000	58.0[G]	...	34.0[G]	...	14	...
T451[E]	0.250–0.499	57.0	...	36.0	...	15	...
	0.500–1.000	58.0[G]	...	36.0[G]	...	14	...
	1.001–2.000	58.0[G]	...	36.0[G]	...	12	...
	2.001–3.000	57.0[G]	...	36.0[G]	...	8	...
T6, T62[D]	0.020–0.039	62.0	...	54.0	...	7	...
	0.040–0.050	63.0	...	55.0	...	7	...
	0.051–0.124	64.0	...	57.0	...	8	...
	0.125–0.249	...	...	...	...	...	...
T62[D], T651[E]	0.250–0.499	64.0	...	57.0	...	8	...
	0.500–1.000	67.0[G]	...	59.0[G]	...	6	...
	1.001–2.000	67.0[G]	...	59.0[G]	...	4	...
	2.001–2.500	65.0[G]	...	58.0[G]	...	2	...
	2.501–3.000	63.0[G]	...	57.0[G]	...	2	...
	3.001–4.000	59.0[G]	...	55.0[G]	...	1	...
F[F]	0.250–1.000	...	...	...	...	...	...
				Alloy 2024			
O	0.010–0.032	...	32.0	...	14.0	12	0
	0.033–0.063	...	32.0	...	14.0	12	1
	0.064–0.128	...	32.0	...	14.0	12	4
	0.129–0.499	...	32.0	...	14.0	12	6
T3	0.008–0.009	63.0	...	42.0	...	10	4
	0.010–0.020	63.0	...	42.0	...	12	4
	0.021–0.051	63.0	...	42.0	...	15	5
	0.052–0.128	63.0	...	42.0	...	15	6
	0.129–0.249	64.0	...	42.0	...	15	8
T351[E]	0.250–0.499	64.0	...	42.0	...	12	...
	0.500–1.000	63.0	...	42.0	...	8	...
	1.001–1.500	62.0	...	42.0	...	7	...
	1.501–2.000	62.0	...	42.0	...	6	...
	2.001–3.000	60.0	...	42.0	...	4	...
	3.001–4.000	57.0	...	41.0	...	4	
T361[H]	0.020–0.051	67.0	...	50.0	...	8	4
	0.052–0.062	67.0	...	50.0	...	8	8
	0.063–0.249	68.0	...	51.0	...	9	8
	0.250–0.499	66.0	...	49.0	...	9	...
	0.500	66.0	...	49.0	...	10	...
T4[C]	0.010–0.020	62.0	...	40.0	...	12	4
	0.021–0.051	62.0	...	40.0	...	15	5
	0.052–0.128	62.0	...	40.0	...	15	6
	0.129–0.249	62.0	...	40.0	...	15	8
T42[D]	0.010–0.020	62.0	...	38.0	...	12	4
	0.021–0.051	62.0	...	38.0	...	15	5
	0.052–0.128	62.0	...	38.0	...	15	6
	0.129–0.249	62.0	...	38.0	...	15	8

ASTM Logo Removed **B 209 – 96**

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
	0.250–0.499	62.0	...	38.0	...	12	10
	0.500–1.000	61.0	...	38.0	...	8	...
	1.001–1.500	60.0	...	38.0	...	7	...
	1.501–2.000	60.0	...	38.0	...	6	...
	2.001–3.000	58.0	...	38.0	...	4	...
T62[D]	0.010–0.499	64.0	...	50.0	...	5	...
	0.500–2.000	63.0	...	50.0	...	5	...
T72[DI]	0.010–0.249	60.0	...	46.0	...	5	...
T81	0.010–0.249	67.0	...	58.0	...	5	...
T851[E]	0.250–0.499	67.0	...	58.0	...	5	...
	0.500–1.000	66.0	...	58.0	...	5	...
	1.001–1.499	66.0	...	57.0	...	5	...
T861[H]	0.020–0.062	70.0	...	62.0	...	3	...
	0.063–0.249	71.0	...	66.0	...	4	...
	0.250–0.499	70.0	...	64.0	...	4	...
	0.500	70.0	...	64.0	...	4	...
F[F]	0.250–3.000	...	...	...	.. .	...	...
			Alclad Alloy 2024				
O	0.008–0.009	...	30.0	...	14.0	10	0
	0.010–0.032	...	30.0	...	14.0	12	0
	0.033–0.062	...	30.0	...	14.0	12	1
	0.063–0.249	...	32.0	...	14.0	12	2
	0.250–0.499	...	32.0	...	14.0	12	3
	0.500–1.750	...	32.0[G]	...	...	12	...
T3	0.008–0.009	58.0	...	39.0	...	10	4
	0.010–0.020	59.0	...	39.0	...	12	4
	0.021–0.040	59.0	...	39.0	...	15	4
	0.041–0.062	59.0	...	39.0	...	15	5
	0.063–0.128	61.0	...	40.0	...	15	5
	0.129–0.249	62.0	...	40.0	...	15	8
T351[E]	0.250–0.499	62.0	...	40.0	...	12	...
	0.500–1.000	63.0[G]	...	42.0[G]	...	8	...
	1.001–1.500	62.0[G]	...	42.0[G]	...	7	...
	1.501–2.000	62.0[G]	...	42.0[G]	...	6	...
	2.001–3.000	60.0[G]	...	42.0[G]	...	4	...
	3.001–4.000	57.0[G]	...	41.0[G]	...	4	...
T361[H]	0.020–0.062	61.0	...	47.0	...	8	4
	0.063–0.187	64.0	...	48.0	...	9	6
	0.188–0.249	64.0	...	48.0	...	9	8
	0.250–0.499	64.0	...	48.0	...	9	...
	0.500	66.0[G]	...	49.0[G]	...	10	...
T4[C]	0.010–0.020	58.0	...	36.0	...	12	4
	0.021–0.040	58.0	...	36.0	...	15	4
	0.041–0.062	58.0	...	36.0	...	15	5
	0.063–0.128	61.0	...	38.0	...	15	5
T42[D]	0.008–0.009	55.0	...	34.0	...	10	4
	0.010–0.020	57.0	...	34.0	...	12	4
	0.021–0.040	57.0	...	34.0	...	15	4
	0.041–0.062	57.0	...	34.0	...	15	5
	0.063–0.128	60.0	...	36.0	...	15	5
	0.129–0.187	60.0	...	36.0	...	15	8
	0.188–0.249	60.0	...	36.0	...	15	8
	0.250–0.499	60.0	...	36.0	...	12	10
	0.500–1.000	61.0[G]	...	38.0[G]	...	8	...
	1.001–1.500	60.0[G]	...	38.0[G]	...	7	...
	1.501–2.000	60.0[G]	...	38.0[G]	...	6	...
	2.001–3.000	58.0[G]	...	38.0[G]	...	4	...
T62[D]	0.010–0.062	60.0	...	47.0	...	5	...
	0.063–0.499	62.0	...	49.0	...	5	...

ASTM Logo Removed **B 209 – 96**

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
T72[DI]	0.010–0.062	56.0	...	43.0	...	5	...
	0.063–0.249	58.0	...	45.0	...	5	...
T81	0.010–0.062	62.0	...	54.0	...	5	...
	0.063–0.249	65.0	...	56.0	...	5	...
T851[E]	0.250–0.499	65.0	...	56.0	...	5	...
	0.500–1.000	66.0[G]	...	58.0[G]	...	5	...
T861[H]	0.020–0.062	64.0	...	58.0	...	3	...
	0.063–0.187	69.0	...	64.0	...	4	...
	0.188–0.249	69.0	...	64.0	...	4	...
	0.250–0.499	68.0	...	62.0	...	4	...
	0.500	70.0[G]	...	64.0[G]	...	4	...
F[F]	0.250–3.000	...	...	...	...	...	...
			1½ % Alclad Alloy 2024				
O	0.188–0.499	...	32.0	...	14.0	12	...
	0.500–1.750	...	32.0[G]	...	...	12	...
T3	0.188–0.249	63.0	...	41.0	...	15	...
T361	0.188–0.249	65.0	...	49.0	...	9	...
	0.250–0.499	65.0	...	48.0	...	9	...
	0.500	66.0[G]	...	49.0[G]	...	10	...
T351[E]	0.250–0.499	63.0	...	41.0	...	12	...
	0.500–1.000	63.0[G]	...	42.0[G]	...	8	...
	1.001–1.500	62.0[G]	...	42.0[G]	...	7	...
	1.501–2.000	62.0[G]	...	42.0[G]	...	6	...
	2.001–3.000	60.0[G]	...	42.0[G]	...	4	...
	3.001–4.000	57.0[G]	...	41.0[G]	...	4	...
T42[D]	0.188–0.249	61.0	...	37.0	...	15	...
	0.250–0.499	61.0	...	37.0	...	12	...
	0.500–1.000	61.0[G]	...	38.0[G]	...	8	...
	1.001–1.500	60.0[G]	...	38.0[G]	...	7	...
	1.501–2.000	60.0[G]	...	38.0[G]	...	6	...
	2.001–3.000	58.0[G]	...	38.0[G]	...	4	...
T62[D]	0.188–0.499	62.0	...	49.0	...	5	...
T72[DI]	0.188–0.249	59.0	...	45.0	...	5	...
T81	0.188–0.249	66.0	...	57.0	...	5	...
T851[E]	0.250–0.499	66.0	...	57.0	...	5	...
	0.500–1.000	66.0[G]	...	58.0[G]	...	5	...
T861	0.188–0.249	70.0	...	65.0	...	4	...
	0.250–0.499	69.0	...	63.0	...	4	...
	0.500	70.0[G]	...	64.0[G]	...	4	...
F[F]	0.250–3.000	...	...	...	...	...	...
			Alclad One-Side Alloy 2024				
O	0.008–0.009	...	31.0	...	14.0	10	...
	0.010–0.062	...	31.0	...	14.0	12	...
	0.063–0.499	...	32.0	...	14.0	12	...
T3	0.010–0.020	61.0	...	40.0	...	12	...
	0.021–0.062	61.0	...	40.0	...	15	...
	0.063–0.128	62.0	...	41.0	...	15	...
	0.129–0.249	63.0	...	41.0	...	15	...
T351[E]	0.250–0.499	63.0	...	41.0	...	12	...
T361	0.020–0.062	64.0	...	48.0	...	8	...
	0.063–0.249	66.0	...	49.0	...	9	...
	0.250–0.499	65.0	...	48.0	...	9	...

ASTM Logo Removed **B 209 – 96**

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
T42[D]	0.010–0.020	59.0	...	35.0	...	12	...
	0.021–0.062	59.0	...	36.0	...	15	...
	0.063–0.249	61.0	...	37.0	...	15	...
	0.250–0.499	61.0	...	37.0	...	12	...
T62[D]	0.010–0.062	62.0	...	48.0	...	5	...
	0.063–0.249	63.0	...	49.0	...	5	...
T72[D,I]	0.010–0.062	58.0	...	44.0	...	5	...
	0.063–0.499	59.0	...	45.0	...	5	...
T81	0.010–0.062	64.0	...	56.0	...	5	...
	0.063–0.249	66.0	...	57.0	...	5	...
T851[E]	0.250–0.499	66.0	...	57.0	...	5	...
T861	0.020–0.062	67.0	...	60.0	...	3	...
	0.063–0.249	70.0	...	65.0	...	4	...
	0.250–0.499	69.0	...	63.0	...	4	...
F[F]	0.250–0.499	...	...	...	...	...	...
			1½ % Alclad One-Side Alloy 2024				
O	0.188–0.499	...	32.0	...	14.0	12	...
T3	0.188–0.249	63.0	...	41.0	...	15	...
T351[E]	0.250–0.499	63.0	...	41.0	...	12	...
T361	0.188–0.249	66.0	...	49.0	...	9	...
	0.250–0.499	65.0	...	48.0	...	9	...
T42[D]	0.188–0.249	61.0	...	37.0	...	15	...
	0.250–0.499	61.0	...	37.0	...	12	...
T62[D]	0.188–0.499	63.0	...	49.0	...	5	...
T72[D,I]	0.188–0.249	59.0	...	45.0	...	5	...
T81	0.188–0.249	66.0	...	57.0	...	5	...
T851[E]	0.250–0.499	66.0	...	57.0	...	5	...
T861	0.188–0.249	70.0	...	65.0	...	4	...
	0.250–0.499	69.0	...	63.0	...	4	...
F[F]	0.250–0.499	...	...	...	...	...	...

Temper	Specified Thickness, in.	Axis of Test Specimen	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
			min	max	min	max		
				Alloy 2124				
T851[E]	1.000–2.000[J]	Longitudinal	66.0	...	57.0	...	6	...
		Long Transverse	66.0	...	57.0	...	5	...
		Short Transverse	64.0	...	55.0	...	1.5	...
	2.001–3.000	Longitudinal	65.0	...	57.0	...	5	...
		Long Transverse	65.0	...	57.0	...	4	...
		Short Transverse	63.0	...	55.0	...	1.5	...
	3.001–4.000	Longitudinal	65.0	...	56.0	...	5	...
		Long Transverse	65.0	...	56.0	...	4	...
		Short Transverse	62.0	...	54.0	...	1.5	...
	4.001–5.000	Longitudinal	64.0	...	55.0	...	5	...
		Long Transverse	64.0	...	55.0	...	4	...
		Short Transverse	61.0	...	53.0	...	1.5	...
	5.001–6.000	Longitudinal	63.0	...	54.0	...	5	...
		Long Transverse	63.0	...	54.0	...	4	...
		Short Transverse	58.0	...	51.0	...	1.5	...

ASTM Logo Removed **B 209 – 96**

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi min	Tensile Strength, ksi max	Yield Strength (0.2 % offset), ksi min	Yield Strength (0.2 % offset), ksi max	Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
				Alloy 2219			
O	0.020–0.250	...	32.0	...	16.0	12	4
	0.251–0.750	...	32.0	...	16.0	12	6
	0.751–1.000	...	32.0	...	16.0	12	8
	1.001–2.000	...	32.0	...	16.0	12	...
	0.020–0.039	46.0	...	29.0	...	8	...
T31[K] (flat sheet)	0.040–0.249	46.0	...	28.0	...	10	...
T351[E,K] plate (formerly T31 plate)	0.250–2.000	46.0	...	28.0	...	10	...
	2.001–3.000	44.0	...	28.0	...	10	...
	3.001–4.000	42.0	...	27.0	...	9	...
	4.001–5.000	40.0	...	26.0	...	9	...
	5.001–6.000	39.0	...	25.0	...	8	...
T37[K]	0.020–0.039	49.0	...	38.0	...	6	...
	0.040–2.500	49.0	...	37.0	...	6	...
	2.501–3.000	47.0	...	36.0	...	6	...
	3.001–4.000	45.0	...	35.0	...	5	...
	4.001–5.000	43.0	...	34.0	...	4	...
T62[D]	0.020–0.039	54.0	...	36.0	...	6	...
	0.040–0.249	54.0	...	36.0	...	7	...
	0.250–1.000	54.0	...	36.0	...	8	...
	1.001–2.000	54.0	...	36.0	...	7	...
T81 sheet	0.020–0.039	62.0	...	46.0	...	6	...
	0.040–0.249	62.0	...	46.0	...	7	...
T851[E] plate (formerly T81 plate)	0.250–1.000	62.0	...	46.0	...	8	...
	1.001–2.000	62.0	...	46.0	...	7	...
	2.001–3.000	62.0	...	45.0	...	6	...
	3.001–4.000	60.0	...	44.0	...	5	...
	4.001–5.000	59.0	...	43.0	...	5	...
	5.001–6.000	57.0	...	42.0	...	4	...
T87	0.020–0.039	64.0	...	52.0	...	5	...
	0.040–0.249	64.0	...	52.0	...	6	...
	0.250–1.000	64.0	...	51.0	...	7	...
	1.001–2.000	64.0	...	51.0	...	6	...
	2.001–3.000	64.0	...	51.0	...	6	...
	3.001–4.000	62.0	...	50.0	...	4	...
	4.001–5.000	61.0	...	49.0	...	3	...
F[F]	0.250–2.000	...	...	...	...	...	...
				Alclad Alloy 2219			
O	0.020–0.200	...	32.0[G]	...	16.0[G]	12	...
T31 (flat sheet)[K]	0.040–0.099	42.0	...	25.0	...	10	...
	0.100–0.249	44.0	...	26.0	...	10	...
T351[E,K] plate (formerly T31 plate)	0.250–0.499	44.0	...	26.0	...	10	...
T37[K]	0.040–0.099	45.0	...	34.0	...	6	...
	0.100–0.499	47.0	...	35.0	...	6	...
T62[D]	0.020–0.039	44.0	...	29.0	...	6	...
	0.040–0.099	49.0	...	32.0	...	7	...
	0.100–0.249	51.0	...	34.0	...	7	...
	0.250–0.499	51.0	...	34.0	...	8	...
	0.500–1.000	54.0[G]	...	36.0[G]	...	8	...
	1.001–2.000	54.0[G]	...	36.0[G]	...	7	...
T81 (flat sheet)	0.020–0.039	49.0	...	37.0	...	6	...
	0.040–0.099	55.0	...	41.0	...	7	...
	0.100–0.249	58.0	...	43.0	...	7	...

ASTM Logo Removed **B 209 – 96**

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
T851[E] plate (formerly T81 plate)	0.250–0.499	58.0	...	42.0	...	8	...
T87	0.040–0.099	57.0	...	46.0	...	6	...
	0.100–0.249	60.0	...	48.0	...	6	...
	0.250–0.499	60.0	...	48.0	...	7	...
F[F]	0.250–2.000	...	...	...	...	...	...
			Alloy 6061				
O	0.006–0.007	...	22.0	...	12.0	10	0
	0.008–0.009	...	22.0	...	12.0	12	0
	0.010–0.020	...	22.0	...	12.0	14	0
	0.021–0.128	...	22.0	...	12.0	16	1
	0.129–0.249	...	22.0	...	12.0	18	2
	0.250–0.499	...	22.0	...	12.0	18	3
	0.500–1.000	...	22.0	...	...	18	...
	1.001–3.000	...	22.0	...	...	16	...
T4	0.006–0.007	30.0	...	16.0	...	10	2
	0.008–0.009	30.0	...	16.0	...	12	2
	0.010–0.020	30.0	...	16.0	...	14	2
	0.021–0.249	30.0	...	16.0	...	16	3
T451[E]	0.250–0.499	30.0	...	16.0	...	18	4
	0.500–1.000	30.0	...	16.0	...	18	...
	1.001–3.000	30.0	...	16.0	...	16	...
T42[D]	0.006–0.007	30.0	...	14.0	...	10	2
	0.008–0.009	30.0	...	14.0	...	12	2
	0.010–0.020	30.0	...	14.0	...	14	2
	0.021–0.249	30.0	...	14.0	...	16	3
	0.250–0.499	30.0	...	14.0	...	18	4
	0.500–1.000	30.0	...	14.0	...	18	...
	1.001–3.000	30.0	...	14.0	...	16	...
T6, T62[D]	0.006–0.007	42.0	...	35.0	...	4	2
	0.008–0.009	42.0	...	35.0	...	6	2
	0.010–0.020	42.0	...	35.0	...	8	2
	0.021–0.036	42.0	...	35.0	...	10	3
	0.037–0.064	42.0	...	35.0	...	10	4
	0.065–0.128	42.0	...	35.0	...	10	5
	0.129–0.249	42.0	...	35.0	...	10	6
T62[D], T651[E]	0.250–0.499	42.0	...	35.0	...	10	7
	0.500–1.000	42.0	...	35.0	...	9	...
	1.001–2.000	42.0	...	35.0	...	8	...
	2.001–4.000	42.0	...	35.0	...	6	...
	4.001–6.000[L]	40.0	...	35.0	...	6	...
F[F]	0.250–3.000	...	...	...	...	...	...
			Alclad Alloy 6061				
O	0.010–0.020	...	20.0	...	12.0	14	...
	0.021–0.128	...	20.0	...	12.0	16	...
	0.129–0.499	...	20.0	...	12.0	18	...
	0.500–1.000	...	22.0[G]	...	...	18	...
	1.001–3.000	...	22.0[G]	...	...	16	...
T4	0.010–0.020	27.0	...	14.0	...	14	...
	0.021–0.249	27.0	...	14.0	...	16	...
T451[E]	0.250–0.499	27.0	...	14.0	...	18	...
	0.500–1.000	30.0[G]	...	16.0[G]	...	18	...
	1.001–3.000	30.0[G]	...	16.0[G]	...	16	...
T42[D]	0.010–0.020	27.0	...	12.0	...	14	...
	0.021–0.249	27.0	...	12.0	...	16	...
	0.250–0.499	27.0	...	12.0	...	18	...
	0.500–1.000	30.0[G]	...	14.0[G]	...	18	...

ASTM Logo Removed **B 209 – 96**

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
	1.001–3.000	30.0[G]	...	14.0[G]	...	16	...
T6, T62[D]	0.010–0.020	38.0	...	32.0	...	8	...
	0.021–0.249	38.0	...	32.0	...	10	...
T62[D], T651[E]	0.250–0.499	38.0	...	32.0	...	10	...
	0.500–1.000	42.0[G]	...	35.0[G]	...	9	...
	1.001–2.000	42.0[G]	...	35.0[G]	...	8	...
	2.001–4.000	42.0[G]	...	35.0[G]	...	6	...
	4.001–5.000	40.0[G]	...	35.0[G]	...	6	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 7075				
O	0.015–0.020	...	40.0	...	21.0	10	1
	0.021–0.062	...	40.0	...	21.0	10	2
	0.063–0.091	...	40.0	...	21.0	10	3
	0.092–0.125	...	40.0	...	21.0	10	4
	0.126–0.249	...	40.0	...	21.0	10	5
	0.250–0.499	...	40.0	...	21.0	10	6
	0.500–2.000	...	40.0	...	...	10	...
T6, T62[D]	0.008–0.011	74.0	...	63.0	...	5	7
	0.012–0.020	76.0	...	67.0	...	7	7
	0.021–0.039	76.0	...	67.0	...	7	8
	0.040–0.062	78.0	...	68.0	...	8	8
	0.063–0.091	78.0	...	68.0	...	8	9
	0.092–0.125	78.0	...	68.0	...	8	10
	0.126–0.249	78.0	...	69.0	...	8	11
T62[D], T651[E]	0.250–0.499	78.0	...	67.0	...	9	14
	0.500–1.000	78.0	...	68.0	...	7	...
	1.001–2.000	77.0	...	67.0	...	6	...
	2.001–2.500	76.0	...	64.0	...	5	...
	2.501–3.000	72.0	...	61.0	...	5	...
	3.001–3.500	71.0	...	58.0	...	5	...
	3.501–4.000	67.0	...	54.0	...	3	...
T73 sheet	0.040–0.249	67.0	...	56.0	...	8	...
T7351[E] plate	0.250–1.000	69.0	...	57.0	...	7	...
	1.001–2.000	69.0	...	57.0	...	6	...
	2.001–2.500	66.0	...	52.0	...	6	...
	2.501–3.000	64.0	...	49.0	...	6	...
	3.001–4.000	61.0	...	48.0	...	6	...
T76 sheet	0.063–0.124	73.0	...	62.0	...	8	...
	0.125–0.249	73.0	...	62.0	...	8	...
T7651 plate[E]	0.250–0.499	72.0	...	61.0	...	8	...
	0.500–1.000	71.0	...	60.0	...	6	...
	1.001–2.000	71.0	...	60.0	...	5	...
F[F]	0.250–4.000	...	...	...	...	...	...
			Alclad Alloy 7075				
O	0.008–0.014	...	36.0	...	20.0	9	1
	0.015–0.032	...	36.0	...	20.0	10	1
	0.033–0.062	...	36.0	...	20.0	10	2
	0.063–0.125	...	38.0	...	20.0	10	3
	0.126–0.187	...	38.0	...	20.0	10	4
	0.188–0.249	...	39.0	...	21.0	10	4
	0.250–0.499	...	39.0	...	21.0	10	6
	0.500–1.000	...	40.0[G]	...	...	10	...
T6, T62[D]	0.008–0.011	68.0	...	58.0	...	5	6
	0.012–0.020	70.0	...	60.0	...	7	6
	0.021–0.039	70.0	...	60.0	...	7	7
	0.040–0.062	72.0	...	62.0	...	8	7
	0.063–0.091	73.0	...	63.0	...	8	8
	0.092–0.125	73.0	...	63.0	...	8	9
	0.126–0.187	73.0	...	63.0	...	8	10

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
	0.188–0.249	75.0	...	64.0	...	8	10
T62[D], T651[E]	0.250–0.499	75.0	...	65.0	...	9	12
	0.500–1.000	78.0[G]	...	68.0[G]	...	7	...
	1.001–2.000	77.0[G]	...	67.0[G]	...	6	...
	2.001–2.500	76.0[G]	...	64.0[G]	...	5	...
	2.501–3.000	72.0[G]	...	61.0[G]	...	5	...
	3.001–3.500	71.0[G]	...	58.0[G]	...	5	...
	3.501–4.000	67.0[G]	...	54.0[G]	...	3	...
T76 sheet	0.040–0.062	67.0	...	56.0	...	8	...
	0.063–0.124	68.0	...	57.0	...	8	...
	0.125–0.187	68.0	...	57.0	...	8	...
	0.188–0.249	70.0	...	59.0	...	8	...
T7651[E] plate	0.250–0.499	69.0	...	58.0	...	8	...
	0.500–1.000	71.0[G]	...	60.0[G]	...	6	...
F[F]	0.250–4.000	...	...	...	...	...	...
Alclad One Side Alloy 7075							
O	0.015–0.032	...	38.0	...	21.0	10	1
	0.033–0.062	...	38.0	...	21.0	10	2
	0.063–0.091	...	39.0	...	21.0	10	3
	0.092–0.125	...	39.0	...	21.0	10	4
	0.126–0.187	...	39.0	...	21.0	10	5
	0.188–0.249	...	39.0	...	21.0	10	5
	0.250–0.499	...	39.0	...	21.0	10	6
	0.500–1.000	...	40.0[G]	...	...	10	...
T6, T62[D]	0.008–0.011	71.0	...	60.0	...	5	...
	0.012–0.014	74.0	...	64.0	...	8	...
	0.015–0.032	74.0	...	64.0	...	8	7
	0.033–0.039	74.0	...	64.0	...	8	8
	0.040–0.062	75.0	...	65.0	...	9	8
	0.063–0.091	76.0	...	66.0	...	9	9
	0.092–0.125	76.0	...	66.0	...	9	10
	0.126–0.187	77.0	...	67.0	...	9	11
	0.188–0.249	78.0	...	67.0	...	9	11
T62[D], T651[E]	0.250–0.499	76.0	...	66.0	...	9	13
	0.500–1.000	78.0[G]	...	68.0[G]	...	7	...
	1.001–2.000	77.0[G]	...	67.0[G]	...	6	...
F[F]	0.250–2.000	...	...	...	...	...	...
7008 Alclad Alloy 7075							
O	0.015–0.499	...	40.0	...	21.0	10	...
	0.500–2.000	...	40.0[G]	...	...	10	...
T6, T62[D]	0.015–0.039	73.0	...	63.0	...	7	...
	0.040–0.187	75.0	...	65.0	...	8	...
	0.188–0.249	76.0	...	66.0	...	8	...
T62[D], T651[E]	0.250–0.499	76.0	...	66.0	...	9	...
	0.500–1.000	78.0[G]	...	68.0[G]	...	7	...
	1.001–2.000	77.0[G]	...	67.0[G]	...	6	...
	2.001–2.500	76.0[G]	...	64.0[G]	...	5	...
	2.501–3.000	72.0[G]	...	61.0[G]	...	5	...
	3.001–3.500	71.0[G]	...	58.0[G]	...	5	...
	3.501–4.000	67.0[G]	...	54.0[G]		3	...
T76 sheet	0.040–0.062	70.0	...	59.0	...	8	...
	0.063–0.187	71.0	...	60.0	...	8	...
	0.188–0.249	72.0	...	61.0	...	8	...
T7651[E] plate	0.250–0.499	71.0	...	60.0	...	8	...
	0.500–1.000	71.0[G]	...	60.0[G]	...	6	...
F[F]	0.250–4.000	...	...	...	...	...	...
7011 Alclad Alloy 7075							

ASTM Logo Removed **B 209 – 96**

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
O	0.015–0.020	...	40.0	...	21.0	10	1
	0.021–0.062	...	40.0	...	21.0	10	2
	0.063–0.091	...	40.0	...	21.0	10	3
	0.092–0.125	...	40.0	...	21.0	10	4
	0.126–0.249	...	40.0	...	21.0	10	5
	0.250–0.499	...	40.0	...	21.0	10	6
	0.500–2.000	...	40.0[G]	...	21.0[G]	10	...
T6, T62[D]	0.015–0.020	73.0	...	63.0	...	7	7
	0.021–0.039	73.0	...	63.0	...	7	8
	0.040–0.062	75.0	...	65.0	...	8	8
	0.063–0.091	75.0	...	65.0	...	8	9
	0.092–0.125	75.0	...	65.0	...	8	10
	0.126–0.187	75.0	...	65.0	...	8	11
	0.188–0.249	76.0	...	66.0	...	8	11
T62[D], T651	0.250–0.499	76.0	...	66.0	...	9	14
	0.500–1.000	78.0[G]	...	68.0[G]	...	7	...
	1.001–2.000	77.0[G]	...	67.0[G]	...	6	...
	2.001–2.500	76.0[G]	...	64.0[G]	...	5	...
	2.501–3.000	72.0[G]	...	61.0[G]	...	5	...
	3.001–3.500	71.0[G]	...	58.0[G]	...	5	...
	3.501–4.000	67.0[G]	...	54.0[G]	...	3	...
T76	0.040–0.062	70.0	...	59.0	...	8	8
	0.063–0.091	71.0	...	60.0	...	8	9
	0.092–0.125	71.0	...	60.0	...	8	10
	0.126–0.187	71.0	...	60.0	...	8	11
	0.188–0.249	72.0	...	61.0	...	8	11
T7651	0.250–0.499	71.0	...	60.0	...	8	...
	0.500–1.000	71.0[G]	...	60.0[G]	...	6	...
F	All	...	...	...	...	...	...
			Alloy 7178				
O	0.015–0.499	...	40.0	...	21.0	10	...
	0.500	...	40.0	...	...	10	...
T6, T62[D]	0.015–0.044	83.0	...	72.0	...	7	...
	0.045–0.249	84.0	...	73.0	...	8	...
T62[D],T651[E]	0.250–0.499	84.0	...	73.0	...	8	...
	0.500–1.000	84.0	...	73.0	...	6	...
	1.001–1.500	84.0	...	73.0	...	4	...
	1.501–2.000	80.0	...	70.0	...	3	...
T76	0.045–0.249	75.0	...	64.0	...	8	...
T7651[E]	0.250–0.499	74.0	...	63.0	...	8	...
	0.500–1.000	73.0	...	62.0	...	6	...
F[F]	0.250–2.000	...	...	...	...	...	...
			Alclad Alloy 7178				
O	0.015–0.062	...	36.0	...	20.0	10	...
	0.063–0.187	...	38.0	...	20.0	10	...
	0.188–0.499	...	40.0	...	21.0	10	...
	0.500	...	40.0[G]	...	...	10	...
T6, T62[D]	0.015–0.044	76.0	...	66.0	...	7	...
	0.045–0.062	78.0	...	68.0	...	8	...
	0.063–0.187	80.0	...	70.0	...	8	...
	0.188–0.249	82.0	...	71.0	...	8	...
T62[D], T651[E]	0.250–0.499	82.0	...	71.0	...	8	...
	0.500–1.000	84.0[G]	...	73.0[G]	...	6	...
	1.001–1.500	84.0[G]	...	73.0[G]	...	4	...
	1.501–2.000	80.0[G]	...	70.0[G]	...	3	...
T76	0.045–0.062	71.0	...	60.0	...	8	...
	0.063–0.187	71.0	...	60.0	...	8	...
	0.188–0.249	73.0	...	61.0	...	8	...
T7651[E]	0.250–0.499	72.0	...	60.0	...	8	...
	0.500–1.000	73.0[G]	...	62.0[G]	...	6	...

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
F[F]	0.250–2.000	...	...	...	...	...	...
		7011 Alclad Alloy 7178					
O	0.015–0.020	...	40.0	...	21.0	10	1
	0.021–0.062	...	40.0	...	21.0	10	2
	0.063–0.091	...	40.0	...	21.0	10	3
	0.092–0.125	...	40.0	...	21.0	10	4
	0.126–0.249	...	40.0	...	21.0	10	5
	0.250–0.499	...	40.0	...	21.0	10	6
	0.500–2.000	...	40.0[G]	...	...	10	...
T6, T62[D]	0.015–0.020	79.0	...	69.0	...	7	7
	0.021–0.044	79.0	...	69.0	...	7	8
	0.045–0.062	81.0	...	70.0	...	8	8
	0.063–0.091	82.0	...	71.0	...	8	9
	0.092–0.125	82.0	...	71.0	...	8	10
	0.126–0.187	82.0	...	71.0	...	8	11
	0.188–0.249	83.0	...	72.0	...	8	14
T62[D], T651	0.250–0.499	83.0	...	72.0	...	8	14
	0.500–1.000	84.0[G]	...	73.0[G]	...	6	...
	1.001–1.500	84.0[G]	...	73.0[G]	...	4	...
	1.501–2.000	80.0[G]	...	70.0[G]	...	3	...
T76	0.045–0.062	73.0	...	62.0	...	8	8
	0.063–0.091	73.0	...	62.0	...	8	9
	0.092–0.125	73.0	...	62.0	...	8	10
	0.126–0.187	73.0	...	62.0	...	8	11
	0.188–0.249	74.0	...	63.0	...	8	11
T7651	0.250–0.499	73.0	...	61.0	...	8	...
	0.500–1.000	73.0[G]	...	62.0[G]	...	6	...
F	All	...	...	...	...	...	...

[A] To determine conformance to this specification, each value for tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E 29.

[B] The basis for establishment of mechanical property limits is shown in Annex A1.

[C] Coiled sheet.

[D] Material in the T42, T62, and T72 tempers is not available from the material producer.

[E] For stress-relieved tempers (T351, T451, T651, T7351, T7651, and T851), characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.

[F] Test for tensile properties in the F temper are not required.

[G] The tension test specimen from plate 0.500 in. and thicker is machined from the core and does not include the cladding.

[H] Applicable to flat sheet and plate only.

[I] The T72 temper is applicable only to Alloys 2024 and Alclad 2024 sheet solution heat treated and artificially overaged by the user to develop increased resistance to stress-corrosion cracking.

[J] Short transverse tensile property limits are not applicable to material less than 1.500 in. in thickness.

[K] Use of Alloys 2219 and Alclad 2219 in the T31, T351, and T37 tempers for finished products is not recommended.

[L] The properties for this thickness apply only to the T651 temper.

TABLE 4 Lot Acceptance Criteria for Resistance to Stress Corrosion and Exfoliation Corrosion

Alloy and Temper	Lot Acceptance Criteria: Electrical Conductivity,[A] %, IACS	Lot Acceptance Criteria: Level of Mechanical Properties	Lot Acceptance Status
7075-T73 and T7351	40.0 or greater	per specified requirements	acceptable
	38.0 through 39.9	per specified requirements yield strength does not exceed minimum by more than 11.9 ksi	acceptable
	38.0 through 39.9	per specified requirements but yield strength exceeds minimum by 12.0 ksi or more	unacceptable[B]
	less than 38.0	any level	unacceptable[B]
7075–*T76 and T7651* *Alclad* 7075–*T76 and T7651* *and* 7008 *Alclad* 7075–*T76 and* –*T7651*	38.0 or greater	per specified requirements	acceptable
	36.0 through 37.9	per specified requirements	unacceptable[B]
	less than 36.0	any level	unacceptable[B]
7178–*T76 and T7651* *Alclad* 7178–*T76 and T7651* 7011 Alclad 7178-T76 and T7651	38.0 or greater	per specified requirements	acceptable
	35.0 through 37.9	per specified requirements	unacceptable[B]
	less than 35.0	any level	unacceptable[B]

[A] The electrical conductivity shall be determined in accordance with Test Method E 1004 in the following locations:

Alloy-Temper	Thickness, in.	Location
7075-T73 and T7351	all	surface of tension-test sample
7075–*T76 and T7651* 7178–*T76 and T7651*	up through 0.100	surface of tension-test sample
	0.101 and over	sub-surface after removal of approximately 10 % of the thickness

For alcad products, the cladding must be removed and the electrical conductivity determined on the core alloy.

[B] When material is found to be unacceptable, it shall be reprocessed (additional precipitation heat treatment or re-solution heat treatment, stress relieving and precipitation heat treatment, when applicable)..

TABLE 5 Components of Clad Products

Alloy	Component Alloys[A]: Core	Component Alloys[A]: Cladding	Total Composite Thickness of Finished Sheet and Plate, in.	Sides Clad	Cladding Thickness per Side, percent of Composite Thickness: Nominal	Average[B]: min	Average[B]: max
Alclad 2014	2014	6003	up through 0.024	both	10	8	
			0.025–0.039	both	7.5	6	
			0.040–0.099	both	5	4	
			0.100 and over	both	2.5	2	
Alclad 2024	2024	1230	up through 0.062	both	5	4	
			0.063 and over	both	2.5	2	
1½ % Alclad 2024	2024	1230	0.188 and over	both	1.5	1.2	3[C]
Alclad one-side 2024	2024	1230	up through 0.062	one	5	4	
			0.063 and over	one	2.5	2	
1½ % Alclad one-side 2024	2024	1230	0.188 and over	one	1.5	1.2	3[C]
Alclad 2219	2219	7072	up through 0.039	both	10	8	
			0.040–0.099	both	5	4	
			0.100 and over	both	2.5	2	
Alclad 3003	3003	7072	all	both	5	4	6[D]
Alclad 3004	3004	7072	all	both	5	4	6[D]
Alclad 6061	6061	7072	all	both	5	4	6[D]
Alclad 7075 and	7075	7072	*up through* 0.062	both	4	3.2	
7008 Alclad 7075	7075	7008	0.063–0.187	both	2.5	2	
			0.188 *and over*	both	1.5	1.2	3[C]
Alclad one-side 7075	7075	7072	up through 0.062	one	4	3.2	
			0.063–0.187	one	2.5	2	
			0.188 and over	one	1.5	1.2	3[C]
Alclad 7178	7178	7072	*up through* 0.062	both	4	3.2	
7011 Alclad 7178	7178	7011	0.063–0.187	both	2.5	2	
			0.188 *and over*	both	1.5	1.2	3[C]

[A] Cladding composition is applicable only to the aluminum alloy bonded to the alloy ingot or slab preparatory to rolling to the specified composite product. The composition of the cladding may be altered subsequently by diffusion between the core and cladding due to thermal treatment.

[B] Average thickness per side as determined by averaging cladding thickness measurements when determined in accordance with the procedure specified in 15.2.

[C] For thicknesses of 0.500 in. and over with 1.5 % of nominal cladding thickness, the average maximum thickness of cladding per side after rolling to the specified thickness of plate shall be 3 % of the thickness of the plate as determined by averaging cladding thickness measurements taken at a magnification of 100 diameters on the cross section of a transverse sample polished and etched for examination with a metallurgical microscope.

[D] Applicable for thicknesses of 0.500 in. and greater.

TABLE 6 Ultrasonic Discontinuity Limits for Plate[A]

Alloy	Thickness, in.	Maximum Weight Per Piece, lb[B]	Discontinuity Class[C]
2014[D], 2024[D], 2124, 2219[D], 7075[D], 7178[D]	0.500–1.499	2000	B
	1.500–3.000	2000	A
	3.001–6.000	2000	B

[A] Discontinuities in excess of those listed in this table shall be allowed if it is established that they will be removed by machining or that they are in noncritical areas.
[B] The maximum weight is either the ordered weight of a plate of rectangular shape or the planned weight of a rectangular plate prior to removing metal to produce a part or plate shape to a drawing.
[C] The discontinuity class limits are defined in Section 11 of Practice B 594.
[D] Also applies for alclad plate.

ANNEXES

(Mandatory Information)

A1. BASIS FOR INCLUSION OF PROPERTY LIMITS

A1.1 Limits are established at a level at which a statistical evaluation of the data indicates that 99 % of the population obtained from all standard material meets the limit with 95 % confidence. For the products described, mechanical property limits for the respective size ranges are based on the analyses of at least 100 data from standard production material with no more than ten data from a given lot. All tests are performed in accordance with the appropriate ASTM test methods. For informational purposes, refer to "Statistical Aspects of Mechanical Property Assurance" in the Related Material section of the *Annual Book of ASTM Standards*, Vol 02.02.

A2. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A2.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1. The Aluminum Association[15] holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A2.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A2.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1. A designation not in conflict with other designation systems or a trade name is acceptable.

A2.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A2.2.3 The complete chemical composition limits are submitted.

A2.2.4 The composition is, in the judgment of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in the specification.

[15] The Aluminum Association, 900 19th Street, NW, Washington, DC 20006.

A2.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

A2.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5.)	
Over 0.55 %	0.X, X.X, etc.
(except that combined Si + Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A2.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A2.1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A2.2).

NOTE A2.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A2.2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

SUMMARY OF CHANGES

This section identifies the principal changes to this standard that have been incorporated since the last issue.

(1) Paragraphs 4.1.8, 9.1.1 and 16.3 have been added.
(2) Paragraph 11.2 has been revised to add alloy 6061.
(3) Paragraphs 13.1 and 13.3.1 have been revised to add 2219-T851 and -T87.
(4) Note 6 has been added under 14.1.
(5) Paragraph 20.2 has been revised to add T3, T4, and 6061-T6 and T651.
(6) Table 2, bend diameter factors have been added for several alloy-temper-thickness combinations.
(7) Table 3, bend diameter factors have been added for many heat-treatable alloys.
(8) Table 3, superscript "K" has been added to T361 and T861 tempers for 2024 and Alclad 2024.
(9) Table 3, minimum elongation for Alclad 2024-T4, 0.021–0.062 in. has been revised.
(10) Table 3, 2124-T851 thickness range has been extended downward to 1.000 in.
(11) Table 3, 7075-T7351 tensile property limits have been added for 3.001–4.000 in.
(12) Table 3, 7011 Alclad 7075 and 7011 Alclad 7178 have been added.
(13) Table 6, plate thickness for ultrasonic inspection has been extended to 6.000 in.
(14) The tensile property limits for 7075-T76 sheet 0.063-0.124 in., 7075-T7651 plate 1.001–2.000 in., and Alclad 7075-T76 sheet 0.040-0.124 in. have been added.
(15) The tensile property limits for Alclad One Side 7075-T6 and T62 have been revised.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM B224: Standard Classification of Coppers

CFR Section(s): 7 CFR 1755.890(i)(5)(vi)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: B 224 – 80$^{\epsilon 1}$

Standard Classification of COPPERS[1]

This standard is issued under the fixed designation B 224; 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 classification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

$^{\epsilon 1}$ NOTE—Reference to "lake copper" has been deleted from Table A1 in October 1982 because such terminology is no longer used.

1. Scope

1.1 This is a classification of the various types of copper currently available in refinery shapes and wrought products in commercial quantities. It is not a specification for the various types of copper.

1.2 In this classification, use is made of the standard copper designations in use by the copper industry.

1.3 Although this classification includes certain UNS designations as described in Practice E 527, these designations are for cross-reference only and are not requirements. Therefore, in case of conflict, this ASTM classification shall govern.

1.4 This classification does not attempt to differentiate between all compositions that could be termed either coppers or copper-base alloys, but in conformance with general usage in the trade, includes those coppers in which the copper is specified as 99.85 % or more, silver being counted as copper.

NOTE 1—Coppers may contain small amounts of certain elements intentionally permitted to impart specific properties, without excessively lowering electrical conductivity. The total copper plus specific permitted elements is usually specified as 99.85 % or more. These intentionally permitted elements normally include, but are not limited to, arsenic, cadmium, chromium, lead, magnesium, silver, sulfur, tellurium, tin, zinc, and zirconium, plus deoxidizers, up to specific levels adopted by the International Standards Organization.

2. Applicable Documents

2.1 *ASTM Standards:*

B 30 Specification for Copper-Base Alloys in Ingot Form[2]

B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[3]

B 379 Specification for Phosphorized Coppers—Refinery Shapes[3]

B 584 Specification for Copper Alloy Sand Castings for General Applications[2]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

3. Basis of Classification

3.1 Table A1 lists the standard designations, and the refinery shapes and fabricators' products currently produced. The listed coppers are not necessarily available in the complete range of sizes in the form shown, nor from any one supplier in all forms.

3.2 Existing ASTM specifications for refinery copper and for wrought copper products may cover more than one of the coppers listed in Table A1 or may include only part of the range covered by any one of the coppers shown in this classification.

4. Description of Terms

4.1 Appendix A2 describes the terms used in designating the various coppers listed.

4.2 Appendix A3 describes the refinery shapes.

4.3 Appendix A4 describes the fabricators' forms.

---

[1] This classification is under the jurisdiction of ASTM Committee B-2 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.01 on Refined Copper.

Current edition approved Jan. 25, 1980. Published March 1980. Originally published as B 224 – 48 T. Last previous edition B 224 – 73.

[2] *Annual Book of ASTM Standards*, Vol 02.01.

[3] *Annual Book of ASTM Standards*, Vol 02.04.

[4] *Annual Book of ASTM Standards*, Vols 02.01, 02.02, 02.03, 02.04, 02.05, and 03.01.

NOTE 2—Copper, as applied to castings other than refinery cast shapes, cakes, billets, wire bars, ingots, and ingot bars, is described in Specifications B 30 and B 584.

APPENDIXES

A1. CLASSIFICATION OF COPPERS

A1.1 Table A1 lists the standard designations, refinery shapes, and fabricator's products.

A2. TERMS USED TO DESIGNATE THE COPPERS

(Alphabetical listing of these terms does not necessarily indicate relative order of commercial importance.)

A2.1 Terms Relating to Method of Refining

A2.1.1 *chemically refined copper*—copper recovered from an aqueous solution by other than electrolytic means. Usually when this term is used alone it refers to chemically refined tough pitch copper. This designation applies to the following:

A2.1.1.1 Copper cast in refinery shapes suitable for hot or cold working or both, and by extension, to fabricators products made therefrom.

A2.1.1.2 Ingots or ingot bars suitable for remelting.

A2.1.2 *electrolytic copper*—copper of any origin, refined by electrolytic deposition including electrowinning. Usually when this term is used alone it refers to electrolytic tough pitch copper. This designation applies to the following:

A2.1.2.1 Cathodes that are the direct product of the refining operation.

A2.1.2.2 Electrodeposited copper cast in refinery shapes suitable for hot or cold working or both, and by extension, to fabricators' products made therefrom.

A2.1.2.3 Electrodeposited copper cast into ingots or ingot bars suitable for remelting.

A2.1.3 *fire-refined copper*—copper of any origin or type finished by furnace refining without having been processed at any stage by electrolytic or chemical refining. Usually when the term fire-refined copper is used alone it refers to fire-refined tough pitch copper. This designation applies to the following:

A2.1.3.1 Copper cast in refinery shapes suitable for hot or cold working or both, and by extension, to fabricators' products made therefrom.

A2.1.3.2 Ingots or ingot bars suitable for remelting.

A2.2 Terms Relating to Characteristics Determined by Method of Casting or Processing

A2.2.1 *deoxidized copper*—copper cast in the form of refinery shapes, produced free of cuprous oxide, as determined by metallographic examination at 75× under polarized light, by the use of metallic or metalloidal deoxidizers. Oxygen may be present as residual deoxidation products. By extension, the term applies to fabricators' products made therefrom.

A2.2.2 *oxygen-free copper*—electrolytic copper produced free of cuprous oxide, as determined by metallographic examination at 75× under polarized light, without the use of metallic or metalloidal deoxidizers. By extension, the term applies to fabricators' products made therefrom.

A2.2.3 *tough pitch copper*—copper of any origin cast in the form of refinery shapes, containing a controlled amount of oxygen in the form of cuprous oxide. By extension the term is also applicable to fabricators' products made therefrom.

A2.3 Terms Relating to Specific Kinds of Copper and to Products Made Therefrom

A2.3.1 *deoxidized copper, high-residual phosphorus*—copper deoxidized with phosphorus residual in amounts 0.015 to 0.04 %. The copper is not susceptible to hydrogen embrittlement, as determined in Specification B 379. The copper is of relatively low-electrical conductivity due to the amount of phosphorus present.

NOTE—International Standards Organization specifications permit up to 0.050 % phosphorus.

A2.3.2 *deoxidized copper, low-residual phosphorus*—copper deoxidized with phosphorous residual in amounts 0.004 to 0.012 %. The copper is not readily susceptible to hydrogen embrittlement, as determined in Specification B 379. The copper in the annealed condition has a minimum conductivity of 98.16 % IACS.

A2.3.3 *high-conductivity copper*—copper that in the annealed condition has a minimum electrical conductivity of 100 % IACS.

A2.3.4 *oxygen-free electronic copper*—high-purity, high-conductivity oxygen-free copper normally intended for electronic applications. The copper has high resistance to hydrogen embrittlement, as determined in Specification B 170. The copper in the annealed condition has a minimum electrical conductivity of 101 % IACS.

A2.3.5 *oxygen-free copper, extra low phosphorus*—oxygen-free copper containing 0.001 to 0.005 % phosphorus. The copper is not readily susceptible to hydrogen embrittlement, as determined in Specification

B 379. The copper in the annealed condition has a minimum conductivity of 98.16 % IACS.

A2.3.6 *oxygen-free copper, low phosphorus*—oxygen-free copper containing 0.005 to 0.012 % phosphorus. The copper is not susceptible to hydrogen embrittlement, as determined in Specification B 379. The copper in the annealed condition has a minimum conductivity of 90 % IACS.

A2.3.7 *deoxidized, phosphorus-arsenical copper.*

A2.3.8 *arsenical, tough-pitch copper.*

A2.3.9 *silver-bearing copper.*

A2.3.10 *sulfur-bearing copper.*

A2.3.11 *deoxidized, phosphorus-tellurium copper.*

A2.3.12 *zirconium-bearing copper.*

NOTE—Coppers listed in A2.3.7 through A2.3.12 contain the designated element or elements in amounts as agreed upon between the manufacturer or supplier and the purchaser.

A3. DEFINITIONS OF REFINERY SHAPES

A3.1 *billet*—refinery shape used for piercing or extrusion into tubular products or for extrusion into rods, bars, and shapes. Circular in cross section, usually 3 to 16 in. (76 to 406 mm) in diameter, normally ranging in weight from 100 to 4200 lb (45 to 1905 kg).

A3.2 *cake*—refinery shape used for rolling into plate, sheet, strip, or shape. Rectangular in cross section and of various sizes, normally ranging in weight from 140 to 62 000 lb (63 to 28 200 kg).

A3.3. *cathode*—unmelted, electrodeposited, and somewhat rough flat plate normally used for melting. The customary size is about 3 ft (0.914 m) square, about ½ to ⅞ in. (12.7 to 22.2 mm) thick, weighing up to about 300 lb (136 kg), and may have hanging loops attached. Cathodes may also be cut to smaller dimensions.

A3.4 *ingot and ingot bar*—refinery shapes used for remelting (not fabrication). Ingots normally range in weight from 20 to 35 lb (9 to 16 kg) and ingot bars from 50 to 70 lb (23 to 32 kg). Both are usually notched to facilitate breaking into smaller pieces.

A3.5 *wire bar*—refinery shape used for rolling into rod or flat product for subsequent processing into wire, strip, or shape. Approximately 3½ to 5 in. (89 to 127 mm) square in cross section, usually 54 in. (1.56 m) in length and ranging in weight from 200 to 420 lb (91 to 191 kg). Usually tapered at both ends.

A4. DEFINITIONS OF FABRICATORS' COPPER PRODUCTS

A4.1 *flat product*—a rectangular or square solid section of relatively great length in proportion to thickness. Included in the designation "flat product" depending on the width and thickness, are plate, sheet, strip, and bar. Also included is the product known as "flat wire."

A4.2 *pipe*—tube conforming to the particular dimensions commerically known as "Standard Pipe Sizes."

A4.3 *rod*—a solid section, round, hexagonal, or octagonal in straight lengths. Round rod for further processing into wire (known as "hot-rolled rod," "wire-rod," "redraw wire," or "drawing stock") is furnished coiled.

A4.4 *shape*—a solid section, other than flat product, rod or wire, furnished in straight lengths. Shapes are usually made by extrusion but may also be fabricated by drawing.

A4.5 *tube*—a unidirectionally elongated hollow product of uniform round or other cross section having a continuous periphery.

A4.6 *wire*—a solid section, including rectangular flat wire but excluding other flat products, furnished in coils or on spools, reels, or bucks.

ASTM Logo Removed

TABLE A1 Classification of Coppers

Designations	Type of Cooper[A]	UNS Nos.[B]	Form in which Copper is Available[C]							
			From Refiners[D]				From Fabricators[E]			
			Wire Bars	Billets	Cakes	Ingots and Ingot Bars	Flat Products	Pipe and Tube	Rod and Wire	Shapes
CATH	Electrolytic cathode		Cathodes only							
Tough-Pitch Coppers										
ETP	Electrolytic tough-pitch	C11000	×	×	×	×	×	×	×	×
RHC	Remelted, high-conductivity tough pitch	C11010	×	×	×	×	×	×	×	×
ETP	Electrolytic tough-pitch (anneal resist)	C11100	×	×	×		×	×	×	×
CRTP	Chemically refined tough-pitch	C11030	×	×	×	×	×	×	×	×
FRHC	Fire-refined, high-conductivity tough-pitch	C11020	×	×	×	×	×	×	×	×
ETP[F]	Silver-bearing, tough-pitch	C11300, C11400, C11500, C11600	×	×	×	×	×	×	×	×
FRTP	Fire-refined, tough-pitch	C12500		×	×	×	×	×	×	×
FRSTP	Fire-refined tough-pitch with silver	C12700, C12800, C12900, C1300		×	×	×	×			×
Oxygen-Free Coppers (Without use of Deoxidants)										
OFE	Oxygen-free, electronic	C10100	×	×	×		×	×	×	×
OF	Oxygen-free	C10200	×	×	×		×	×	×	×
OFS	Oxygen-free, silver-bearing	C10400, C10500, C10700	×	×	×		×	×	×	×
OFXLP	Oxygen-free, extra low phosphorus	C10300	×	×	×		×	×	×	×
OFLP	Oxygen-free, low-phosphorus	C10800	×	×	×		×	×	×	×
Deoxidized Coppers										
DLP	Phosphorized, low-residual phosphorus	C12000		×	×		×	×	×	×
DLPS[G]	Phosphorized, low-residual phosphorus silver-bearing	C12100		×	×		×	×	×	×
DHP[H]	Phosphorized, high-residual phosphorus	C12200		×	×		×	×	×	×
DHPS[G]	Phosphorized, high-residual phosphorus silver-bearing	C12300		×	×		×	×	×	×
DPA	Phosphorized, arsenic-bearing	C14200		×			×	×		
DPTE[I]	Phosphorized, tellurium-bearing	C14500		×					×	
Other Coppers										
	Sulfur-bearing	C14700		×					×	
	Zirconium-bearing	C15000		×	×		×		×	

TABLE A1 *Continued*

[A] See Appendix A2.

[B] The chemical compositions associated with these numbers are listed in the product specifications and in the Standard Designations for Copper and Copper Alloys that appear in this publication under "Related Material".

[C] The "×" in the table indicates commercial availability.

[D] See Appendix A3.

[E] See Appendix A4.

[F] This includes Types ETP, CRTP, and FRHC coppers to which silver has been added in amounts agreed upon.

[G] This includes oxygen-free copper to which phosphorus and silver have been added in amounts agreed upon.

[H] This includes oxygen-free copper to which phosphorus has been added.

[I] This includes oxygen-free tellurium-bearing copper to which phosphorus has been added in amounts agreed upon.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM B557: Tension Testing Wrought and Cast Aluminum and Magnesium-Alloy Products

CFR Section(s): 49 CFR 178.46(i)(3)(i)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: B 557 – 84

Standard Methods of
TENSION TESTING WROUGHT AND CAST ALUMINUM- AND MAGNESIUM-ALLOY PRODUCTS[1]

This standard is issued under the fixed designation B 557; 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.

These methods have been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 These methods cover the tension testing of wrought and cast aluminum- and magnesium-alloy products, excepting aluminum foil.[2]

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—Exceptions to the provisions of these methods may need to be made in individual specifications or test methods for a particular material.

NOTE 2—A complete metric companion to Methods B 557 has been developed—Methods B 557M; therefore, no metric equivalents are presented in these methods.

2. Applicable Documents

2.1 The following documents of the issue in effect on the date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards*:

E 4 Methods of Load Verification of Testing Machines[3]

E 6 Definitions of Terms Relating to Methods of Mechanical Testing[4]

E 8 Methods of Tension Testing of Metallic Materials[4]

E 29 Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values[5]

E 83 Method of Verification and Classification of Extensometers[4]

E 345 Methods of Tension Testing of Metallic Foil[4]

3. Significance

3.1 Tension tests provide information on the strength and ductility of materials under uniaxial tensile stresses. This information may be useful in comparisons of materials, alloy development, quality control, and design under certain circumstances.

3.2 The results of tension tests of specimens machined to standardized dimensions from selected portions of a part or material may not totally represent the strength and ductility properties of the entire end product or its in-service behavior in different environments.

3.3 For quality control purposes, results derived from standardized tension test specimens can be considered to be indicative of the response of the material from which they were taken to processing and heat treatment.

4. Definitions

4.1 The definitions of terms relating to tension testing appearing in Definitions E 6 shall be considered as applying to the terms used in these methods.

---

[1] These methods are under the jurisdiction of ASTM Committee B-7 on Light Metals and Alloys and are the direct responsibility of Subcommittee B07.05 on Testing.

Current edition approved Feb. 24, 1984. Published April 1984. Originally published as B 557 – 71. Last previous edition B 557 – 81.

[2] For methods of tension testing of aluminum foil, see Methods E 345.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

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

[5] *Annual Book of ASTM Standards*, Vol 14.02.

5. Apparatus

5.1 *Testing Machines*:

5.1.1 Machines used for tension testing shall conform to the requirements of Methods E 4. The loads used in determining tensile strength and yield strength shall be within the loading range of the testing machine as defined in Methods E 4.

5.2 *Gripping Devices*:

5.2.1 *General*—Various types of gripping devices may be used to transmit the measured load applied by the testing machine to the test specimens. To ensure axial tensile stress within the gage length, the axis of the test specimen must coincide with the center line of the heads of the testing machine. Any departure from this requirement may introduce bending stresses that are not included in the usual stress computation (load divided by cross-sectional area).

NOTE 3—The effect of this eccentric loading may be illustrated by calculating the bending moment and stress thus added. For a standard 0.500-in. diameter specimen, the stress increase is 1.5 percentage points for each 0.001 in. of eccentricity. This error increases to 2.24 percentage points/0.001 in. for a 0.350-in. diameter specimen and to 3.17 percentage points/0.001 in. for a 0.250-in. diameter specimen.

5.2.2 *Wedge Grips*—Testing machines usually are equipped with wedge grips. These wedge grips generally furnish a satisfactory means of gripping long specimens of ductile metal. If, however, for any reason, one grip of a pair advances farther than the other as the grips tighten, an undesirable bending stress may be introduced. When liners are used behind the wedges, they must be of the same thickness and their faces must be flat and parallel. For best results, the wedges should be supported over their entire length by the heads of the testing machine. This requires that liners of several thicknesses be available to cover the range of specimen thickness. For proper gripping, it is desirable that the entire length of the serrated face of each wedge be in contact with the specimen. Proper alignment of wedge grips and liners is illustrated in Fig. 1. For short specimens it is generally necessary to use machined test specimens and to use a special means of gripping to ensure that the specimens, when under load, shall be as nearly as possible in uniformly distributed pure axial tension (see 5.2.3, 5.2.4, and 5.2.5).

5.2.3 *Grips for Threaded and Shouldered Specimens*—A schematic diagram of a gripping device for threaded-end specimens is shown in Fig. 2, while Fig. 3 shows a device for gripping specimens with shouldered ends. Both of these gripping devices should be attached to the heads of the testing machine through properly lubricated spherical-seated bearings. The distance between spherical bearings should be as large as feasible.

5.2.4 *Grips for Sheet Materials*—The self-adjusting grips shown in Fig. 4 have proved satisfactory for testing sheet materials that cannot be tested satisfactorily in the usual type of wedge grips.

5.2.5 *Grips for Wire*—Grips of either the wedge or snubbing types as shown in Figs. 4 and 5 or flat wedge grips may be used.

5.3 *Dimension-Measuring Devices*—Micrometers and other devices used for measuring linear dimensions shall be accurate to at least one half the smallest unit to which the individual dimension is required to be measured.

6. Test Specimens

6.1 *General*:

6.1.1 Test specimens shall be of the full section of the material whenever practical. Otherwise, machined specimens of rectangular or round cross section shall be used.

6.1.2 Rectangular specimens shall be 0.500 in. wide in accordance with Fig. 6 or Fig. 12 (for tubular products), and shall be of the full thickness of the material when practical. When necessary, 0.250-in. wide subsize specimens as shown in Fig. 6 may be used, but elongation values from such specimens are not applicable to specification requirements.

6.1.2.1 Pin ends as shown in Fig. 7 may be used. In order to avoid buckling in tests of thin and high-strength materials, it may be necessary to use stiffening plates at the grip ends.

6.1.3 Round specimens shall be the standard 0.500-in. diameter specimen in Fig. 8, except when the dimensions of the product make this impossible. In such cases, small-size specimens proportional to the standard specimen shown in Fig. 8 may be used. Unless otherwise specified in the product specification, the selection of round tension specimens shall be as specified in Table 1. Unless permitted by the product specification, the dimensions of the smallest specimen used shall not be less than the following:

	Wrought	Cast
Diameter of reduced section, in.	0.160	0.250
Length of reduced section, in.	¾	1¼
Radius of fillet, in.	⅛	3/16
Diameter of end section, in.	15/64	⅜
Over-all length, in.		
With shouldered ends	1½	2⅜
With threaded ends	2	3
With plain cylindrical ends	3	4

6.1.3.1 The shape of the ends of the specimens outside of the gage length shall be suitable to the material and of a shape to fit the holders or grips of the testing machine so that the loads are applied axially. Figure 9 shows specimens with various types of ends that have given satisfactory results.

6.1.4 Special care is required in the manufacture and testing of smaller specimens because the effects of machining (for example, the amount of end load applied and the amount of heat generated) and testing (for example, eccentricity and gage marking) variables are greater upon them than upon larger specimens. Therefore, the largest practical specimen shall always be used. With some types of materials, notably castings, the result of tests of small specimens may be more variable due to the increasing significance of variations in metallic structure or the character of the surfaces. Low values derived from small specimens should be carefully evaluated in accordance with 8.1 to be certain that the results are valid.

6.1.5 While tensile strengths and yield strengths can properly be compared with results derived from test specimens of various dimensions, elongation values may vary with specimen size and type. Therefore elongation values should be obtained with specimens of the type from which the published tensile properties were established.

6.2 *Type, Direction, and Location in Products*:

6.2.1 *Sheet and Plate*:

6.2.1.1 Rectangular specimens shall be used for thicknesses less than 0.500 in., and round specimens for all others.

6.2.1.2 For thicknesses 0.500 in. through 1.500 in., specimens shall be taken from the center of the thickness; for larger thicknesses, they shall be taken midway from the center to the surface.

6.2.1.3 For nonheat-treatable aluminum alloys, specimens shall be taken parallel to the direction of rolling.

6.2.1.4 For heat-treatable aluminum alloys, specimens shall be taken perpendicular to the direction of rolling (long-transverse). For widths too narrow for long-transverse standard rectangular or 0.500-in. diameter specimens, specimens shall be taken parallel to the direction of rolling.

6.2.1.5 For magnesium alloys, specimens shall be taken parallel to the direction of rolling.

6.2.2 *Wire, Rod, and Bar*:

6.2.2.1 Full-section specimens shall be used when practical. It is permissible to reduce the section slightly throughout the test section in order to ensure fracture within the gage length. Otherwise, round specimens shall be used, except that for rectangles less than 0.500 in. thick rectangular specimens of the full thickness may be used.

6.2.2.2 All specimens shall be longitudinal. The specimens shall be taken from the locations specified in Table 2.

6.2.3 *Shapes*:

6.2.3.1 Round specimens shall be used whenever it is not practical to use full-section specimens, except that for shapes less than 0.500 in. thick, rectangular specimens may be used.

6.2.3.2 All specimens shall be taken in the longitudinal direction from the predominant section of the shape. The specimens shall be taken from a location that most nearly satisfies the intent of Table 2.

6.2.4 *Tube and Pipe*—All specimens shall be longitudinal.

6.2.4.1 For all small tube (Note 4), particularly sizes 1 in. and under in nominal outside diameter, and frequently for larger sizes, except as limited by the testing equipment, it is standard practice to use tension test specimens of full-size tubular sections. Snug-fitting metal plugs shall be inserted far enough into the ends of such tubular specimens to permit the testing machine jaws to grip the specimens properly. The plugs shall not extend into that part of the specimen on which the elongation is measured. Figure 10 shows a suitable form of plug, the location of the plugs in the specimen, and the location of the specimen in the grips of the testing machine.

NOTE 4—The term "tube" is used to indicate tubular products in general, and includes pipe, tube, and tubing.

6.2.4.2 When it is not practical to test full-section specimens, 0.500-in. wide specimens in accordance with Fig. 12 taken as in Fig. 11

shall be used if practical. Otherwise, round specimens shall be taken from the center of wall thicknesses through 1.500 in.; for thicknesses over 1.500 in., they shall be taken midway from center of thickness to surface.

6.2.5 *Die Forgings*—Round specimens shall be used for section thicknesses 0.500 in. and greater. Either subsize round or rectangular specimens may be used for section thicknesses from 0.312 to 0.499 in. Rectangular specimens shall be used for section thicknesses less than 0.312 in. The axis of the specimen shall be substantially parallel to the direction of grain flow, unless specimens in other directions are required. Specimens shall be taken from the center of the predominant or thickest part of the forging from which a coupon can be obtained, from a prolongation of the forging, or from coupons separately forged from the same stock used to produce the forgings.

6.2.6 *Hand Forgings*—Round specimens shall be used. They shall be taken in the long-transverse direction, and when specified, in the longitudinal and short-tranverse directions. A longitudinal specimen shall be taken so that its axis coincides with the longitudinal center line of the forging. A long-transverse or short-transverse specimen shall be taken so that the midpoint of its axis lies on the longitudinal center line of the forging. Each specimen shall be so chosen that the distance from the midpoint of its axis to the end of the forging is at least half the thickness of the forging.

6.3 *Type of Specimen from Castings*:

6.3.1 Test specimens shall be separately cast or, if called for by product specification or customer requirements, machined from the casting itself.

6.3.2 *Cast Test Specimens*—The test section of any separately cast test specimen shall be consistent with Fig. 8.

6.3.3 *Specimens Machined from Castings*:

6.3.3.1 Round specimens in accordance with Fig. 8 shall be used for section thicknesses 0.500 in. and greater.

6.3.3.2 Either small-size round specimens proportional to the standard specimen in Fig. 8 or rectangular specimens in accordance with Fig. 6 may be used for section thicknesses from 0.312 to 0.499 in., except as limited by 6.1.3.

6.3.3.3 Rectangular specimens in accordance with Fig. 6 shall be used for section thicknesses less than 0.312 in.

6.3.3.4 All test specimens must have a machined finish of 63 micro in. RMS (57 micro-in. AA) or smoother.

6.4 *Specimen for Die Castings*:

6.4.1 For testing die castings the test specimen shown in Fig. 13 shall be used unless otherwise provided in the product specifications.

6.5 *Specimens for Powdered Metals*:

6.5.1 For testing powdered metals the test specimens shown in Figs. 14 and 15 shall be used, unless otherwise provided in the product specifications.

7. Procedures

7.1 *Measurement of Dimensions of Test Specimens*:

7.1.1 To determine the cross-sectional area of a tension test specimen, measure the dimensions of the cross section at the center of the reduced section except that for referee testing of specimens under 3/16 in. in their least dimension, measure the dimensions where the least cross-sectional area is found. Measure and record the cross-sectional dimensions of tension test specimens 0.200 in. and over to the nearest 0.001 in.; the cross-sectional dimensions less than 0.200 in. and not less than 0.100 in. to the nearest 0.0005 in.; the cross-sectional dimensions less than 0.100 in. and not less than 0.020 in., to the nearest 0.0001 in.; and when practical, the cross-sectional dimensions less than 0.020 in., to at least the nearest 1 % but in all cases to at least the nearest 0.0001 in.

NOTE 5—Measurements of dimensions presume smooth surface finishes for the specimens. Rough surfaces due to the manufacturing process such as hot rolling, metallic coating, etc., may lead to inaccuracy of the computed areas greater than the measured dimensions would indicate. Therefore, cross-sectional dimensions of tension test specimens with rough surfaces due to processing may be measured and recorded to the nearest 0.001 in.

7.1.2 Determine cross-sectional areas of full-size tension test specimens of nonsymmetrical cross sections by weighing a length not less than 20 times the largest cross-sectional dimension and using the value of density of the material. Determine the weight to the nearest 0.5 % or less.

7.1.3 When using specimens of the type shown in Figure 12 from tubes, the cross-sectional area shall be determined using the following formula:

$$A = \left[\frac{W}{2}\sqrt{R^2 - \frac{W^2}{4}} + R^2 \cdot ARCSIN\frac{W}{D}\right] - \left[\frac{W}{2}\sqrt{r^2 - \frac{W^2}{4}} + r^2 \cdot ARCSIN\frac{W}{d}\right]$$

where:

A = cross-section area,
D = outside diameter,
d = inside diameter,
R = outside radius,
r = inside radius, and
W = width of specimen reduced section.

7.2 *Speed of Testing*:

7.2.1 Speed of testing may be defined (*a*) in terms of free-running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), (*b*) in terms of rate of separation of the two heads of the testing machine during a test, (*c*) in terms of the elapsed time for completing part or all of the test, (*d*) in terms of rate of stressing the specimen, or (*e*) in terms of rate of straining the specimen. For some materials the first of these, which is the least accurate, may be adequate, while for other materials one of the others, listed in increasing order of precision, may be necessary in order to obtain test values within acceptable limits. Suitable limits for speed of testing should be specified for materials for which the differences resulting from the use of different speeds are of such magnitude that the test results are unsatisfactory for determining the acceptability of the material. In such instances, depending upon the material and the use for which it is intended, one or more of the methods described in the following paragraphs is recommended for specifying speed of testing.

7.2.2 *Free-Running Crosshead Speed*—The allowable limits for the rate of movement of the crosshead of the testing machine, when not under load, shall be specified in inches per inch of length of reduced section (or distance between grips for specimens not having reduced sections) per minute. The limits for the crosshead speed may be further qualified by specifying different limits for various types and sizes of specimens. The average crosshead speed can be experimentally determined by using a suitable measuring device and a timing device.

7.2.3 *Rate of Separation of Heads During Tests*—The allowable limits for rate of separation of the heads of the testing machine during a test shall be specified in inches per inch of length of reduced section (or distance between grips for specimens not having reduced sections) per minute. The limits for the rate of separation may be further qualified by specifying different limits for various types and sizes of specimen. Many testing machines are equipped with pacing or indicating devices for the measurement and control of the rate of separation of the heads of the machine during a test, but in the absence of such a device the average rate of separation of the heads can be experimentally determined by using a suitable length-measuring device and a timing device.

7.2.4 *Elapsed Time*—The allowable limits for the elapsed time from the beginning of loading (or from some specified stress) to the instant of fracture, to the maximum load, or to some other stated stress, shall be specified in minutes or seconds. The elapsed time can be determined with a timing device.

7.2.5 *Rate of Stressing*—The allowable limits for rate of stressing shall be specified in pounds per square inch per minute. Many testing machines are equipped with pacing devices for the measurement and control of the rate of stressing, but in the absence of such a device the average rate of stressing can be determined with a timing device by observing the time required to apply a known increment of stress.

7.2.6 *Rate of Straining*—The allowable limits for rate of straining shall be specified in inches per inch per minute. Some testing machines are equipped with pacing or indicating devices for the measurement and control of rate of straining, but in the absence of such a device the average rate of straining can be determined with a timing device by observing the time required to effect a known increment of strain.

7.2.7 Unless otherwise specified, any convenient speed of testing may be used up to one half the specified yield strength, or up to one quarter the specified tensile strength, whichever is smaller. The speed above this point shall be within the limits specified. If different speed limitations are required for use in determining yield strength, tensile strength, and elongation, they should be stated in the product specifications. In the absence of any more specified limitations on speed of testing the following general rules shall apply:

7.2.7.1 The speed of testing shall be such that the loads and strains used in obtaining the test results are accurately indicated.

7.2.7.2 During the conduct of the test to determine yield strength the rate of stress application shall not exceed 100 000 psi/min. The speed may be increased after removal of the extensometer, but it shall not exceed 0.5 in./in. of gage length (or distance between grips or specimens not having reduced sections) per minute.

7.3 *Rounding*—Round each value of strength to the nearest 0.1 ksi. Round each value of elongation determined in accordance with 7.6.1 to the nearest 0.5 %, unless specified otherwise. Perform rounding according to the rounding method of Recommended Practice E 29.

7.3.1 If elongation is determined in accordance with 7.6.4, round each value in accordance with 7.6.4.4.

7.4 *Yield Strength*—Determine yield strength by the offset method at an offset of 0.2 %. Acceptance or rejection of material may be decided on the basis of Extension-Under-Load Method. For referee testing, the offset method shall be used.

7.4.1 *Offset Method*—To determine the yield strength by the "offset method," it is necessary to secure data (autographic or numerical) from which a stress-strain diagram may be drawn. Then on the stress-strain diagram (Fig. 16) lay off *Om* equal to the specified value of the set, draw *mn* parallel to *OA*, and thus locate *r*, the intersection of *mn* with the stress-strain diagram (Note 7). In reporting values of yield strength obtained by this method, the specified value of "offset" used should be stated in parentheses after the term yield strength. Thus:

Yield strength (offset = 0.2 %) = 52 000 psi

In using this method a Class B2 extensometer (see Methods E 83) would be sufficiently sensitive for most materials.

NOTE 6—Automatic devices are available that determine offset yield strength without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated to be satisfactory.

NOTE 7—If the load drops before the specified offset is reached, technically the material does not have a yield strength (for that offset), but the stress at the maximum load attained before the specified offset is reached may be reported instead of the yield strength.

7.4.2 *Extension-Under-Load Method*—For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified offset occurs will be known within satisfactory limits; therefore, in such tests a specified total strain may be used, and the stress on the specimen, when this total strain is reached, is taken to be the value of the yield strength (Fig. 17). The total strain can be obtained satisfactorily by use of a Class B2 extensometer. It is recommended that this approximate method be used only after agreement between the manufacturer and the purchaser, with the understanding that check tests be made for obtaining stress-strain diagrams for use with the offset method to settle any misunderstandings.

7.5 *Tensile Strength*:

7.5.1 Calculate the tensile strength by dividing the maximum load carried by the specimen during a tension test by the original cross-sectional area of the specimen.

7.6 *Elongation*:

7.6.1 Fit ends of the fractured specimen together carefully and measure the distance between the gage marks to the nearest 0.01 in. A percentage scale reading to 0.5 % of the gage length may be used. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In reporting elongation values, give both the percentage increase and the original gage length.

7.6.2 If any part of the fracture takes place outside of the middle half of the gage length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is required, but the location of fracture shall be noted. If the elongation is less than the minimum requirements, discard the test and test a replacement specimen as allowed in 8.1.1.

7.6.3 In determining extension at fracture (elastic plus plastic extension), autographic or automated methods using extensometers may be employed.

7.6.3.1 In determining percent elongation from extension at fracture, only the plastic extension shall be used. The elastic portion can be estimated graphically or by calculation and subtracted from the total extension at fracture.

7.6.4 When required by the material specification, or when making retests or for referee tests of products other than wire and the specified elongation is less than 3 % or the elongation measured in the usual manner is less than 4 %, determine the elongation of a round specimen as follows:

7.6.4.1 Mark the original gage length of the specimen and measure to an accuracy of ±0.002 in.

7.6.4.2 Remove any partly torn fragments that might influence the final measurement from the broken ends of the specimen.

7.6.4.3 Match the broken ends together to obtain an integral fit, and apply an end load of approximately 2 ksi. If desired, the load may then be removed carefully, provided the specimen remains intact.

7.6.4.4 Measure the final gage length to at least the nearest 0.002 in., and report the elongation to at least the nearest 0.1 % in 2 in. or 0.2 % in shorter gage lengths.

7.6.5 Measure elongations of ½-in. wide rectangular specimens and of full-section specimens from tube and pipe in 2 in.

7.6.6 Measure elongation of round specimens taken from products 0.125 in. or larger in 4*D* except die casting and wire for electric conductors.

7.6.7 For wire for electric conductors the gage length shall be in 10 in. and elongation shall be measured and reported to the nearest 0.1 %.

7.6.8 Measure elongation of die cast specimens in 8*D* (see Fig. 13).

7.6.9 Measurement of elongation of shapes less than 0.062 in. in thickness and of wire, other than electric conductors, 0.125 in. and less in diameter is not required.

8. Replacement Tests

8.1 A test specimen may be discarded and a replacement specimen selected from the same lot of material when (*1*) the specimen had a poorly machined surface, was not of the proper dimensions, or had its properties changed by poor machining practice; (*2*) the test procedure was incorrect or the test equipment malfunctioned; or (*3*) the fracture was outside the middle half of the gage length, and the elongation was below the specified value.

8.2 In the case of specimens machined from wrought products or castings, discontinuities such as cracks, ruptures, flakes and porosity revealed in the fracture that are considered indicative of inferior or defective material are not reasons for the selection of a replacement test specimen.

8.3 In the case of separately cast test specimens, flaws other than gas porosity, such as cracks or inclusions, are not the cause of rejection of the castings based upon tensile properties, and so the presence of such flaws in the fracture is justification for replacement testing.

9. Retests

9.1 If one or more test specimens fail to conform to the requirements of the product specification, the lot represented by the specimen or specimens shall be subject to rejection except as provided below.

9.2 If a material lot is subject to rejection, retests of that lot will be permitted by:

9.2.1 Testing, for each specimen that failed, at least two additional specimens from an area in the original sample adjacent to the area represented by the failure or failures, or

9.2.2 Testing an additional specimen from the specified location in each of at least two other samples for each sample that failed from the same lot.

9.2.3 In the case of separately cast test specimens, testing two additional cast speciments from the same lot for each specimen that failed.

9.3 If any retest fails, the lot shall be subject to rejection, except that the lot may be resubmitted for testing provided the producer has reworked the lot, as necessary, to correct the deficiencies or has removed the nonconforming material.

10. Precision and Bias

10.1 *Precision*—The degree of agreement within the results obtained in tests made to evaluate a particular property in accordance with the procedures stated in this standard.

10.1.1 Precision is influenced by the homogeneity of specimens. By homogeneity, the material itself, the specimen shape, the gripping methods and measurement methods are meant.

10.1.2 Precision is related to laboratories, the design and condition of the machines and auxiliary equipment and to the skill used by operators.

10.1.3 Results obtained under single operator, single-machine testing can represent the optimum precision.

10.2 *Bias*—The accuracy of the results in tension testing is the degree of agreement between the property defined by the results and an accepted standard which is the average of a number of observations obtained by operators using the highest skills; using the most suitable machines and equipment and by laboratories having the highest degree of supervision.

10.2.1 Testing machine load accuracy influences accuracy of properties related to force. Specimen geometry, symmetry and alignment influence stress accuracy and strain uniformity. Accuracy of extensometry influences strain magnitude. Gripping devices, qualifications of operators and speed of testing may influence accuracy.

10.3 Statistical methods and procedures exist to calculate precision, establish bias and make statistical judgement that numbers defining properties are different only by chance.

NOTE 8—Test results that can be used for statistical evaluation to establish the precision of these methods are not available but are being solicited by ASTM Committee B-7.

NOTE 9—At this time, statements of the accuracy of the results in tension testing should be limited to the documented performance of particular laboratories.

TABLE 1 Guidelines for Selecting Round Tensile Specimens

Specified Material Thickness, in.	Min. Material Section Thickness Length or Width, in.	Specimen Diameter, in.
0.250 through 0.374	1½	0.160
0.375 through 0.499	2½	0.250
0.500 through 0.624	3¼	0.350
0.625 and over	4¾	0.500

TABLE 2 Location of Axis of Specimens in Rod, Bar, and Shapes

Section Diameter, Thickness or Width, in.	Location of Axis of Specimen with Respect to Thickness (*T*) and Width (*W*) of Bar and Shapes or Diameter (*D*) of Rod		
	Thickness	Width	Diameter
Up through 1.500, incl	$T/2$	$W/2$	$D/2$
Over 1.500	$T/4$	$W/4$	$D/4$

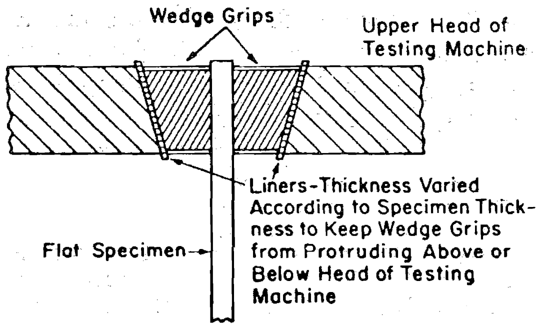


FIG. 1 Wedge Grips with Liners for Flat Specimens

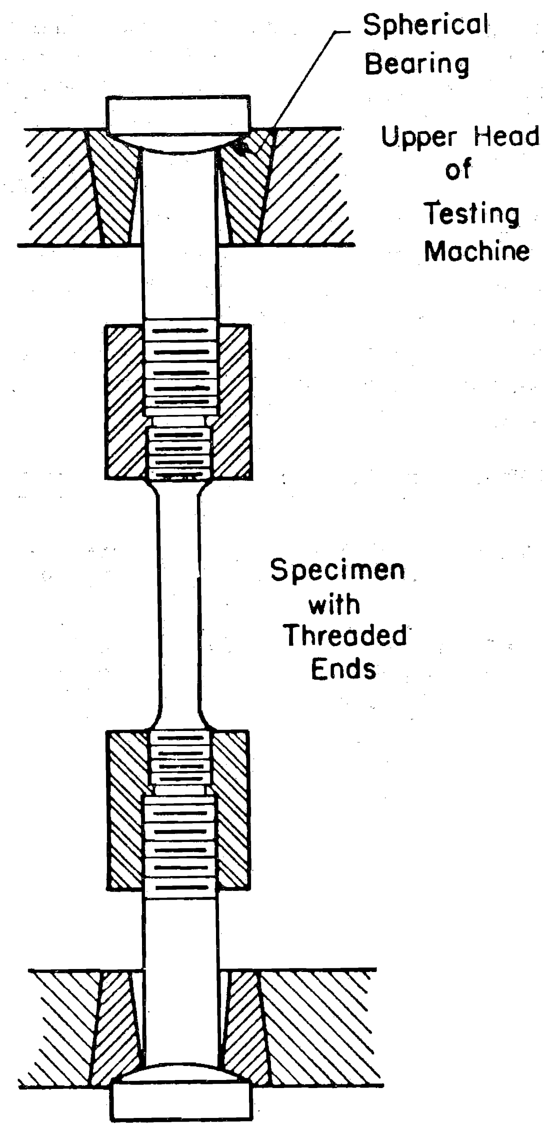


FIG. 2 Gripping Device for Threaded-End Specimens

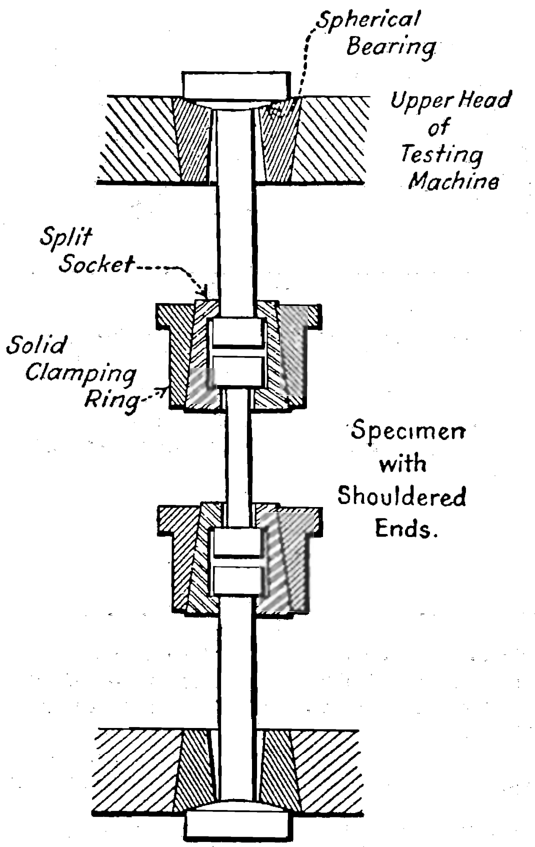


FIG. 3 Gripping Device for Shouldered-End Specimens

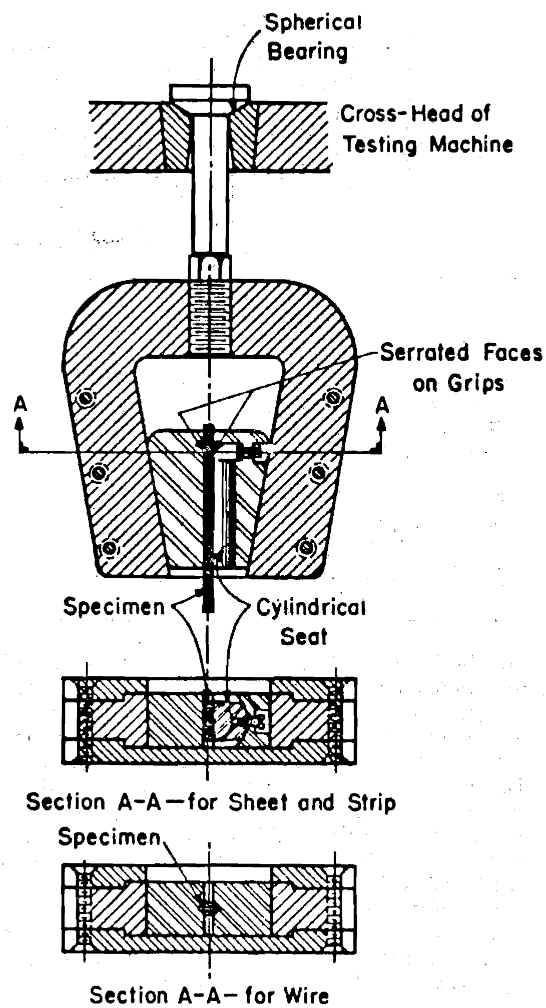


FIG. 4 Gripping Devices for Sheet and Wire Specimens

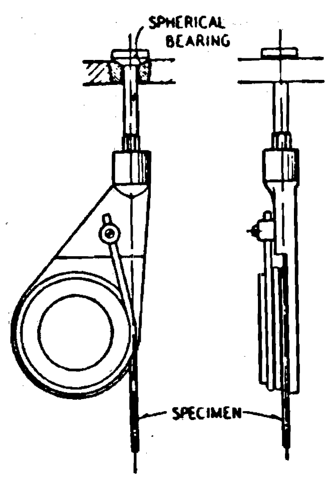
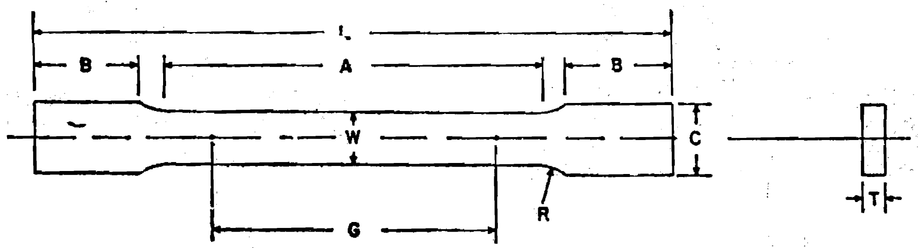


FIG. 5 Snubbing Device for Testing Wire



	Dimensions, in.	
	Standard Specimen Sheet-Type, ½-in. Wide	Subsize Specimen ¼-in. Wide
G— Gage length	2.000 ± 0.005	1.000 ± 0.003
W— Width (Notes 1 and 2)	0.500 ± 0.010	0.250 ± 0.002
T— Thickness (Note 3)	thickness of material	thickness of material
R— Radius of fillet, min	½	¼
L— Over-all length, min (Note 4)	8	4
A— Length of reduced section, min	2¼	1¼
B— Length of grip section, min (Note 5)	2	1¼
C— Width of grip section, approximate (Notes 2 and 6)	¾	⅜

NOTE 1—The ends of the reduced section shall not differ in width by more than 0.002 in. for the 2.00-in. gage length specimen or 0.001 in. for the 1.00-in. gage length specimen. There may be a gradual taper in width from the ends of the reduced section to the center, but the width at each end shall not be more than 1 % greater than the width at the center.

NOTE 2—For each of the specimens, narrower widths (*W* and *C*) may be used when necessary. In such cases the width of the reduced section should be as large as the width of the material being tested permits; however, unless stated specifically, the requirements for elongation in a product specification shall not apply when these narrower specimens are used. If the width of the material is less than *W*, the sides may be parallel throughout the length of the specimen.

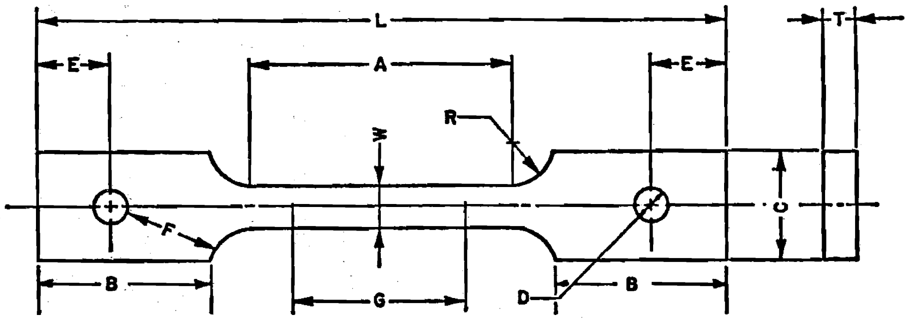
NOTE 3—The dimension *T* is the thickness of the test specimen as stated in the applicable material specifications. Maximum nominal thicknesses of ½-in. and ¼-in. wide specimens shall be ½ in. and ¼ in., respectively.

NOTE 4—To aid in obtaining axial loading during testing of ¼-in. wide specimens, the over-all length should be as large as the material will permit, up to 8 in.

NOTE 5—It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips. If the thickness of ½-in. wide specimens is over ⅜ in., longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.

NOTE 6—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.01 and 0.005 in., respectively.

FIG. 6 Rectangular Tension Test Specimens



	Dimensions, in.
G— Gage length	2.000 ± 0.005
W—Width (Note 1)	0.500 ± 0.010
T— Thickness, max (Note 2)	⅝
R— Radius of fillet, min (Note 3)	½
L— Over-all length, min	8
A— Length of reduced section, min	2¼
B— Length of grip section, min	2
C— Width of grip section, approximate	2
D— Diameter of hole for pin, min (Note 4)	½
E— Edge distance from pin, approximate	1½
F— Distance from hole to fillet, min	½

NOTE 1—The ends of the reduced section shall differ in width by not more than 0.002 in. There may be a gradual taper in width from the ends of the reduced section to the center, but the width at each end shall be not more than 1 % greater than the width at the center.

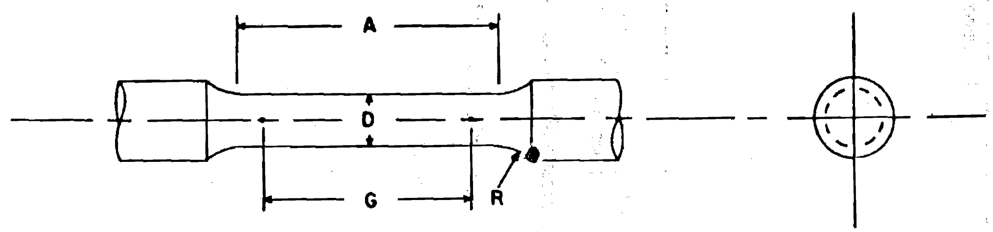
NOTE 2—The dimension *T* is the thickness of the test specimen as stated in the applicable product specifications.

NOTE 3—For some materials, a fillet radius *R* larger than ½ in. may be needed.

NOTE 4—Holes must be on center line of reduced section, within ±0.002 in.

NOTE 5—Variations of dimensions *C*, *D*, *E*, *F*, and *L* may be used that will permit failure within the gage length.

FIG. 7 Pin-Loaded Tension Test Specimen with 2-in. Gage Length



Nominal Diameter	Dimensions, in.			
	Standard Specimen	Small-Size Specimens Proportional to Standard		
	0.500	0.350	0.250	0.160
G—Gage length	2.000 ± 0.005	1.400 ± 0.005	1.000 ± 0.005	0.640 ± 0.005
D—Diameter (Note 1)	0.500 ± 0.010	0.350 ± 0.007	0.250 ± 0.005	0.160 ± 0.003
R—Radius of fillet, min	3⁄8	1⁄4	3⁄16	5⁄32
A—Length of reduced section, min (Note 2)	2¼	1¾	1¼	¾

NOTE 1—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 % larger in diameter than the center (controlling dimension).

NOTE 2—If desired, the length of the reduced section may be increased to accommodate an extensometer of any covenient gage length. Reference marks for the measurement of elongation should, nevertheless, be spaced at the indicated gage length.

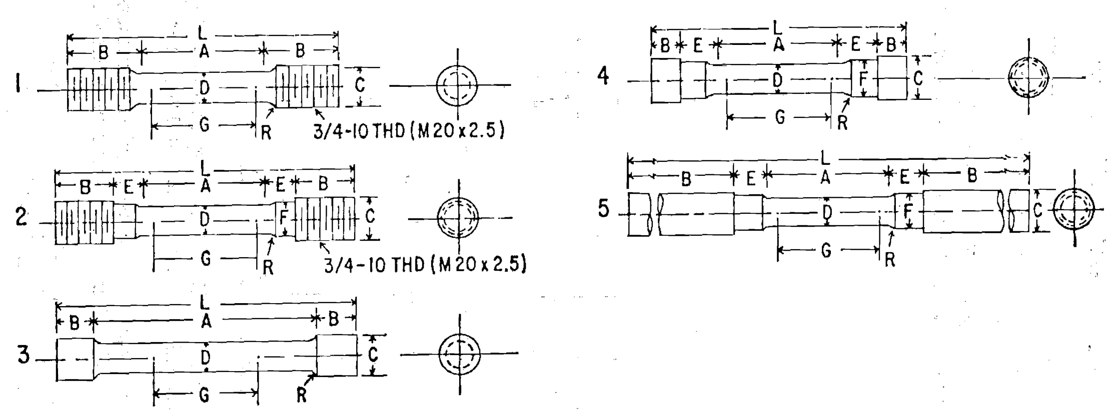
NOTE 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial (see Fig. 9). If the ends are held in wedge grips it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

NOTE 4—On the round specimens in Figs. 8 and 9, the gage lengths are equal to four times the nominal diameter. In some product specifications other specimens may be provided for, but unless the 4-to-1 ratio is maintained within dimensional tolerances, the elongation values may not be comparable with those obtained from the standard test specimen.

NOTE 5—The use of specimens smaller than 0.250-in. diameter shall be restricted to cases when the material to be tested is of insufficient size to obtain larger specimens or when all parties agree to their use for acceptance testing. Smaller specimens require suitable equipment and greater skill in both machining and testing.

NOTE 6—Four sizes of specimens often used have diameters of approximately 0.505, 0.357, 0.252, and 0.160 in., the reason being to permit easy calculations of stress from loads, since the corresponding cross-sectional areas are equal or close to 0.200, 0.100, 0.0500, and 0.0200 $in.^2$, respectively. Thus, when the actual diameters agree with these values, the stresses (or strengths) may be computed using the simple multiplying factors 5, 10, 20, and 50, respectively.

FIG 8 Standard 0.500-in. Round Tension Test Specimen with 2-in. Gage Length and Examples of Small-Size Specimens Proportional to the Standard Specimen



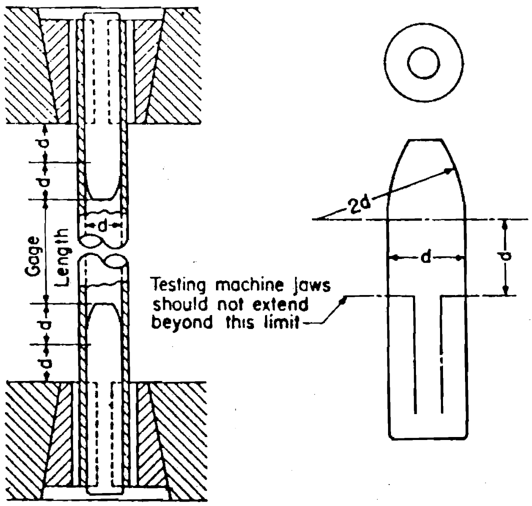
	Dimensions, in.				
	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
G—Gage length	2.000 ± 0.005	2.000 ± 0.005	2.000 ± 0.005	2.000 ± 0.005	2.000 ± 0.005
D—Diameter (Note 1)	0.500 ± 0.010	0.500 ± 0.010	0.500 ± 0.010	0.500 ± 0.010	0.500 ± 0.010
R—Radius of fillet, min	3/8	3/8	1/16	3/8	3/8
A—Length of reduced section	2¼, min	2¼, min	4, approximately	2¼, min	2¼, min
L—Over-all length, approximate	5	5½	5½	4¾	9½
B—Length of end section (Note 2)	1⅜, approximately	1, approximately	¾, approximately	½, approximately	3, min
C—Diameter of end section	¾	¾	23/32	7/8	¾
E—Length of shoulder and fillet section, approximate	. . .	5/8	. . .	¾	5/8
F—Diameter of shoulder	. . .	5/8	. . .	5/8	19/32

NOTE 1—The reduced section may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. larger in diameter than the center.

NOTE 2—On Specimen 5 it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

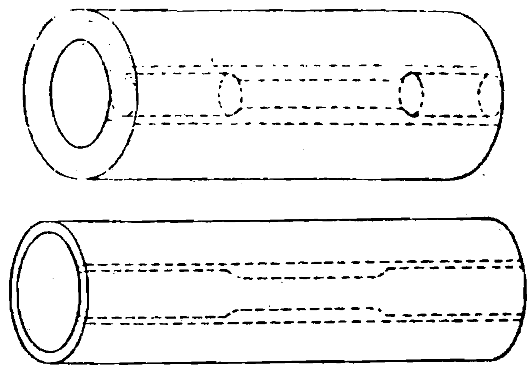
FIG 9 Various Types of Ends for Standard Round Tension Test Specimen

ASTM Logo Removed



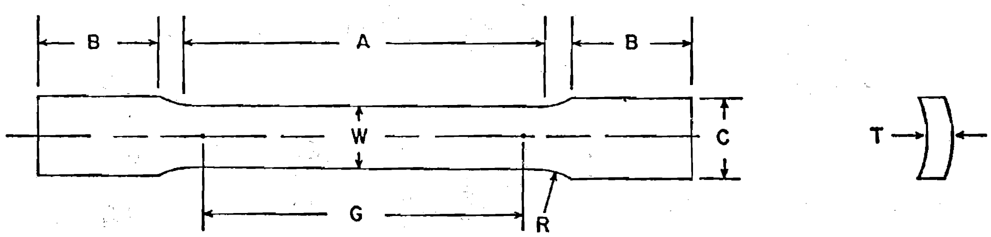
NOTE—The diameter of the plug shall have a slight taper from the line limiting the testing machine jaws to the curved section.

FIG. 10 Metal Plugs for Testing Tubular Specimens, Proper Location of Plugs in Specimen and of Specimen in Heads of Testing Machine



NOTE—The edges of the specimen shall be cut parallel to each other.

FIG. 11 Location from Which Longitudinal Tension Test Specimens Are to Be Cut from Large-Diameter Tube



	Dimensions, in.
W— Width (Note 1)	0.500 ± 0.010
G— Gage length	2.000 ± 0.005
T— Thickness	Note 2
R— Radius of fillet, min	½
A— Length of reduced section, min	2¼
B— Length of grip section, min (Note 3)	3
C— Width of grip section, approximate (Note 4)	1¹⁄₁₆

NOTE 1—The ends of the reduced section shall not differ in width by more than 0.002 in. There may be a gradual taper in width from the ends of the reduced section to the center, but the width at each end shall not be more than 1 % greater than the width at the center.

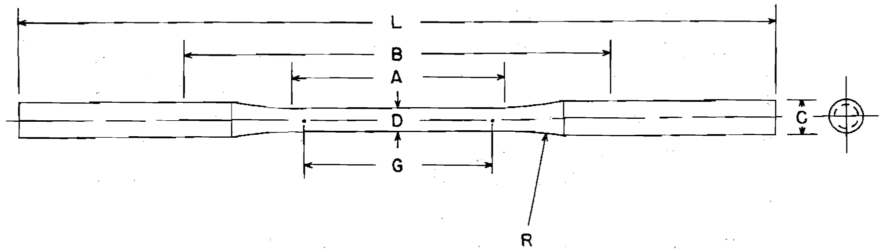
NOTE 2—The dimension *T* is the thickness of the tubular section as provided for in the applicable material specifications.

NOTE 3—It is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

NOTE 4—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.05 in.

NOTE 5—For circular segment, the cross-sectional area shall be calculated using the formula shown in 7.1.3.

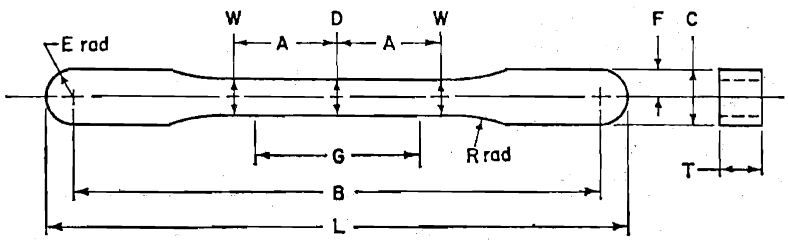
FIG. 12 Longitudinal Tension Test Specimens for Large-Diameter Tubular Products



	Dimensions, in.
G—Gage length	2.000 ± 0.005
D—Diameter (see Note)	0.250 ± 0.005
R—Radius of filet, min	3
A—Length of reduced section, min	2¼
L—Over-all length, min	9
B—Distance between grips, min	4½
C—Diameter of end section, approximate	⅜

NOTE—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 0.005 in. larger in diameter than the center.

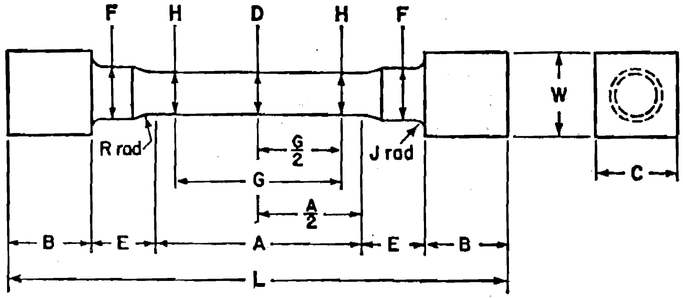
FIG. 13 Standard Tension Test Specimen for Die Castings



Pressing Area = 1.00 in.^{2}
Dimensions Specified except *G*, are Those of the Die.

	Dimensions, in.
G— Gage length	1.000 ± 0.005
D— Width at center	0.225 ± 0.001
W— Width at end of reduced section	0.235 ± 0.001
T— Compact to this thickness	0.200 to 0.250
R— Radius of fillet	1
A— Half-length of reduced section	⅝
B— Grip length	3.187 ± 0.001
L— Over-all length	3.529 ± 0.001
C— Width of grip section	0.343 ± 0.001
F— Half width of grip section	0.1715 ± 0.0010
E— End radius	0.171 ± 0.001

FIG. 14 Standard Tension Test Specimen for Powdered Metal Products—Flat Unmachined Tension Test Specimen



Pressing Area of Unmachined Compact = 1.5 $in.^2$

Machining Recommendations

1. Rough Machine to 5/16 in. dia
2. Finish Turn 0.250 in. dia with Radii and Taper
3. Polish with 00 Emery Cloth
4. Lap with Crocus Cloth

	Dimensions, in.
G— Gage length	1.000 ± 0.005
D— Diameter at center of reduced section	0.250 ± 0.001
H— Diameter at ends of gage length	*D* + 0.001 to 0.002 in.
R— Radius of fillet	1/4
A— Length of reduced section	1 1/4
L— Over-all length (die cavity length)	3
B— Length of end section	1/2
C— Compact to this end thickness	0.500 ± 0.050
W— Die cavity width	1/2
E— Length of shoulder and fillet	3/8
F— Diameter of shoulder	5/16
J— End fillet radius, max	1/16

NOTE—The gage length and fillets of the specimen shall be as shown. The ends as shown are designed to provide a total pressing area of 1.00 $in.^2$ Other end designs are acceptable, and in some cases are required for high-strength sintered materials. Some suggested alternative end designs include:

1. Longer ends, of the same general shape and configuration as the standard, provide more surface area for gripping.
2. Shallow transverse grooves, or ridges, may be pressed in the ends to be gripped by jaws machined to fit the specimen contour.

FIG. 15 Standard Tension Test Specimen for Powdered Metal Products—Round Machined Tension Test Specimen

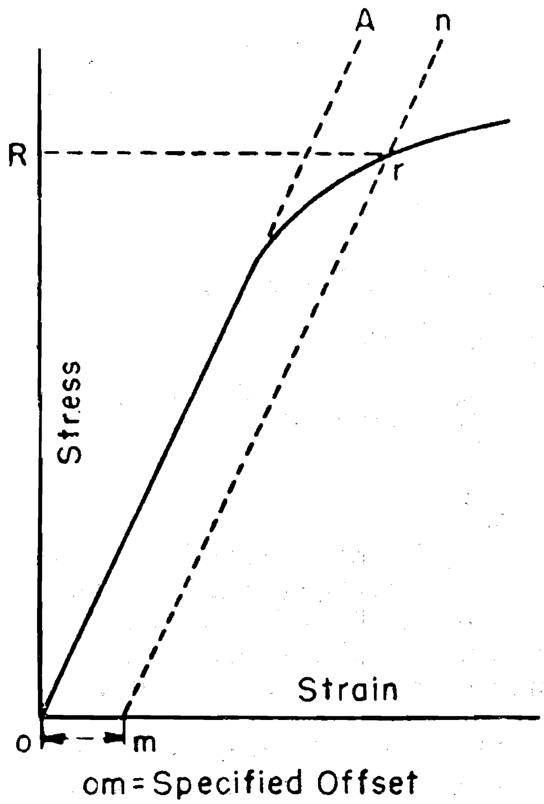


FIG. 16 Stress-Strain Diagram for Determination of Yield Strength by the Offset Method

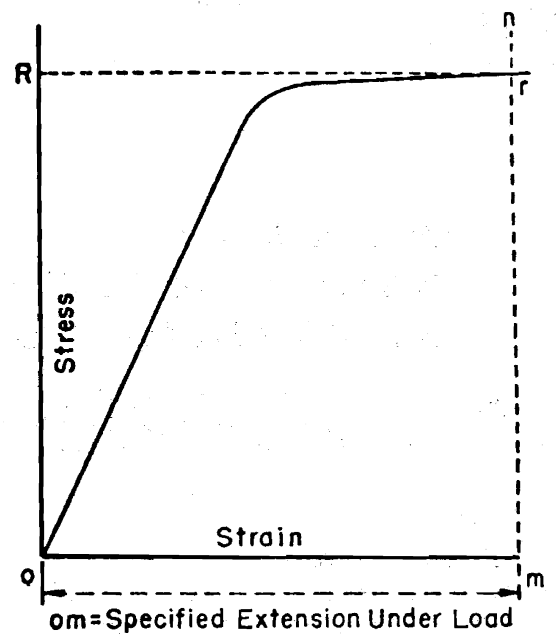


FIG. 17 Stress-Strain Diagram for Determination of Yield Strength by the Extension-Under-Load Method

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM B580: Standard Specification for Anodized Oxide Coatings on Aluminum

CFR Section(s): 49 CFR 171.7

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: B 580 - 79

An American National Standard

Standard Specification for Anodic Oxide Coatings on Aluminum[1]

This standard is issued under the fixed designation B 580; 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 specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers requirements for electrolytically formed porous oxide coatings on aluminum and aluminum alloy parts where appearance, abrasion resistance, electrical properties, and protection against corrosion are important. Nonporous, barrier layer anodic coatings used for electrical capacitors are not covered. Seven types of coatings as shown in Table 1 are provided. Definitions and typical examples of service conditions are provided in Appendix X1.

NOTE 1—It is recognized that uses exist in which modifications of the coatings covered by this specification may be required. In such cases the particular properties desired by the purchaser should be the subject of agreement between the purchaser and the manufacturer.

2. Referenced Documents

2.1 *ASTM Standards:*

B 110 Test Method for Dielectric Strength of Anodically Coated Aluminum[2]

B 117 Method of Salt Spray (Fog) Testing[3]

B 136 Method for Measurement of Stain Resistance of Anodic Coatings on Aluminum[3]

B 137 Method for Measurement of Weight of Coating on Anodically Coated Aluminum[3]

B 244 Method for Measurement of Thickness of Anodic Coatings on Aluminum and of Other Nonconductive Coatings on Nonmagnetic Basis Metals with Eddy-Current Instruments[3]

B 368 Method for Copper-Accelerated Acetic Acid-Salt Spray (Fog) Testing (CASS Test)[3]

B 457 Method for Measurement of Impedance of Anodic Coatings on Aluminum[3]

B 487 Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section[3]

B 538 Method of FACT (Ford Anodized Aluminum Corrosion Test) Testing[3]

B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings[3]

D 658 Test Method for Abrasion Resistance of Organic Coatings by the Air Blast Abrasive Test[4]

E 429 Method for Measurement and Calculation of Reflecting Characteristics of Metallic Surfaces Using Integrating Sphere Instruments[5]

E 430 Method for Measurement of Gloss of High-Gloss Surfaces by Goniophotometry[5]

2.2 *Other Standards:*

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes[6]

MIL-STD-414 Sampling Procedures and Tables for Inspection by Variables for Percent Defective[6]

3. Manufacture

3.1 Defects in the surface of the basis metal, such as scratches, porosity, inclusions, roll and die marks, cold shuts, and cracks, will adversely affect the appearance and performance of applied coatings despite the observance of best anodizing practices. Accordingly, defects in the coating that result from such conditions shall not be cause for rejection.

NOTE 2—To minimize problems of this sort, the specifications covering the basis material or the item to be anodized should contain appropriate limitations on such basis metal conditions.

3.2 The basis metal shall be subjected to such mechanical finishing operations, cleaning, and chemical or electrolytic pretreatments as are necessary to yield anodic coatings with the final quality and appearance specified by the purchaser.

3.3 Except where specifically excluded, anodized parts shall be sealed in water or aqueous chemical solutions of such purity, composition, pH, and temperature, as to impart the properties specified herein.

4. Significant Surfaces

4.1 Significant surfaces are defined as those normally visible (directly or by reflection) which are essential to the appearance of serviceability of the article when assembled in normal position; or those surfaces which can be the source of corrosion products that will deface visible surfaces and interfere with functional surfaces on the assembled article. When necessary, the significant surfaces shall be the subject of agreement between purchaser and manufacturer and shall be indicated on the drawings of the parts, or by the provision of suitably marked samples.

NOTE 3—When significant surfaces are involved on which the specified thickness or density of the coating cannot readily be controlled, such as threads, holes, deep recesses, and similar areas, the purchaser

[1] This specification is under the jurisdiction of ASTM Committee B-8 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.06 on Anodic and Chemical Conversion Coatings on Aluminum and Magnesium Alloys.

Current edition approved May 25, 1979. Published August 1979. Originally published as B 580 – 73. Last previous edition B 580 – 73.

[2] Discontinued, see *1981 Annual Book of ASTM Standards*, Part 9.

[3] *Annual Book of ASTM Standards*, Vol 02.05.

[4] *Annual Book of ASTM Standards*, Vol 06.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] Available from the Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120.

and the manufacturer should recognize the necessity for either thicker films on the more accessible surfaces or for special racking.

5. Manner of Specifying Requirements

5.1 *Coating Description*—When ordering articles to be finished in accordance with this specification, the purchaser shall state:

5.1.1 The ASTM designation number,

5.1.2 The coating type and description (see Table 1),

5.1.3 The minimum anodic film thickness,

5.1.4 Special post anodic treatments,

5.1.5 Applicable quality assurance requirements (see Section 6),

5.1.6 Significant surface appearance requirements such as color, texture, or reflectivity, and

5.1.7 The alloy to which the coating is to be applied.

5.2 *Supplementary Coating*—Any supplementary coating that is required in addition to normal or special sealing must either be described in detail along with its requirements or the appropriate specification(s) must be referenced.

6. Quality Assurance

6.1 Anodic oxide coatings can be produced to have many different characteristics. No single coating can be expected to have all of these characteristics. Therefore, the quality assurance requirements for a given coating should be selected to control those properties necessary to the expected end use for the product.

6.2 Anodic coatings supplied under this specification shall meet the minimum requirements for film thickness as stated in Table 1.

TABLE 1 Anodic Coatings Descriptions

NOTE—Hard coatings may vary in thickness from 12 µm to more than 100 µm. If the thickness of Type A is not specified it shall be 50 µm min. Type A coatings will not be sealed unless so specified.

Type	Coating (Industry) Description	Minimum Film Thickness (µm)
A	Engineering Hard Coat	50
B	Architectural Class I	18
C	Architectural Class II	10
D	Automotive—Exterior	8
E	Interior—Moderate Abrasion	5.0
F	Interior—Limited Abrasion	3
G	Chromic Acid	1

6.3 The following ASTM methods are applicable to anodic coatings within the scope of this specification: B 110, B 117, B 136, B 137, B 244, B 368, B 457, B 487, B 538, D 658, E 429, and E 430. The selection of tests to be required and the level of performance against each test, with the exception of minimum film thickness, shall be subject to agreement between purchaser and manufacturer. The Dye Stain Test, as described in Method B 136, shall not be required for Type G coatings or for Types B through F coatings sealed only in dichromate solutions, or for unsealed Type A coatings.

7. Workmanship and Appearance

7.1 *Workmanship*—The anodic coatings shall be continuous, smooth, adherent, uniform in appearance, and shall be free of powdery areas (burns), loose films, stains, discolorations, and discontinuities such as pits, breaks and scratches, or other damage. The size and number of contact marks shall be the minimum consistent with good practice. The location of contact marks shall be in areas of minimum exposure to service environmental conditions when important to the function of the part.

7.2 *Appearance*—If applicable, the color and finish appearance (bright, dull, or satin) shall be a reasonably close approximation to that of a sample consisting of treated pieces agreed upon as the standard range by the manufacturer and the purchaser.

NOTE 4—This range, representing the limits that the manufacturer will supply and that the purchaser will accept, should be established before any work is performed to meet this specification.

8. Sampling

8.1 Test methods are time consuming and often destructive; therefore 100 % inspection is usually impractical. The purchaser should select a suitable sampling plan for the acceptance testing of lots of coated items. In order that the manufacturer may know the quality standard he is expected to meet, the plan selected should be made a part of the purchase contract.

8.2 Information on sampling procedures is given in Method B 602. Standard sampling plans are suggested in Military Standards MIL-STD-105 and MIL-STD-414.

APPENDIX

(Nonmandatory Information)

TABLE X1.1 Definitions of Service Conditions and Examples of Typical Applications and Applicable Coating Types

SC No.	Definition	Typical Applications	Applicable Coating Types
Very Severe (5)	Exposure to atmospheric weathering that can be expected to extend for many years or to prolonged high bearing load wear conditions.	Unmaintained exterior architectural facades, machinery parts, marine	A and B
Severe (4)	Exposure that includes likely damage from denting, scratching, and abrasive wear coupled with corrosive environments.	1-Automotive—exterior, 2-maintained architectural exterior facades, windows	C and D
Moderate (3)	Exposure that is likely to include occasional wetting with coating subject to moderate wear or abrasion.	Lighting reflectors—exterior, athletic equipment, appliances, nameplates, lawn furniture	E
Mild (2)	Exposure indoors in normally dry atmospheres with coating subject to minimum wear or abrasion.	Automotive—interior, houseware items, lighting reflectors—enclosed	F
Crevice Condition (1)	Exposure to humid atmospheres with little or no abrasive condition. Particularly for lap joints.	Spot-welded or riveted assemblies such as aircraft and electronic components.	G

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM B694: Standard Specification for Copper, Copper Alloy, and Copper-Clad Stainless Steel Sheet and Strip for Electrical Cable Shielding

CFR Section(s): 7 CFR 1755.390(i)(5)(v)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: B 694 – 86

Standard Specification for Copper, Copper Alloy, and Copper-Clad Stainless Steel Sheet and Strip for Electrical Cable Shielding[1]

This standard is issued under the fixed designation B 694; 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.

1. Scope

1.1 This specification covers selected copper, copper alloy, and copper-clad stainless steel materials, sheet and strip, in various thicknesses, for use as electrostatic or electromagnetic shielding for insulated power, control, instrumentation, and communication cables.

NOTE 1—See Specification B 736, for related standards for aluminum-based shielding materials.

1.2 The materials covered are the following:

Copper or Copper Alloy UNS No.[A]	Type of Material
C11000	copper
C19400	copper-iron alloy
C22000	commercial bronze
C66400	copper-zinc-iron-cobalt alloy
C66410	copper-zinc-iron alloy
C71000	cupro-nickel 20 %
...	copper-clad steel[B]

[A] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix can be used to accommodate composition variations of the base alloy.

[B] Cladding ratio must be specified. (See 3.1, 7.5, 13.5, and Appendix X3.)

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

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

A 176 Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip[2]

B 152 Specification for Copper Sheet, Strip, Plate, and Rolled Bar[3]

B 193 Test Method for Resistivity of Electrical Conductor Materials[4]

B 248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar[3]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[3]

E 527 Practice for Numbering Metals and Alloys (UNS)[5]

B 736 Specification for Aluminum, Aluminum Alloy and Aluminum-Clad Steel Cable Shielding Stock[6]

3. Definition

3.1 *cladding ratio*—ratio by percent thickness of the component layers, for example, 20/60/20.

4. Ordering Information

4.1 Orders for material under this specification should include the following information:

4.1.1 Quantity: total for each item, pounds (or kilograms),

4.1.2 Name of material: cable shielding (or "cable wrap"),

4.1.3 Form of material: strip,

4.1.4 Type of material: copper, commercial bronze, etc. (see 1.2),

4.1.5 Alloy number when appropriate (see 1.2),

4.1.6 Temper (see Section 8),

4.1.7 Dimensions: thickness and width (see Section 13),

4.1.8 How furnished: coils (rolls), traverse wound on reels or spools, etc.,

4.1.9 Whether the resistivity test is required for any item (Section 12),

4.1.10 Coil dimension: inner or outer coil diameter limitation, or both, if required,

4.1.11 Weight of coils: coil weights or coil size limitations, if required,

4.1.12 Cladding ratio when appropriate (see 7.5),

4.1.13 Certification, if required,

4.1.14 Mill test report, if required,

4.1.15 Specification designation and year of issue, and

4.1.16 Special tests or exceptions, if any.

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification B 248.

6. Materials and Manufacture

6.1 The material shall be of such quality that it conforms to the properties and characteristics prescribed in this specification.

6.2 Cladding metals as appropriate may be bonded to the specified base metal by any method that will produce a clad

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.01 on Plate, Sheet, and Strip.

Current edition approved Jan. 31, 1986. Published March 1986. Originally published as B 694 – 81. Last previous edition B 694 – 83$^{\epsilon 1}$.

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

[3] *Annual Book of ASTM Standards*, Vol 02.01.

[4] *Annual Book of ASTM Standards*, Vols 02.01 and 02.03.

[5] *Annual Book of ASTM Standards*, Vols 01.01 and 02.01.

[6] *Annual Book of ASTM Standards*, Vol 02.02.

TABLE 1 Chemical Requirements

Element	Composition, %: Copper or Copper Alloy UNS No.						Copper Coating of Bimetallic Copper or Copper Alloy UNS No.	
	C11000	C19400	C22000	C66400	C66410	C71000	C10300	C12200
Copper (incl silver)	99.90 min	97.0 min	89.00–91.0	remainder	remainder	74.0 min	99.95 min[A]	99.9 min
Iron	...	2.1–2.6	0.05 max	1.3–1.7	1.8–2.3	1.0 max	...	...
Lead, max	...	0.03	0.05	0.015	0.015	0.05	...	...
Tin	...	...	...	0.05 max	0.05 max	...	...	...
Zinc	...	0.05–0.20	remainder	11.0–12.0	11.0–12.0	1.0 max	...	...
Nickel (incl cobalt)	...	...	...	...	0.05 max	19.0–23.0	...	...
Manganese	...	...	...	...	0.05 max	1.0 max	...	...
Phosphorus	...	0.015–0.15	...	...	0.02 max	...	0.001–0.005	0.015–0.040
Cobalt	...	...	...	0.30–0.7	...	...	...	...
Silver	...	...	...	...	0.05 max	...	...	...
Silicon	...	...	...	...	0.05 max	...	...	...
Aluminum	...	...	...	...	0.05 max	...	...	...

[A] Copper + silver + phosphorus, min.

material that will conform to this specification.

7. Chemical Composition

7.1 Homogeneous copper-bearing materials shall conform to the chemical requirements prescribed in Table 1.

7.2 Copper cladding shall be, unless otherwise specified, a copper conforming in chemical composition to that covered by Specification B 152, Copper UNS No. C10300 (Table 1). By agreement between manufacturer or supplier and purchaser, Copper UNS No. C12200 (Table 1) may be supplied.

7.3 The specification limits do not preclude the presence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

7.4 For copper alloys in Table 1, copper may be taken as the difference between all the elements analyzed and 100 %.

7.4.1 *Alloys C19400 and C22000*—When all the elements in Table 1 are analyzed, their sum shall be 99.8 % min.

7.4.2 *Alloys C66400, 664100, and C71000*—When all the elements in Table 1 are analyzed, their sum shall be 99.5 % min.

7.5 Clad cores shall be a stainless steel conforming in chemical composition to any of those covered by Specification A 176. Unless otherwise specified, stainless steel in accordance with UNS No. S43000 (Type 430) shall be supplied.

7.6 Unless otherwise stated (4.1.12), the cladding ratio shall be one of the standard ratios listed in Tables 2 and X2.1, and shall be expressed as XX/XX/XX, copper/stainless steel/copper.

8. Temper

8.1 Materials furnished to this specification shall be annealed or cold-rolled to the temper specified (4.1.6). The standard designations as defined in Practice B 601 are shown. Standard tempers commonly available are listed in Table 2; special or nonstandard tempers are subject to negotiation between manufacturer or supplier and purchaser.

9. Mechanical Properties of Cold-Rolled and Annealed Tempers

9.1 The tension test shall be the standard test for all tempers of cold rolled strip and for annealed Copper UNS No. C11000 and Copper Alloy UNS Nos. C19400, C66400, and C66410 and acceptance or rejection shall depend only on the tensile properties which shall conform to the applicable requirements prescribed in Table 2. Tension test specimens shall be taken so the longitudinal axis of such specimens is parallel to the direction of rolling.

9.2 The mechanical properties of copper-clad steel material in tempers other than fully annealed and with cladding ratios other than listed in Tables 2 and X3.1 shall be as agreed upon between purchaser and supplier.

10. Grain Size Requirements of Annealed Tempers

10.1 Grain size shall be the standard test for annealed strip of Copper Alloy UNS Nos. C22000 and C71000, and acceptance or rejection shall depend only on the grain size. The average grain size of each of two samples of annealed material, as determined on a plane parallel to the surface of the strip, shall be within the limits prescribed in Table 3.

10.2 Although no minimum grain size is prescribed for fully annealed copper-clad steel material, it shall be fully recrystallized in both cladding and core.

11. Rockwell Hardness

11.1 Since Rockwell hardness tests offer a quick and convenient method of checking the conformity of the material to the requirements for tensile strength or grain size, the approximate Rockwell hardness values are given in Table 2 for general information and assistance in testing but shall not be used as a basis for rejection. For copper-clad material, copper should be etched off with suitable reagent prior to testing the steel.

12. Electrical Conductivity

12.1 When specified in the order, the electrical conductivity determined on annealed samples shall have the following value when tested at a temperature of 20°C (68°F):

Material or UNS No.	Electrical Conductivity, min, % IACS
C11000	100.00
C19400	60
C22000	40
C66400	30
C66410	30

TABLE 2 Tensile Strength Requirements and Approximate Hardness Values for Shielding Materials in Commonly Ordered Tempers

Description		Temper Designation		Tensile Strength, ksi[A] (MPa[B])		Approximate Rockwell Hardness[D]	
Copper or Copper Alloy UNS No.	Type of Material	Standard	Former	Min	Max	Other Scales Thicknesses >0.020 in.	Superficial 30T Thicknesses >0.012 in.
			Cold-Rolled Tempers:				
C11000	Copper	H00	eighth hard	32 (220)	40 (275)	F 54–82	up to 49
		H01	quarter hard	34 (235)	42 (290)	F 60–84	18–51
		H02	half hard	37 (255)	46 (315)	F 77–89	43–57
			Annealed Tempers:				
		O61	annealed	. . .	34 (235)	. . .	. . .
			Annealed Tempers:				
C19400	Copper-iron alloy	O61	annealed[C]	45 (310)	55 (380)	. . .	. . .
		O50	light annealed[C]	50 (345)	60 (415)	. . .	. . .
		H02	half hard	53 (365)	63 (435)	B 49–69	52–63
			Cold-Rolled Tempers:				
C22000	Commercial bronze	H01	quarter hard	40 (275)	50 (345)	B 27–52	38–53
		H02	half hard	47 (325)	57 (395)	B 50–63	52–61
			Annealed Tempers:				
		O81	quarter hard	39 (270)	46 (315)	. . .	. . .
			Annealed Temper:				
C66400	Copper-zinc-iron-cobalt alloy	O60	soft[C]	53 (365)	60 (415)	. . . . . .	. . .
C66410	Copper-zinc-iron alloy	O60	soft[C]	53 (365)	60 (415)	. . . . . .	. . .
			Cold-Rolled Tempers:				
C71000	Cupro-nickel 20 %	H01	quarter hard	47 (325)	63 (435)	B 45–72	46–65
		H02	half hard	56 (385)	70 (485)	B 64–78	59–69
			Annealed Tempers:				
		OS035	0.035-mm grain size	52 (355)		B 18–35	28–40
		OS015	0.015-mm grain size	53 (365)		B 35–88	40–58
Copper-Clad Steel							
Cladding Ratio	Total Thickness in. (mm)						
			Annealed Tempers				
20/60/20	0.004 (0.10)	O61	annealed[C]	51 (350)		15T 89 max	. . .
16/68/16	0.005 (0.13)	O61	annealed[C]	55 (380)	68 (470)	15T 89 max	. . .
33.3/33.3/33.3	0.006 (0.15)	O61	annealed[C]	44 (305)		15T 89 max	. . .

[A] ksi = 1000 psi.
[B] See Appendix X4.
[C] There is no grain size requirement but all annealed metal shall be fully recrystallized.
[D] Rockwell values normally apply as follows: The B and F scales apply to metal 0.020 to 0.036 in. (0.5 to 0.91 mm) in thickness. The Superficial 30-T scale applies to metal 0.012 to 0.028 in. (0.30 to 0.71 mm) in thickness.

Material or UNS No.	Electrical Conductivity, min, % IACS
C71000	6
Copper-clad steel	[A]

[A] Conductivity for preferred thicknesses and cladding ratios shall be as shown in Table X3.1. Conductivity for other thicknesses or for other cladding ratios shall be as agreed upon between purchaser and supplier.

12.2 The electrical resistivity of the material shall be determined in accordance with Test Method B 193; the conductivity shall be calculated in accordance with Explanatory Notes 3 and 4 of Test Method B 193.

13. Dimensions and Permissible Variations

13.1 *General*—For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimension may be cause for rejection.

13.2 *Thickness*—The standard method of specifying thickness shall be in decimal fractions of an inch. For material 0.021 in. (0.53 mm) and under in thickness, it is recommended that the nominal thicknesses be stated not closer than the nearest half-thousandth. (For example, specify 0.006 or 0.0065 in. (0.15 or 0.165 mm), but not 0.0063 in. (0.160 mm).) A list of preferred thicknesses is shown in Appendix X1. The thickness tolerance shall be those shown in Tables 4(*a*) and 4(*b*).

TABLE 3 Grain Size Requirements for Annealed Material

Copper Alloy UNS No.	Temper Designation		Average Grain Size, mm		
	Standard	Former	Nominal	Min	Max
C22000	OS010		0.010	[A]	0.020
C71000	OS015	annealed	0.015	[A]	0.025

[A] Although no minimum grain size is required, this material must be fully recrystallized.

13.3 *Width*—The width tolerances shall be those required by Specification B 248, Paragraph 5.3, unless otherwise stated in the purchase order.

13.4 *Straightness*—The straightness tolerances shall be those required by Specification B 248, paragraph 5.5, unless otherwise stated in the purchase order.

13.5 *Cladding Ratio*—Cladding ratios shall be within ±10 % of nominal; test method shall be metallurgical

TABLE 4(*a*) Thickness Tolerances

Material	Thickness, in. (mm)	Tolerance, plus and minus in. (mm): 12 in. (305 mm) and under in Width	Tolerance, plus and minus in. (mm): Over 12 in. (305 mm) and up to 24 in. (610 mm) in width
Copper and copper alloys	0.004 (0.102) and under	0.0003 (0.0076)	0.0006 (0.015)
	Over 0.004 to 0.005 (0.127), incl	0.0004 (0.010)	0.0008 (0.020)
	Over 0.005 to 0.009 (0.229), incl	0.0005 (0.013)	0.001 (0.025)
	Over 0.009 to 0.013 (0.330), incl	0.0008 (0.020)	0.0015 (0.038)
Copper-clad steel	0.004 (0.102) and under		
	Over 0.004 to 0.006 (0.152), incl	0.0005 (0.013)	
	Over 0.006 to 0.009 (0.229), incl	0.0006 (0.015)	

microsection of at least three samples per lot. See Appendix X3 for preferred cladding ratios.

14. Workmanship, Finish, and Appearance

14.1 All material shall be uniform in quality and condition, sound and free of internal and external defects of a nature that interferes with normal fabrication or the performance of the cable shielding. It shall be well-cleaned and free of dirt. A superficial film of residual light lubricant is permissible, unless otherwise specified.

14.2 Copper-clad material shall be free of defects including unbond or delamination of a nature that interferes with normal commercial operations.

TABLE 4(*b*) Width Tolerances for Slit Metal and Slit Metal with Rolled Edges

(Applicable to all materials listed in 1.2)

Width, in. (mm)	Width Tolerances,[A] plus and minus, For All Thicknesses: in.	mm
2 (50.8) and under	0.005	0.13
Over 2 to 12 (50.8 to 305), incl	0.008	0.20
Over 12 to 24 (305 to 610), incl	0.015	0.38

[A] If tolerances are specified as all plus or all minus, double the values given.

APPENDIXES

(Nonmandatory Information)

X1. EXPLANATORY NOTE—CABLE SHIELDING

X1.1 Cable shielding or "cable wrap" is normally used by manufacturers of electrical insulated wire and cable in strips of various widths. The material is wrapped around an insulated wire or group of wires, and may be applied over an intervening layer of wrapping material or over a jacket. The material may be applied in various configurations depending upon the requirements of the finished cable:

X1.1.1 *Helical wrap*—overlapped, butted, or gapped.

X1.1.2 *Longitudinal application*—corrugated or smooth, overlapped, butted, gapped, or welded/soldered.

X1.2 The selection of the particular material and of the thickness of the material to be used is dependent largely upon the specification requirements for the finished wire or cable. Military and Federal Specifications, Rural Electrification Administration (REA) specifications, ICEA (Insulated Cable Engineers Association) specifications among others, typically apply.

X1.3 Electrical conductivity of the material is an important characteristic considered in the selection process, and is affected by the material, its thickness, and the method of application. Corrosion resistance is important for various environments. Physical strength requirements may include such features as resistance to tensile stress, resistance to bending stress (including repeated bending), resistance to gopher attack, etc.

X2. PREFERRED THICKNESSES

X2.1 It is recommended that wherever possible, material purchased to this specification be ordered in a thickness as listed in Table X2.1.

TABLE X2.1 Preferred Thickness, Nominal

Material or UNS No.	Thickness, in. (mm)
C11000	0.005 (0.13) 0.010 (0.25)
C19400	0.006 (0.15) 0.007 (0.18)
C22000	0.005 (0.13) 0.007 (0.18) 0.010 (0.25)
C66400	0.0055 (0.14)
C66410	0.0055 (0.14)
C71000	0.005 (0.13)
Copper-clad steel	0.004 (0.10)[A] 0.005 (0.13)[A] 0.006 (0.15)[A]

[A] Total thickness of strip. See Table X3.1 for preferred cladding ratio.

X3. PREFERRED CLADDING RATIOS FOR COPPER-CLAD STEEL

X3.1 It is recommended that wherever possible, material purchased to this specification be ordered in thicknesses and cladding ratios as listed in Table X3.1. Conductivity for these recommended materials is indicated.

TABLE X3.1 Preferred Cladding Ratios—Copper-Clad Steel

Nominal Total Thickness of Strip		Cladding Ratio, Cu/ss/Cu	Nominal Thickness, in. (mm)			Conductivity, % IACS	
in.	mm		Copper	Steel	Copper	nominal	min
0.004	0.10	20/60/20	0.0008 (0.02)	0.0024 (0.06)	0.0008 (0.02)	32	30
0.005	0.13	16/68/16	0.0008 (0.02)	0.0034 (0.09)	0.0008 (0.02)	30	28
0.006	0.15	33.3/33.3/33.3	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	61	60

X4. METRIC EQUIVALENTS

X4.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM C5: Standard Specification for Quicklime for Structural Purposes

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: C 5 – 79 (Reapproved 1997)

Standard Specification for Quicklime for Structural Purposes[1]

This standard is issued under the fixed designation C 5; 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 all classes of quicklime such as crushed lime, granular lime, ground lime, lump lime, pebble lime, and pulverized lime, used for structural purposes.

2. Referenced Documents

2.1 *ASTM Standards:*

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime[2]

C 50 Practice for Sampling, Inspection, Packing, and Marking of Lime and Limestone Products[2]

C 51 Terminology Relating to Lime and Limestone (As Used by the Industry)[2]

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

3. Terminology

3.1 *Definitions*—Unless otherwise specified, for definitions of terms used in this standard, refer to Terminology C 51.

4. Chemical Composition

4.1 The quicklime shall conform to the following requirements as to chemical composition, calculated on a nonvolatile basis:

	Calcium Lime	Magnesium Lime
Calcium oxide, min, %	75	
Magnesium oxide, min, %		20
Calcium and magnesium oxide, min, %	95	95
Silica, alumina, and oxide of iron, max, %	5	5
Carbon dioxide, max, %:		
If sample is taken at place of manufacture	3	3
If sample is taken at any other place	10	10

5. Residue

5.1 The quicklime shall contain no more than 15 weight % of residue.

6. General Requirements

6.1 Quicklime shall be slaked and aged in accordance with the printed directions of the manufacturer. The resulting lime putty shall be stored until cool.

6.2 Lime putty prepared in accordance with X1.4.2 and adjusted to standard consistency in accordance with Test Methods C 110, shall show no pops or pits when tested in accordance with Test Methods C 110.

6.3 Lime putty prepared as above shall have a plasticity figure of not less than 200.

7. Sampling, Inspection, etc.

7.1 The sampling, inspection, rejection, retesting, packing, and marking shall be conducted in accordance with Methods C 50.

8. Test Methods

8.1 Conformance to chemical requirements shall be determined in accordance with Test Methods C 25.

8.2 Conformance to plasticity and residue requirements shall be determined in accordance with Test Methods C 110.

9. Keywords

9.1 building (structural); calcium oxide; dolomitic lime; high calcium lime; lime putty; magnesium oxide; plasticity; quicklime; residue; slaking

---

[1] This specification is under the jurisdiction of ASTM Committee C-7 on Lime and is the direct responsibility of Subcommittee C07.02 on Structural Lime.

Current edition approved Nov. 30, 1979. Published January 1980. Originally published as C 5 – 13 T. Last previous edition C 5 – 59 (1974).

[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

APPENDIX

(Nonmandatory Information)

X1. SLAKING AND PREPARATION OF LIME PUTTY

X1.1 *Introduction*

X1.1.1 Quicklime can never be used as such for structural purposes; it must always be slaked first. Since the method of slaking is an important factor in determining the quality of the finished product, the following directions for the preparation of lime putty are given, not as a part of the specification, but as information for the further protection of the purchaser.

X1.1.2 Different kinds of lime vary considerably in the way in which they behave with water. A little supervision over the operation of slaking will amply pay for itself by ensuring the production of the greatest possible quantity and the best possible quality of putty. To find out how to slake a new lot of lime, it is safest to try a little of it and see how it works. Since different lots of the same brand of lime vary somewhat, and since the weather conditions at the time have a decided influence, it is wise to try a sample from each lot used, whether familiar with the brand or not.

X1.2 Classification of Limes

X1.2.1 In a bucket, put two or three lumps of lime about the size of one's fist, or, in the case of granular lime, an equivalent amount. Add sufficient water to just barely cover the lime, and note how long it takes for slaking to begin. Slaking has begun when pieces split off from the lumps or when the lumps crumble. Water of the same temperature should be used for test and field practice.

X1.2.2 If slaking begins in less than 5 min, the lime is quick slaking; from 5 to 30 min, medium slaking; over 30 min, slow slaking.

X1.3 Directions for Slaking

X1.3.1 Slake quicklime in accordance with the printed directions of the manufacturer. When such directions are not provided, proceed as follows:

X1.3.2 For quick-slaking lime, always add the lime to the water, not the water to the lime. Have sufficient water at first to cover all the lime completely. Have a plentiful supply of water available for immediate use—a hose throwing a good stream, if possible. Watch the lime constantly. At the slightest appearance of escaping steam, hoe thoroughly and quickly, and add enough water to stop the steaming. Do not be afraid of using too much water with this kind of lime.

X1.3.3 For medium–slaking lime, add the water to the lime. Add enough water so that the lime is about half submerged. Hoe occasionally if steam starts to escape. Add a little water now and then if necessary to prevent the putty from becoming dry and crumbly. Be careful not to add any more water than required, and not too much at a time.

X1.3.4 For slow–slaking lime, add enough water to the lime to moisten it thoroughly. Let it stand until the reaction has started. Cautiously add more water, a little at a time, taking care that the mass is not cooled by the fresh water. Do not hoe until the slaking is practically complete. If the weather is very cold, it is preferable to use hot water, but if this is not available, the mortar box may be covered in some way to retain the heat.

X1.4 Preparation of Putty for Use

X1.4.1 After slaking, prepare putty for use as follows:

X1.4.2 *White Coat*—After slaking and aging finishing quicklime in accordance with the printed directions of the manufacturer, store the putty until cool. If no printed directions are provided by the manufacturer, prepare the putty for use as follows: After the action has ceased, run off the putty through a No. 10 (2.00-mm) sieve conforming to Specification E 11, and store for a minimum of 2 weeks.

X1.4.3 *Base Coats*—After the action has ceased, run off the putty through a No. 8 (2.36-mm) sieve conforming to Specification E 11. Add sand up to equal parts by weight, all of the hair or other fibers required, and store for a minimum of 2 weeks.

X1.4.4 *Masons' Mortar*—After the action has ceased, add part or all of the sand required, and store for a minimum of 24 h.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM C150: Standard Specification for Portland Cement

CFR Section(s): 30 CFR 250.198

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

ASTM Logo Removed

Designation: C 150 – 99a

Standard Specification for Portland Cement[1]

This standard is issued under the fixed designation C 150; 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 eight types of portland cement, as follows (see Note 1):

1.1.1 *Type I*—For use when the special properties specified for any other type are not required.

1.1.2 *Type IA*—Air-entraining cement for the same uses as Type I, where air-entrainment is desired.

1.1.3 *Type II*—For general use, more especially when moderate sulfate resistance or moderate heat of hydration is desired.

1.1.4 *Type IIA*—Air-entraining cement for the same uses as Type II, where air-entrainment is desired.

1.1.5 *Type III*—For use when high early strength is desired.

1.1.6 *Type IIIA*—Air-entraining cement for the same use as Type III, where air-entrainment is desired.

1.1.7 *Type IV*—For use when a low heat of hydration is desired.

1.1.8 *Type V*—For use when high sulfate resistance is desired.

1.2 When both SI and inch-pound units are present, the SI units are the standard. The inch-pound units are approximations listed for information only.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)[3]

C 114 Test Methods for Chemical Analysis of Hydraulic Cement[3]

C 115 Test Method for Fineness of Portland Cement by the Turbidimeter[3]

C 151 Test Method for Autoclave Expansion of Portland Cement[3]

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement[3]

C 185 Test Method for Air Content of Hydraulic Cement Mortar[3]

C 186 Test Method for Heat of Hydration of Hydraulic Cement[3]

C 191 Test Method for Time of Setting of Hydraulic Cement by Vicat Needle[3]

C 204 Test Method for Fineness of Hydraulic Cement by Air Permeability Apparatus[3]

C 226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Portland Cement[3]

C 266 Test Method for Time of Setting of Hydraulic Cement Paste by Gillmore Needles[3]

C 451 Test Method for Early Stiffening of Hydraulic Cement (Paste Method)[3]

C 452 Test Method for Potential Expansion of Portland Cement Mortars Exposed to Sulfate[3]

C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements[3]

C 563 Test Method for Optimum SO_3 in Hydraulic Cement Using 24-h Compressive Strength[3]

C 1038 Test Method for Expansion of Portland Cement Mortar Bars Stored in Water[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *portland cement*—a hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition.

3.1.2 *air-entraining portland cement*—a hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition, and with which there has been interground an air-entraining addition.

[1] This specification is under the jurisdiction of ASTM Committee C-1 on Cement and is the direct responsibility of Subcommittee C01.10 on Portland Cement.

Current edition approved Oct. 10, 1999. Published November 1999. Originally published as C 150 – 40 T. Last previous edition C 150 – 99.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

4. Ordering Information

4.1 Orders for material under this specification shall include the following:

4.1.1 This specification number and date,

4.1.2 Type or types allowable. If no type is specified, Type I shall be supplied,

4.1.3 Any optional chemical requirements from Table 2, if desired,

4.1.4 Type of setting-time test required, Vicat or Gillmore. If not specified, the Vicat shall be used,

4.1.5 Any optional physical requirements from Table 3, if desired.

NOTE 1—Cement conforming to the requirements for all types are not carried in stock in some areas. In advance of specifying the use of cement other than Type I, determine whether the proposed type of cement is, or can be made, available.

5. Additions

5.1 The cement covered by this specification shall contain no addition except as follows:

5.1.1 Water or calcium sulfate, or both, if added, shall be in amounts such that the limits shown in Table 1 for sulfur trioxide and loss-on-ignition are not exceeded.

5.1.2 Processing additions used in the manufacture of the cement shall have been shown to meet the requirements of Specification C 465 in the amounts used or greater.

5.1.3 Air-entraining portland cement shall contain an interground addition conforming to the requirements of Specification C 226.

6. Chemical Composition

6.1 Portland cement of each of the eight types shown in Section 1 shall conform to the respective standard chemical requirements prescribed in Table 1. In addition, optional chemical requirements are shown in Table 2.

NOTE 2—When comparing oxide analyses and calculated compounds from different sources or from different historic times, be aware that they may not have been reported on exactly the same basis. Chemical data obtained by Reference and Alternate Test Methods of Test Methods C 114 (wet chemistry) may include titania and phosphorus as alumina unless proper correction has been made (see Test Methods C 114), while data obtained by rapid instrumental methods usually do not. This can result in small differences in the calculated compounds. Such differences are usually within the precision of the analytical methods, even when the methods are properly qualified under the requirements of Test Methods C 114.

7. Physical Properties

7.1 Portland cement of each of the eight types shown in Section 1 shall conform to the respective standard physical requirements prescribed in Table 3. In addition, optional physical requirements are shown in Table 4.

TABLE 1 Standard Chemical Requirements

Cement Type[A]	I and IA	II and IIA	III and IIIA	IV	V
Silicon dioxide (SiO_2), min, %	...	20.0[B,C]	...	...	...
Aluminum oxide (Al_2O_3), max, %	...	6.0	...	...	...
Ferric oxide (Fe_2O_3), max, %	...	6.0[B,C]	...	6.5	...
Magnesium oxide (MgO), max, %	6.0	6.0	6.0	6.0	6.0
Sulfur trioxide (SO_3),[D] max, %					
When (C_3A)[E] is 8 % or less	3.0	3.0	3.5	2.3	2.3
When (C_3A)[E] is more than 8 %	3.5	[F]	4.5	[F]	[F]
Loss on ignition, max, %	3.0	3.0	3.0	2.5	3.0
Insoluble residue, max, %	0.75	0.75	0.75	0.75	0.75
Tricalcium silicate (C_3S),[E] max, %	...	...	...	35[B]	...
Dicalcium silicate (C_2S),[E] min, %	...	...	...	40[B]	...
Tricalcium aluminate (C_3A)[E] max, %	...	8	15	7[B]	5[C]
Tetracalcium aluminoferrite plus twice the tricalcium aluminate[E] ($C_4AF + 2(C_3A)$), or solid solution ($C_4AF + C_2F$), as applicable, max, %	...	...	...	...	25[C]

[A] See Note 1.
[B] Does not apply when the heat of hydration limit in Table 4 is specified.
[C] Does not apply when the sulfate resistance limit in Table 4 is specified.
[D] There are cases where optimum SO_3(using Test Method C 563) for a particular cement is close to or in excess of the limit in this specification. In such cases where properties of a cement can be improved by exceeding the SO_3 limits stated in this table, it is permissible to exceed the values in the table, provided it has been demonstrated by Test Method C 1038 that the cement with the increased SO_3 will not develop expansion in water exceeding 0.020 % at 14 days. When the manufacturer supplies cement under this provision, he shall, upon request, supply supporting data to the purchaser.
[E] All values calculated as described in this note shall be rounded according to Practice E 29. When evaluating conformance to a specification, round values to the same number of places as the corresponding table entry before making comparisons. The expressing of chemical limitations by means of calculated assumed compounds does not necessarily mean that the oxides are actually or entirely present as such compounds.

When expressing compounds, C = CaO, S = SiO_2, A = Al_2O_3, F = Fe_2O_3. For example, $C_3A = 3CaO{\cdot}Al_2O_3$.

Titanium dioxide and phosphorus pentoxide (TiO_2 and P_2O_5) shall not be included with the Al_2O_3 content. See Note 2.

When the ratio of percentages of aluminum oxide to ferric oxide is 0.64 or more, the percentages of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite shall be calculated from the chemical analysis as follows:

Tricalcium silicate = $(4.071 \times \%\ CaO) - (7.600 \times \%\ SiO_2) - (6.718 \times \%\ Al_2O_3) - (1.430 \times \%\ Fe_2O_3) - (2.852 \times \%\ SO_3)$

Dicalcium silicate = $(2.867 \times \%\ SiO_2) - (0.7544 \times \%\ C_3S)$

Tricalcium aluminate = $(2.650 \times \%\ Al_2O_3) - (1.692 \times \%\ Fe_2O_3)$

Tetracalcium aluminoferrite = $3.043 \times \%\ Fe_2O_3$

When the alumina-ferric oxide ratio is less than 0.64, a calcium aluminoferrite solid solution (expressed as $ss(C_4AF + C_2F)$) is formed. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulas:

$ss(C_4AF + C_2F) = (2.100 \times \%\ Al_2O_3) + (1.702 \times \%\ Fe_2O_3)$

Tricalcium silicate = $(4.071 \times \%\ CaO) - (7.600 \times \%\ SiO_2) - (4.479 \times \%\ Al_2O_3) - (2.859 \times \%\ Fe_2O_3) - (2.852 \times \%\ SO_3)$.

No tricalcium aluminate will be present in cements of this composition. Dicalcium silicate shall be calculated as previously shown.

[F] Not applicable.

ASTM Logo Removed

TABLE 2 Optional Chemical Requirements[A]

Cement Type	I and IA	II and IIA	III and IIIA	IV	V	Remarks
Tricalcium aluminate (C_3A),[B] max, %	...	...	8	...	...	for moderate sulfate resistance
Tricalcium aluminate (C_3A),[B] max, %	...	...	5	...	...	for high sulfate resistance
Sum of tricalcium silicate and tricalcium aluminate,[B] max, %	...	58[C]	...	...	...	for moderate heat of hydration
Equivalent Alkalies ($Na_2O + 0.658K_2O$), max, %	0.60[D]	0.60[D]	0.60[D]	0.60[D]	0.60[D]	low-alkali cement

[A] These optional requirements apply only when specifically requested. Verify availability before ordering. See Note 1 in Section 4.

[B] All values calculated as described in this note shall be rounded according to Practice E 29. When evaluating conformance to a specification, round values to the same number of places as the corresponding table entry before making comparisons. The expressing of chemical limitations by means of calculated assumed compounds does not necessarily mean that the oxides are actually or entirely present as such compounds.

When expressing compounds, C = CaO, S = SiO_2, A = Al_2O_3, F = Fe_2O_3. For example, $C_3A = 3CaO \cdot Al_2O_3$.

Titanium dioxide and phosphorus pentoxide (TiO_2 and P_2O_5) shall not be included with the Al_2O_3 content. See Note 2.

When the ratio of percentages of aluminum oxide to ferric oxide is 0.64 or more, the percentages of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite shall be calculated from the chemical analysis as follows:

Tricalcium silicate = $(4.071 \times \% \; CaO) - (7.600 \times \% \; SiO_2) - (6.718 \times \% \; Al_2O_3) - (1.430 \times \% \; Fe_2O_3) - (2.852 \times \% \; SO_3)$

Dicalcium silicate = $(2.867 \times \% \; SiO_2) - (0.7544 \times \% \; C_3S)$

Tricalcium aluminate = $(2.650 \times \% \; Al_2O_3) - (1.692 \times \% \; Fe_2O_3)$

Tetracalcium aluminoferrite = $3.043 \times \% \; Fe_2O_3$

When the alumina-ferric oxide ratio is less than 0.64, a calcium aluminoferrite solid solution (expressed as ss ($C_4AF + C_2F$)) is formed. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulas:

$ss(C_4AF + C_2F) = (2.100 \times \% \; Al_2O_3) + (1.702 \times \% \; Fe_2O_3)$

Tricalcium silicate = $(4.071 \times \% \; CaO) - (7.600 \times \% \; SiO_2) - (4.479 \times \% \; Al_2O_3) - (2.859 \times \% \; Fe_2O_3) - (2.852 \times \% \; SO_3)$.

No tricalcium aluminate will be present in cements of this composition. Dicalcium silicate shall be calculated as previously shown.

[C] The optional limit for heat of hydration in Table 4 shall not be requested when this optional limit is requested.

[D] Specify this limit when the cement is to be used in concrete with aggregates that are potentially reactive and no other provisions have been made to protect the concrete from deleteriously reactive aggregates. Refer to Specification C 33 for information on potential reactivity of aggregates.

TABLE 3 Standard Physical Requirements

Cement Type[A]	I	IA	II	IIA	III	IIIA	IV	V
Air content of mortar,[B] volume %:								
max	12	22	12	22	12	22	12	12
min	...	16	...	16	...	16	...	...
Fineness,[C] specific surface, m^2/kg (alternative methods):								
Turbidimeter test, min	160	160	160	160	...	...	160	160
Air permeability test, min	280	280	280	280	...	...	280	280
Autoclave expansion, max, %	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Strength, not less than the values shown for the ages indicated as follows:[D]								
Compressive strength, MPa (psi):								
1 day	...	...	...	...	12.0 (1740)	10.0 (1450)	...	...
3 days	12.0 (1740)	10.0 (1450)	10.0 (1450) 7.0[E] (1020)[E]	8.0 (1160) 6.0[E] (870)[E]	24.0 (3480)	19.0 (2760)	...	8.0 (1160)
7 days	19.0 (2760)	16.0 (2320)	17.0 (2470) 12.0[E] (1740)[E]	14.0 (2030) 9.0[E] (1310)[E]	...	...	7.0 (1020)	15.0 (2180)
28 days	...	...	...	...	...	...	17.0 (2470)	21.0 (3050)
Time of setting (alternative methods):[F]								
Gillmore test:								
Initial set, min, not less than	60	60	60	60	60	60	60	60
Final set, min, not more than	600	600	600	600	600	600	600	600
Vicat test:[G]								
Time of setting, min, not less than	45	45	45	45	45	45	45	45
Time of setting, min, not more than	375	375	375	375	375	375	375	375

[A] See Note 1.

[B] Compliance with the requirements of this specification does not necessarily ensure that the desired air content will be obtained in concrete.

[C] The testing laboratory shall select the fineness method to be used. However, when the sample fails to meet the requirements of the air-permeability test, the turbidimeter test shall be used, and the requirements in this table for the turbidimetric method shall govern.

[D] The strength at any specified test age shall be not less than that attained at any previous specified test age.

[E] When the optional heat of hydration or the chemical limit on the sum of the tricalcium silicate and tricalcium aluminate is specified.

[F] The time-of-setting test required shall be specified by the purchaser. In case he does not so specify, the requirements of the Vicat test only shall govern.

[G] The time of setting is that described as initial setting time in Test Method C 191.

TABLE 4 Optional Physical Requirements[A]

Cement Type[A]	I	IA	II	IIA	III	IIIA	IV	V
False set, final penetration, min, %	50	50	50	50	50	50	50	50
Heat of hydration:								
7 days, max, kJ/kg (cal/g)	...	...	290 (70)[B]	290 (70)[B]	...	...	250 (60)[C]	...
28 days, max, kJ/kg (cal/g)	...	...	...	...	...	...	290 (70)[C]	...
Strength, not less than the values shown:								
Compressive strength, MPa (psi)								
28 days	28.0 (4060)	22.0 (3190)	28.0 (4060) 22.0[B] (3190)[B]	22.0 (3190) 18.0[B] (2610)[B]	...	...	...	...
Sulfate resistance,[D] 14 days, max, % expansion	...	...	...[E]	...[E]	...	...	...	0.040

[A] These optional requirements apply only when specifically requested. Verify availability before ordering. See Note 1 in Section 4.
[B] The optional limit for the sum of the tricalcium silicate and tricalcium aluminate in Table 2 shall not be requested when this optional limit is requested. These strength requirements apply when either heat of hydration or the sum of tricalcium silicate and tricalcium aluminate requirements are requested.
[C] When the heat of hydration limit is specified, it shall be instead of the limits of C3S, C2S, C3A, SiO_2, and Fe_2O_3 listed in Table 1.
[D] When the sulfate resistance is specified, it shall be instead of the limits of C_3A, $C_4AF + 2\ C_3A$, SiO_2, and Fe_2O_3 listed in Table 1.
[E] Cement meeting the high sulfate resistance limit for Type V are deemed to meet the moderate sulfate resistance requirement of Type II.

8. Sampling

8.1 When the purchaser desires that the cement be sampled and tested to verify compliance with this specification, perform sampling and testing in accordance with Practice C 183.

8.2 Practice C 183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

9. Test Methods

9.1 Determine the applicable properties enumerated in this specification in accordance with the following test methods:

9.1.1 *Air Content of Mortar*—Test Method C 185.
9.1.2 *Chemical Analysis*—Test Methods C 114.
9.1.3 *Strength*—Test Method C 109.
9.1.4 *False Set*—Test Method C 451.
9.1.5 *Fineness by Air Permeability*—Test Method C 204.
9.1.6 *Fineness by Turbidimeter*—Test Method C 115.
9.1.7 *Heat of Hydration*—Test Method C 186.
9.1.8 *Autoclave Expansion*—Test Method C 151.
9.1.9 *Time of Setting by Gillmore Needles*—Test Method C 266.
9.1.10 *Time of Setting by Vicat Needles*—Test Method C 191.
9.1.11 *Sulfate Resistance*—Test Method C 452 (sulfate expansion).
9.1.12 *Calcium Sulfate (expansion of) Mortar*—Test Method C 1038.
9.1.13 *Optimum* SO_3—Test Method C 563.

10. Inspection

10.1 Inspection of the material shall be made as agreed upon between the purchaser and the seller as part of the purchase contract.

11. Rejection

11.1 The cement shall be rejected if it fails to meet any of the requirements of this specification.

11.2 At the option of the purchaser, retest, before using, cement remaining in bulk storage for more than 6 months or cement in bags in local storage in the custody of a vendor for more than 3 months after completion of tests and reject the cement if it fails to conform to any of the requirements of this specification. Cement so rejected shall be the responsibility of the owner of record at the time of resampling for retest.

11.3 Packages shall identify the mass contained as net weight. At the option of the purchaser, packages more than 2 % below the mass marked thereon shall be rejected and if the average mass of packages in any shipment, as shown by determining the mass of 50 packages selected at random, is less than that marked on the packages, the entire shipment shall be rejected.

12. Manufacturer's Statement

12.1 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of any air-entraining addition and of any processing addition used, and also, if requested, shall supply test data showing compliance of such air-entraining addition with Specification C 226 and of such processing addition with Specification C 465.

13. Packaging and Package Marking

13.1 When the cement is delivered in packages, the words" Portland Cement," the type of cement, the name and brand of the manufacturer, and the mass of the cement contained therein shall be plainly marked on each package. When the cement is an air-entraining type, the words "air-entraining" shall be plainly marked on each package. Similar information shall be provided in the shipping documents accompanying the shipment of packaged or bulk cement. All packages shall be in good condition at the time of inspection.

NOTE 3—With the change to SI units, it is desirable to establish a standard SI package for portland cements. To that end 42 kg (92.59 lb) provides a convenient, even-numbered mass reasonably similar to the traditional 94-lb (42.6384-kg) package.

14. Storage

14.1 The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building that will protect the cement from dampness and minimize warehouse set.

15. Manufacturer's Certification

15.1 Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at the time of shipment stating the results of tests made on samples of the material taken during production or transfer and certifying that the cement conforms to applicable requirements of this specification.

16. Keywords

16.1 hydraulic cement; portland cement; specification

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).