EXHIBIT 150
PART 2

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.

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

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

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]

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[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.

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 $0.03D$, 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 $0.025D$, 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-

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 (cm²)	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.

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.

Document Name:

CFR Section(s):

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APPROVED

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

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.

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[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 I and Ia, 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 man-

ufacturer 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		Minimum Average Height of Deformations, in.[d]
					Maximum in.	Minimum in.	
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)

Deformed Wire Size Number[a, e]	Nominal Dimensions			Deformation Requirements			
	Unit Weight, kg/m	Diameter, mm[b]	Cross-Sectional Area, (mm^2)[c]	Perimeter, mm	Spacing		Minimum Average Height of Deformations, mm[d]
					Maximum mm	Minimum mm	
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".

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.

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WASHINGTON, D.C.

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 ft² 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.

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[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.

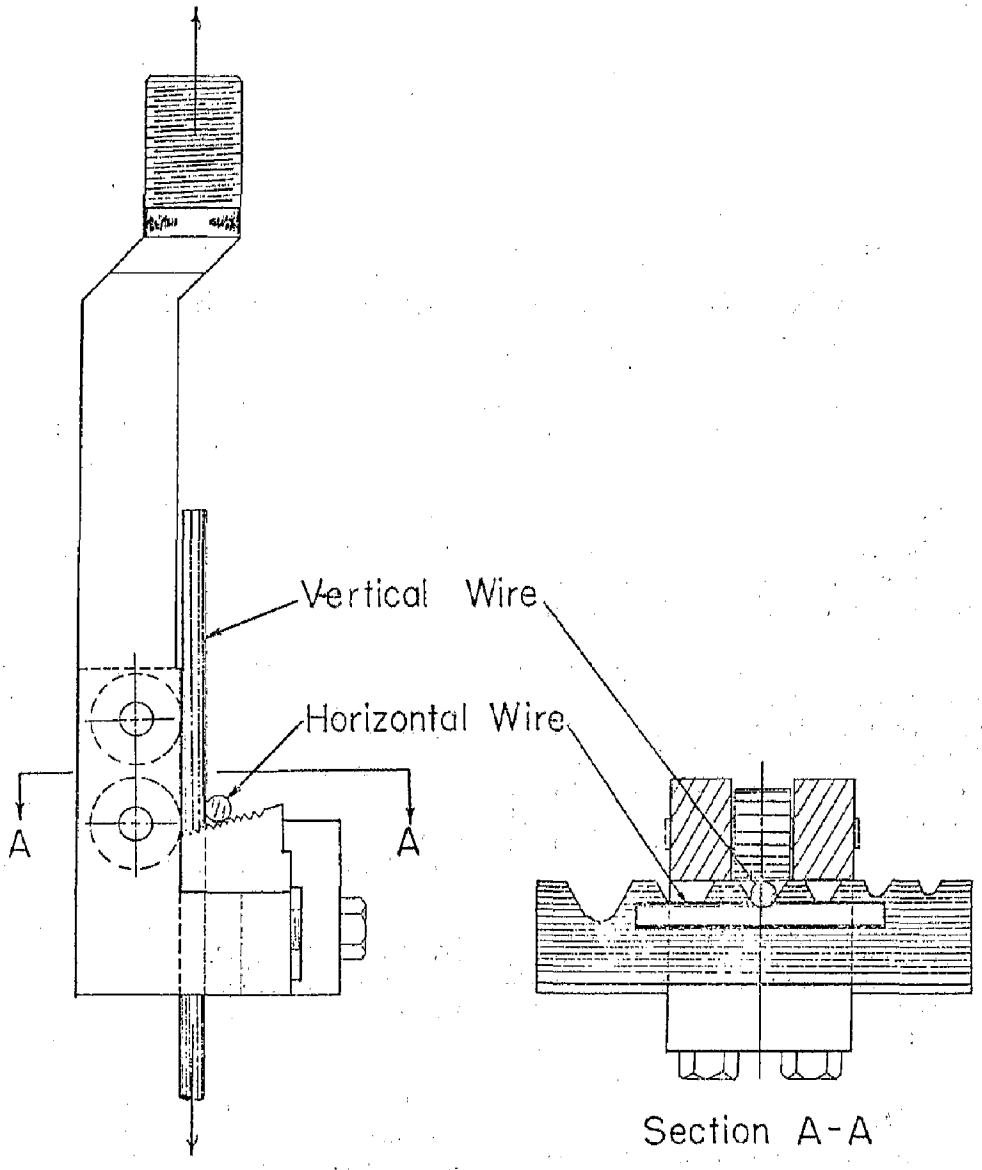

FIG. 1 Welded Wire Fabric Weld Tester.

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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.

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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.[5]

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.

[5] *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 ⅛ 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

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

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Document Name: ASTM A501: Hot-Formed Welded and Seamless Carbon Steel Structural Tubing

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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.

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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 $\frac{1}{16}$ 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.

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 33⅓ 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.

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)

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	4.32 (6.43)	0.141 (3.58)
(76.2 by 50.8)	5.59 (8.32)	0.188 (4.78)
	7.10 (10.56)	0.250 (6.35)
4 by 2	5.78 (8.60)	0.156 (3.96)
(101.6 by 50.8)	6.86 (10.21)	0.188 (4.78)
	8.80 (13.09)	0.250 (6.35)
4 by 3	6.88 (10.24)	0.156 (3.96)
(101.6 by 76.2)	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	9.31 (13.85)	0.188 (4.78)
(127.0 by 76.2)	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	10.58 (15.74)	0.188 (4.78)
(152.4 by 76.2)	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	11.86 (17.65)	0.188 (4.78)
(152.4 by 101.6)	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	14.41 (21.44)	0.188 (4.78)
(177.8 by 127.0)	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	14.41 (21.44)	0.188 (4.78)
(203.2 by 101.6)	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	16.85 (25.07)	0.188 (4.78)
(203.2 by 152.4)	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	25.44 (37.85)	0.250 (6.35)
(254.0 by 152.4)	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

CERTIFICATE

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THE UNITED STATES OF AMERICA
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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.

Document Name: ASTM A502: Steel Structural Rivets

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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.

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[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.

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		Acceptable Quality Level 10.0	
		Acceptance[a]	Rejection[b]	Acceptance[a]	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.

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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.

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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 %.

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[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.

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.

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Document Name: ASTM A522: Forged or Rolled 8 and 9% Nickel Alloy Steel Flanges, Fittings, Valves, and Parts for Low-Temperature Service

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WASHINGTON, D.C.

Designation: A 522/A 522M – 95b

Standard Specification for Forged or Rolled 8 and 9 % Nickel Alloy Steel Flanges, Fittings, Valves, and Parts for Low-Temperature Service[1]

This standard is issued under the fixed designation A 522/A 522M; 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 8 and 9 % nickel-alloy steel forged or rolled flanges, fittings, valves, and parts intended for use in welded pressure vessels for low-temperature service. The specification is applicable to forgings with maximum section thickness of 3 in. [75 mm] in the double normalized and tempered condition and 5 in. [125 mm] in the quenched and tempered condition. Forgings under this specification are intended for service at operating temperatures not lower than −320°F [−196°C] for Type I or −275°F [−170°C] for Type II or higher than 250°F [121°C].

1.2 Material under this specification is available in two types having different chemical compositions as follows:

Type	Nominal Nickel Content, %
I	9
II	8

1.3 Supplementary requirements S1 and S2 are optional and shall apply when specified by the purchaser.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

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 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 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[3]

A 788 Specification for Steel Forgings, General Requirements[4]

[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 A01.22 on Valves and Fittings.

Current edition approved June 15, 1995. Published August 1995. Originally published as A 522 – 64. Last previous edition A 522/A 522M – 95a.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-522 in Section II of that Code.

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

[4] *Annual Book of ASTM Standards*, Vol 01.05.

3.1 Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.1.1 Quantity,

3.1.2 Size and pressure class or dimensions (Tolerances and surface finishes should be included),

3.1.3 Specification number and type (The year date should be included),

3.1.4 Supplementary requirements, and

3.1.5 Additional requirements, (See 4.4, 11.6, 16.1, 17.1, 17.2, and 18.3).

4. Materials and Manufacture

4.1 The steel shall be produced in accordance with the melting process section of Specification A 788.

4.2 Material for forgings shall consist of ingots, or either forged or rolled blooms, billets, or bars.

4.3 The finished product shall be a forging as defined in the Terminology Section of Specification A 788.

4.4 When specified in the order, the manufacturer shall submit for purchaser's approval a sketch showing the shape of the rough forging before machining.

5. Chemical Composition

5.1 The steel shall conform to the requirements for chemical composition as prescribed in Table 1. Test Methods, Practices, and Terminology A 751 shall apply.

6. Tensile Requirements

6.1 The forgings shall conform to the tensile property requirements prescribed in Table 2.

6.2 The forgings shall be tested in accordance with the latest issue of Test Methods and Definitions A 370.

7. Impact Requirements

7.1 Impact tests shall be conducted at −320°F [−195°C] for Type I and at −275°F [−170°C] for Type II, except when a higher temperature is specified in accordance with Supplementary Requirement S2. Each test shall consist of three specimens and each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [15 mils] [0.38 mm].

7.2 The values of energy absorption in footpounds (or joules) and the fracture appearance in percent shear shall be recorded and reported for information.

TABLE 1 Chemical Requirements

	Composition, %	
	Type I	Type II
Carbon, max	0.13	0.13
Manganese, max	0.90	0.90
Phosphorus, max		
Heat analysis	0.025	0.025
Product analysis	0.030	0.030
Sulfur, max	0.025	0.025
Silicon[A]		
Heat analysis	0.15–0.30	0.15–0.30
Product analysis	0.13–0.32	0.13–0.32
Nickel		
Heat analysis	8.5–9.5	7.5–8.5
Product analysis	8.40–9.60	7.40–8.60

[A] When vacuum carbon deoxidation is used, the maximum silicon content shall be 0.10 %.

TABLE 2 Tensile Requirements at Room Temperature

Tensile strength, min, ksi [MPa]	100 [690]
Yield strength, min, (0.2 % off-set), ksi [MPa]	75 [515]
Elongation in 2 in. [50mm], min, %	22
Reduction of area, min, %	45

8. Heat Treatment

8.1 The forgings shall be heat treated by the manufacturer by either of the following methods as mutually agreed upon between the purchaser and the manufacturer.

8.1.1 *Quenched and Tempered*—Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time of 1 h/in. (2.4 min/mm) of thickness but in no case less than 30 min; quench by immersion in circulating water. Reheat until the forging attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. of thickness but in no case less than 30 min; cool in air or water quench, at a rate not less than 300°F [165°C]/h.

8.1.2 *Double Normalized and Tempered*—Heat to a uniform temperature of 1650°F [900°C]; hold at this temperature for a minimum time of 1 h/in. (2.4 min/mm) of thickness but in no case less than 30 min; cool in air. Reheat until the forging attains a uniform temperature of 1450°F [790°C]; hold at this temperature for a minimum time of 1 h/in. of thickness but in no case less than 30 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. of thickness but in no case less than 30 min; cool in air or water quench, at a rate not less than 300°F [165°C]/h.

8.2 When stress relieving is to be performed after fabrication, the recommended stress-relieving treatment is as follows: gradually and uniformly heat the steel to a temperature between 1025 and 1085°F [550 and 585°C]; hold for a minimum of 2 h for thicknesses up to 1 in. [25 mm]. For thicknesses over 1 in. [25 mm], a minimum additional holding time in the ratio of 1 h/in. (2.4 min/mm) of thickness in excess of 1 in. [25 mm] shall be added. Cool at a minimum rate of 300°F [165°C]/h to a temperature not exceeding 600°F [315°C].

9. Cast or Heat (Formerly Ladle) Analysis

9.1 An analysis of each heat of steel shall be made by the manufacturer to determine percentages of the elements specified in Table 1.

10. Product (Check) Verification Analysis

10.1 An analysis may be made by the purchaser from a forging representing each heat. Samples for analysis shall be taken not less than ¼ in. [6 mm] below the surface of the forgings, or from tension test specimens. The chemical composition thus determined shall conform to the requirements specified in Table 1.

11. Test Specimens

11.1 The tension and impact specimens may be obtained from a rough or finished production forging, or prolongation thereof, or from special forged blocks, suitably worked and heat treated with the production forgings. These tension and impact tests may represent all forgings from the same heat and heat treatment charge, provided the maximum thickness of such forgings is not greater than the thickness of the test forging, prolongation, or special test block. Such special test blocks shall be forged in a manner similar to and shall have a maximum reduction not greater than the forgings represented. The manufacturer shall provide the required extra forgings or test blocks.

11.2 The test specimens shall be located at any point midway between the center and surface of solid forgings, and at any point midthickness of the heaviest section of hollow or bored forgings. For solid forgings where test metal is provided on the periphery, test specimens shall be taken at mid-thickness of the test prolongation.

11.3 Tests shall be oriented so that the longitudinal axis of the specimen is parallel to the major direction of grain flow.

11.4 The tension test specimens shall be machined to the standard specimen form and dimensions shown in Fig. 4 of Test Methods and Definitions A 370. In the case of sections too small to accommodate the standard specimen, the largest practicable small-size specimen shown in Fig. 4 of Test Methods and Definitions A 370 shall be used.

11.5 Standard Charpy V-notch specimens in accordance with Fig. 10 of Test Methods and Definitions A 370 shall be used, except where the material is of insufficient thickness to permit their use, in which case the largest obtainable specimens shown in 20.2.2 of Test Methods and Definitions A 370 shall be used.

11.6 When fabrication requires stress relieving, the purchaser shall specify stress relieving of the test pieces prior to machining of the test specimens. Stress relieving shall be carried out as prescribed in 8.2.

12. Method of Impact Testing

12.1 The impact test shall be made in accordance with the simple beam, Charpy type of test described in the latest issue of Test Methods and Definitions A 370.

12.2 Precaution shall be taken so that when broken, the test specimens shall be within ±3°F [1.7°C] of the specified test temperature.

13. Workmanship, Finish, and Appearance

13.1 The forgings shall have a workman-like finish and shall be free of injurious defects.

14. Number of Tests and Retests

14.1 At least one tension test and one set of impact tests (three specimens) shall be made from each heat in each heat-treatment charge, subject to the provisions of 11.5.

14.2 If any test specimens fail due to mechanical causes, such as testing-equipment failure or improper specimen preparation, the specimens may be discarded and replacement specimens shall be considered as original tests.

14.3 If the results of the mechanical tests do not conform to the specified requirements, the manufacturer may retreat the forgings, but not more than three additional times. Retests shall be made in accordance with this section.

14.4 If the percentage elongation of any tension test specimen is less than that prescribed in Table 2 and any part of the fracture is outside the middle half of the gage length, a retest shall be allowed.

14.5 If the results of mechanical tests do not conform to the specified requirements because a flaw develops in the test specimen, a retest shall be allowed if the defect is not caused by ruptures, cracks, or flakes in the steel.

14.6 If the result from a test on one Charpy impact specimen from a set is below 0.015 in. [0.38 mm] in lateral expansion but not below 0.010 in. [0.25 mm] and the average test result on the set of specimens equals or exceeds 0.015 in. [0.38 mm], one retest of three additional specimens may be made. Each of the test results on the retested specimens shall equal or exceed 0.015 in. [0.38 mm].

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 the inspector 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 conducted so as not to interfere unnecessarily with the operation of the works.

15.2 The manufacturer shall report to the purchaser or the purchaser's representative the heat treatments applied to the material and to the test blocks and the results of the chemical analysis and mechanical tests made in accordance with this specification and the heat number or his heat identification.

16. Rejection

16.1 Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported to the manufacturer within 60 days from the receipt of samples or test reports by the purchaser.

16.2 Each forging in which injurious metal defects are exposed during subsequent machining shall be rejected and the manufacturer notified.

17. Certification

17.1 For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards unless written certification is required by the purchaser, the application of identification marks as required in Section 18 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification.

17.2 Test reports, when required, shall include certification that all requirements of this specification have been met. The manufacturer shall provide the following where applicable:

17.2.1 Whether Type 1 or Type 11 material has been supplied and the chemical analysis results in accordance with Section 6,

17.2.2 Type of heat treatment used,

17.2.3 Results of tension and Charpy impact tests including the impact test temperature, and test coupon stress relief details if applicable,

17.2.4 Results of any additional or supplementary requirements specified by the purchaser, and

17.2.5 The year date and revision letter, if any, of the specification. Note, this information is not required to be marked on the forgings.

18. Product Marking

18.1 Each forging shall be legibly stamped by the manufacturer with the heat number or his heat identification, the manufacturer's name (Note) or trademark, and this specification number, A 522/A 522M, 8NI, or 9NI as applicable, and QT or NNT as applicable.

NOTE—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

18.2 Forgings impact tested at temperatures other than that specified in 7.1 shall be marked with the letters LTV following the specification number. These letters shall be followed by the impact test temperature in degrees Fahrenheit. A prefix 0 to the test temperature indicates a temperature below 0°F [−17.8°C], for example LTV0300 indicates −300°F [−184°C].

18.3 The purchaser may specify additional identification marking and the location of all stamping. The type of stamps shall be round or "interrupted-dot" die stamps having a radius of 1/32 in. [0.8 mm].

18.4 *Bar Coding*—In addition to the requirements in 18.1, 18.2, and 18.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 nickel alloy steel; pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, alloy; steel valves; temperature service applications, low

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below may be included in purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Nondestructive Tests

S1.1 *Ultrasonic Tests*—Ultrasonic tests may be made by agreement between manufacturer and purchaser.

S1.2 *Liquid Penetrant Tests*—Liquid penetrant tests may be made by agreement between manufacturer and purchaser.

S2. Other Impact Test Temperatures

S2.1 The purchaser may specify an impact test temperature higher than that in 7.1 but no higher than the minimum intended operating temperature for the forging.

S2.2 Marking shall be in accordance with 18.2.

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.

Document Name: ASTM A539: Standard Specification for Electric-Resistance-Welded Coiled Steel Tubing for Gas and Fuel Oil Lines

CFR Section(s): 24 CFR 3280.705(b)(4)

Standards Body: American Society for Testing and Materials

APPROVED

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

Designation: A 539 – 90a

Standard Specification for Electric-Resistance-Welded Coiled Steel Tubing for Gas and Fuel Oil Lines[1]

This standard is issued under the fixed designation A 539; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers one grade of electric-resistance-welded coiled steel tubing 2⅜ in. (60.3 mm) and under in outside diameter and 0.035 to 0.125 in. (0.89 to 3.18 mm), inclusive, in average wall thickness. The tubing is intended for conveyance of gas and fuel oil.

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

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[2]

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[3]

3. General Requirements for Delivery

3.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

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

4.1.1 Quantity (number of feet),

4.1.2 Name of material (electric-resistance-welded tubing),

4.1.3 Tube size (specified outside diameter and wall thickness),

4.1.4 Check analysis (see 6.1),

4.1.5 Specification designation,

4.1.6 End use of material, and

4.1.7 Test pressure, if higher than minimum specified (see 11.4).

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1. For referee purposes, Test Methods E 30 shall be used.

5.2 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in Table 1 is not permitted.

6. Check Analysis

6.1 When requested in the purchase order, a check analysis shall be made by the supplier from one coil per lot (Note 1). The chemical composition, thus determined, shall conform to the specified requirements.

NOTE 1—A lot consists of 250 coils or less of one size produced from the same heat of steel.

6.2 If the original test for check analysis fails, retests of two additional coils shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise, all remaining material in the lot shall be rejected or, at the option of the producer, each coil may be tested for acceptance. Coils which do not meet the requirements of this specification shall be rejected.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

NOTE 2—Footnote *A* of Table 2 gives the computed minimum elongation values for each 1/32 in. (0.79 mm) decrease in wall thickness. Where the wall thickness lies between two values shown, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00$$

where:

E = elongation in 2 in. or 50 mm, %, and

t = actual thickness of specimen, in. (mm).

8. Height of Flash

8.1 The inside welding flash need not be removed. The height of flash shall not exceed the wall thickness or 3/32 in. (4.8 mm) whichever is smaller.

TABLE 1 Chemical Requirements

Element	Composition, %, max
Carbon	0.15
Manganese	0.63
Phosphorus	0.035
Sulfur	0.035

[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 Steel Pipe.

Current edition approved July 27, 1990. Published September 1990. Originally published as A 539 – 65 T. Last previous edition A 539 – 90.

[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 2 Tensile Requirements

Tensile strength, min, ksi (MPa)	45 (310)
Yield strength, min, ksi (MPa)	35 (241)
Elongation in 2 in. or 50 mm, min, %:	21
Basic minimum elongation for 0.125-in. (3.18-mm) wall	
For tube walls lighter than 0.125 in. (3.18 mm), a deduction for each 1/32 in. (0.79 mm) decrease in wall thickness below 0.125 in. from the basic minimum elongation of the following percentage points	1.50[A]

[A] The following table gives the computed minimum values:

Wall Thickness		Elongation in 2 in. or 50 mm, min, %
in.	mm	
1/8 (0.125)	3.18	21.0
3/32 (0.094)	2.38	20.0
1/16 (0.062)	1.59	18.0
1/32 (0.031)	0.79	17.0

9. Dimensions and Permissible Variations

9.1 The outside diameter shall not vary more than ±0.007 in. (±0.18 mm) from the specified size.

9.2 The minimum wall thickness at any point shall be not more than 10.0 % under the specified wall thickness.

10. Workmanship, Finish, and Appearance

10.1 Tubing shall be free of imperfections in excess of 10 % of the specified wall thickness and shall have a workmanlike finish.

11. Number of Tests

11.1 One longitudinal tension test shall be made on one length from each lot of 250 coils or fraction thereof.

11.2 A flattening test shall be made on both crop ends cut from each coil of tubing, with the weld located alternately at zero and 90° from the line of direction of force.

11.3 Each tube shall be tested by the non-destructive electric method.

11.4 Each coil of tubing shall be pressure tested at the mill at 150 psi (1034 kPa) gage min pressure for a minimum of 10 s.

12. Product Marking

12.1 In addition to the marking specified in Specification A 450/A 450M, the marking shall include the test pressure, when that pressure is higher than the minimum specified in 11.4. The marking shall be legibly stenciled on a tag securely attached to each coil.

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.

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.

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:

Grade	Mechanical Properties: Yield Point, min, psi (MPa)	Mechanical Properties: 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

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ASTM F1193-2006: Standard Practice for Quality, Manufacture, and Construction of Amusement Rides and Devices as required by:
Commonwealth of Virginia, 13 VAC 5-31-40(A)(2)
State of Indiana, 685 IAC 1-2-9
State of Florida, FAC 5F-8.0011

Designation: F 1193 – 06

Standard Practice for Quality, Manufacture, and Construction of Amusement Rides and Devices[1]

This standard is issued under the fixed designation F 1193; 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 practice establishes the minimum requirements for a quality assurance program and the manufacturing of amusement rides and devices (including major modifications).

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 543 Practice for Agencies Performing Nondestructive Testing

F 770 Practice for Operation Procedures for Amusement Rides and Devices

F 853 Practice for Maintenance Procedures for Amusement Rides and Devices

F 1193 Practice for Amusement Ride and Device Manufacturer Quality Assurance Program and Manufacturing Requirements

F 1950 Specification for Physical Information to be Transferred With Used Amusement Rides and Devices

F 2291 Practice for Design of Amusement Rides and Devices

2.2 *AWS Standards:*[3]

As applicable.

2.3 *ASME Standards:*[4]

As applicable.

2.4 *ASNT Document:*[5]

Recommended Practice SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

3. Significance and Use

3.1 The purpose of this practice is to provide the minimum manufacturing requirements for amusement rides and devices and to provide the minimum requirements for a written quality assurance program for an amusement ride or device manufacturer, or component supplier. This is not intended to include suppliers of off-the-shelf components (for example, fasteners, electrical wire, etc.).

4. Drawing Control Procedure

4.1 A procedure shall be in effect so that appropriate manufacturing drawings, their engineering revisions, and related documents are utilized.

5. Material and Component Control Procedure

5.1 A procedure shall be in effect so that materials, processes, and components, including raw materials, are in accordance with the engineering specifications.

5.1.1 This procedure shall provide the purchasing agent with all the information required to order appropriate material.

5.1.2 A receiving procedure shall be in effect so that incoming material and components are checked against the purchasing specifications.

5.1.3 A procedure shall be in effect so that material in stock can be properly identified for future use.

5.1.4 Documentation on any material, process, or components certified shall be filed for reference.

6. Manufacturing

6.1 Amusement ride and device components and systems shall be manufactured and assembled in accordance with the designer/engineer specified criteria.

6.2 Changes to the designer/engineer specified criteria shall be documented and approved by the designer/engineer or a

[1] This practice is under the jurisdiction of ASTM Committee F24 on Amusement Rides and Devices and is the direct responsibility of Subcommittee F24.24 on Design and Manufacture.

Current edition approved March 1, 2006. Published March 2006. Originally approved in 1988. Last previous edition approved in 2005 as F 1193 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from The American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[5] Available from The American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518.

qualified engineer before components, subassemblies, or systems are placed into use.

6.3 *Quality Assurance Program*:

6.3.1 The manufacturer of an amusement ride or device shall have a written quality assurance program as specified in Practice F 1193 for use in conjunction with the design, manufacture, construction, modification, or reconditioning of the amusement ride or device.

6.3.2 Quality assurance documents, that is, material certifications, test reports, and inspection reports, shall be retained for a period of time as deemed appropriate by the manufacturers.

7. Inspection

7.1 A procedure shall be in effect so that appropriate inspections are made on manufactured parts and subassemblies, for conformance with the designer/engineer specified criteria.

7.2 A procedure shall be in effect so that appropriate inspections are made on purchased components.

7.3 A procedure shall be in effect so that completed subassemblies, or where practical, the assembled amusement rides or devices are inspected prior to delivery.

7.4 Non-conforming components found in 7.1, 7.2, or 7.3 shall be identified and evaluated. Disposition of the non-conforming components shall be one of the following:

7.4.1 The non-conforming component shall be scrapped or rejected, or

7.4.2 The non-conforming component shall be altered such that it cannot be used in the specific intended application for the component, or

7.4.3 The non-conforming component shall be reworked to bring it into compliance and re-inspected in conformance with 7.1, 7.2, or 7.3 of this practice.

7.4.4 The design of the non-conforming component shall be re-evaluated in accordance with 6.2 of this practice, and the drawing or documentation shall be modified or created to allow the component to be used as is.

8. Welding

8.1 Welding and welding procedures shall be in accordance with the appropriate American Welding Society (ANSI.AWS D1 specification) or the American Society of Mechanical Engineers, or other equivalent standard, and be performed by appropriately certified or qualified welders as required by the standard.

8.2 Documentation for certified or qualified welders shall be maintained.

9. Certification

9.1 Before a manufacturer ships an amusement ride or device, the manufacturer shall generate a document certifying that the amusement ride or device is in compliance with Practice F 1193. This certification shall be retained with other quality assurance documents for the amusement ride or device. When requested by an amusement ride or device-certifying authority, purchaser, or owner, the manufacturer shall provide a copy of this certification document.

10. Information Requirements

10.1 The information given in 10.2 and 10.3–10.15.3 shall be included, where applicable, on the information plate as specified in 10.2, and in the documented operating and maintenance instructions to be furnished by the manufacturer or seller at the time of sale of each amusement ride or device.

10.2 *Information Plate*—A manufacturer-issued information plate, printed in English, shall be permanently affixed to the ride or device in a visible location, and shall be designed to remain legible for the expected life of the ride or device. The plate shall include, but not be restricted to, all applicable items listed in 10.2-10.2.8.

10.2.1 *Ride Serial Number*—A manufacturer-issued unique identifying number or code affixed to the ride in a permanent fashion.

10.2.2 *Ride Name and Manufacturer*—A manufacturer-issued unique identifying ride name, including the name of the manufacturer by city, state, and country.

10.2.3 *Ride Model Number*—A manufacturer-issued unique identifying number or code assigned to each manufactured type of ride having the same structural design or components.

10.2.4 *Date of Manufacture*—The date (month and year) determined by the manufacturer that the given ride or device met his required construction specifications.

10.2.5 *Ride Speed*—Maximum and minimum revolutions per minute, feet per second, or miles per hour, as applicable.

10.2.6 *Direction of Travel*—When the proper direction of travel is essential to the design operation of the ride, the manufacturer shall designate the direction of travel, including reference point for this designation.

10.2.7 *Passenger Capacity by Weight*—Maximum total passenger weight per passenger position and per ride.

10.2.8 *Passenger Capacity by Number*—Maximum total number of adult or child passengers per passenger position and per ride.

10.3 *Ride Duration*—The actual time the ride is in operation or a passenger is exposed to the elements of the ride functions, including passenger restrictions to maximum exposure time, shall be included.

10.4 *Recommended Balance of Passenger Loading or Unloading*—When passenger distribution is essential to the proper operation of the ride or device, the appropriate loading and unloading procedure with respect to weight distribution shall be provided.

10.5 *Environmental Restrictions*—Recommendations for operational restrictions relating to environmental conditions such as, but not limited to, wind, rain, salt corrosion, and extreme heat or cold.

10.6 *Recommended Passenger Restrictions*—Where applicable, any recommended passenger limitations such as, but not limited to, height passenger placement, or any other appropriate restrictions.

10.7 *Electrical Power Requirements*—Total electrical power required to properly operate the ride or device designated in watts and volts, including minimum and maximum voltage limits.

10.8 *Mechanical Power Requirements*—Minimum horsepower necessary to operate ride properly.

10.9 *Water Flow*—Minimum/maximum water flow rates.

10.10 *Static Information*—The following information shall be provided for the amusement ride or device when it is in a nonoperational state with no passengers: height, width, diameter, and weight.

10.11 *Dynamic Information*—The following information shall be provided for the amusement ride or device when it is in an operational state: height, width, diameter, and weight.

10.12 *Trailering Information*—Each trailer necessary for the transport of a portable amusement ride or device shall be provided with the following information: height, width, length, and weight.

10.13 *Fastener Schedule*—A manufacturer-issued schedule for the correct grade, torque, and placement of all fasteners used in the assembly, or erection, or both, of the ride or device.

10.14 *Load Distribution per Footing*—Maximum static loading and maximum dynamic loading of each footing of an amusement ride or device.

10.15 *Elements and Structures*—Provided the proposed owner/operator furnishes the manufacturer with necessary data concerning proposed installation and usage of the ride or device, the manufacturer shall provide to the proposed owner/operator a description of all structural interface between the ride or device and the owner/operator supports. This structural requirement definition shall include the following:

10.15.1 Maximum static design loads of each footing or equivalent structural connection,

10.15.2 Maximum dynamic design loads of each footing or equivalent structural connection, and

10.15.3 Any other structural interface design specification.

11. Operational Instruction Requirements

11.1 The manufacturer of an amusement ride or device shall provide, with delivery of each ride or device, documented, recommended operating instructions in the English language. These instructions shall include, but not be limited to the following:

11.1.1 Description of the ride or device operation, including the function and operation of its major components.

11.1.1.1 Description of the motion(s) of the ride or device during operation.

11.1.1.2 Description of the recommended passenger loading procedures during operation, including recommended seating, where applicable.

11.1.2 Recommended safety procedures and instructions, and information about safety equipment pertaining to patrons and ride or device operators and attendants.

11.1.2.1 Maximum total passenger weight and maximum number of passengers by carrier unit or ride total.

11.1.2.2 Description of the passenger restraint system, its recommended use and operation.

11.1.2.3 Ride or device operator and attendant safety check: recommended visual or other inspections to be performed by ride or device operators and attendants prior to and during each ride or device cycle.

11.1.2.4 Instructions to the patron: recommended information that should be made available to each patron of the ride or device.

11.1.2.5 Recommendations for operational restriction relating to environmental conditions such as wind, rain, or temperature fluctuation.

11.1.3 Manufacturer's recommended ride or device operating procedures, including the location of ride or device operators and attendants.

11.1.3.1 Description of the recommended, daily preopening inspection to be performed by ride or device operator(s) and attendants that is in addition to previously performed maintenance or other inspections.

11.1.3.2 Description of the recommended ride or device operator(s) and attendants positions and functions.

11.1.3.3 Description of the recommended series of steps, to be followed in a definite order, to complete the operation of the ride or device.

11.1.4 Manufacturer's recommended emergency procedures.

11.1.4.1 Recommended evacuation procedures for the ride or device.

11.1.4.2 Use of emergency power equipment, if provided with the ride or device.

11.1.4.3 Description of any emergency equipment that is provided with the ride or device, and its uses.

11.1.4.4 Description of any emergency procedure made necessary by an interruption of power, and restart procedures.

12. Testing Performance Requirements

12.1 *Developmental Testing Requirements*:

12.1.1 Where applicable, as determined by the manufacturer/designer, the following test procedures shall be developed and performed on a prototype amusement ride or device in order that the manufacturer/designer may determine the appropriateness for use, of not only the parts, but the entire system of a newly designed ride or device.

12.1.1.1 *Procedures to Verify Maximum Safe Design Loads*:

12.1.1.2 Procedures to verify such design characteristics as relevant deflections, loads, and forces that are placed on both the equipment and the passengers during operation of the ride or device,

12.1.1.3 A procedure to determine operational limits and restart criteria due to environmental conditions,

12.1.1.4 Procedures to allow the manufacturer to determine such factors as component variability and certification requirements of components, and

12.1.1.5 Any other procedures necessary to demonstrate a ride or device's appropriateness for its intended use.

12.2 *Installation Testing Requirements*:

12.2.1 This section of the guide covers those tests relevant not only to installation, but also includes post-modification and major modifications. The original manufacturer or supplier of an amusement ride or device shall also provide, where applicable, the following standard testing guides:

12.2.1.1 *Materials Testing*—Acceptable test procedures for the certification of all major structural components shall be provided. Where possible, this testing should be referenced to ASTM or to other commonly accepted industry standards.

12.2.1.2 *Erection/Modification Acceptance Testing*—Test procedures or criteria for the acceptance of such construction operations as welding and fastening shall be provided. Again,

where possible, reference should be made to ASTM or to other currently accepted industry standards for this purpose.

12.2.1.3 *Performance Testing*—This should consist of a series of specified tests that can be used to determine that the newly erected ride or device conforms to the original design criteria.

12.3 *Operational Testing Requirements*:

12.3.1 The manufacturer of a ride or device shall develop specific operational tests along with minimum intervals for these tests to be performed that will allow the owner/operator of the ride or device to determine whether a given ride or device is operating within prescribed operational limits.

12.3.2 All operational tests, except those necessarily recommended subsequent to the sale because of information not reasonably available to the manufacturer at the time of sale, should be recommended to the owner/operator at the time of sale. All tests, whether recommended at the time of sale, or subsequent tests, shall meet the following criteria:

12.3.2.1 All tests shall have been satisfactorily performed by the manufacturer prior to sale.

12.3.2.2 The tests must be such that the ride, device, or element can reasonably be expected to pass during the expected design life, assuming recommended maintenance and operative procedures have been followed.

12.3.2.3 All tests must be reasonable and such that the owner/operator can reasonably be expected to be competent to perform or cause to be performed.

12.3.2.4 Any operational test including load testing performed on an amusement ride or device shall be completely nondestructive in nature. Overload testing exceeding the above limits shall be deemed inappropriate.

12.3.2.5 Any installation or operational testing conducted on an amusement ride or device shall be accomplished within the rated limits of the information provided by the manufacturer.

12.4 *Non-Destructive Testing Requirements*:

12.4.1 This section pertains to the nondestructive testing of amusement ride and device components as recommended by the manufacturer. These tests shall be performed by a qualified NDT inspector in accordance with Practice E 543 or ASNT Recommended Practice SNT-TC-1A, or both. It is not intended to preclude any other schedule of NDT, inspection, or testing.

12.4.1.1 Nondestructive testing (NDT) is the development and application of technical methods such as radiographic, magnetic particle, ultrasonic, liquid penetrant, electromagnetic, neutron radiographic, acoustic emission, visual, and leak testing to examine materials or components in ways that do not impair the future usefulness and serviceability in order to detect, locate, measure and evaluate discontinuities, defects, and other imperfections; to assess integrity, properties and composition; and to measure geometrical characters.

12.4.1.2 NDT shall be used to verify the integrity of components which due to their design, location, or installation, or combination thereof, cannot be adequately evaluated by other means.

12.4.1.3 A schedule for testing on a given ride or device component shall be defined in terms of hours, days, or other units of operation. The initial design shall be developed to expect a period between tests to be no more frequent than annually.

12.4.1.4 The manufacturer shall recommend components to be tested along with appropriate acceptance criteria. The manufacturer may recommend the test method but shall not specify how the testing is to be conducted except where certain procedures might endanger other components on the ride or device. Any changes or additions to these recommendations shall be communicated to all known owner/operators of the ride or device, and inspection agencies via manufacturers' bulletins. Tests shall meet the requirements of 12.3.2.1-12.3.2.3.

12.4.1.5 The manufacturer shall include in an appropriate section of the ride or device manual the list and location of components to be tested, recommending specific areas to test and the schedule by which they shall be tested in accordance with 12.4.1.4.

12.4.1.6 Components found to have relevant indications that do not meet the acceptance criteria shall be replaced or reconditioned in accordance with Practice F 1193.

12.4.1.7 Components found free of relevant indications that meet the acceptance criteria or have been reconditioned shall be further tested at the regular schedule in accordance with 12.4.1.3.

12.4.1.8 Within a reasonable time following a request by an owner/operator or inspection agency, the manufacturer of an amusement ride or device whose manual does not contain testing recommendations shall either provide a component listing or statement that no NDT is recommended on the ride or device as per the criteria outline of 12.4.1.2 When a manufacturer's list or statement is not available, it may be compiled by a registered professional engineer or engineering agency or by any individual qualified by training and experience to compile such a list or statement based upon the ride or device's specifications and history and using accepted engineering practices.

13. Maintenance Procedure Requirements (from Practice F 853)

13.1 The manufacturer of an amusement ride or device shall provide, with delivery of each ride or device, documented maintenance instructions in the English language. These instructions shall include, but not be limited to, the following:

13.1.1 Description of the ride or device operation, including the function and operation of its major components.

13.1.1.1 Description of the designed motion(s) of the ride or device during operation.

13.1.2 Description of the recommended procedures for installation, setup, disassembly, and transportation of an amusement ride or device.

13.1.3 Recommended lubrication procedures for the amusement ride or device.

13.1.3.1 Recommended types and specifications of lubricants.

13.1.3.2 Recommended frequency of lubrication.

13.1.3.3 A lubrication drawing, chart, or instruction, showing the location of lubrication points.

13.1.3.4 Recommended special method of lubrication, where applicable.

13.1.4 Description of the recommended daily, preopening inspection to be performed and identification of special care areas and recommended procedures for inspection and maintenance of these areas.

13.1.5 Description, including frequency, of recommended maintenance inspections and testing, other than daily preopening inspection.

13.1.5.1 Recommended wear limits or tolerances, where deemed necessary by the manufacturer.

13.1.5.2 Recommended operational tests, along with minimum intervals for these tests to be performed, that will allow the owner/operator of the ride or device to determine whether a given ride or device is operating within recommended prescribed operational limits.

13.1.5.3 Where applicable, recommended nondestructive testing along with appropriate acceptance criteria, including suggested frequency and the special parts of areas to be tested.

13.1.5.4 Tests recommended pursuant to 13.1.5 shall meet the following criteria:

(1) The tests shall have been performed satisfactorily by the manufacturer prior to the sale of the amusement ride or device,

(2) The test shall be a test that the amusement ride or device, or element, can reasonably be expected to pass during the expected life of the amusement ride or device, or element, assuming recommended maintenance and operating procedures have been followed, and

(3) The test shall be a test that is reasonable, and that the owner/operator can reasonably be expected to be competent to perform or cause to be performed.

13.1.6 Recommended specifications for the use of replacement fasteners, and recommended torque requirements for fasteners, where applicable. If appropriate, precautionary information will be provided relating to the continued use of fasteners that have been loosened or retorqued.

13.1.7 Schematics of electrical power, lighting, controls, and other systems, including location charts and manufacturer's troubleshooting guide, where applicable.

13.1.7.1 Description of recommended maintenance procedures for electrical components.

13.1.7.2 The name of the component manufacturer and appropriate identification number or specifications, or both, will be provided for electrical components used within the amusement ride or device.

13.1.7.3 Each electrical component used within the amusement ride or device will be assigned an individual identification number, symbol, or code to facilitate its location and identity on the electrical schematics.

13.1.8 Schematics of hydraulic and pneumatic systems, including recommended pressures, location of components, line specification, fitting specification, type of fluid, location chart, and manufacturer's troubleshooting guide.

13.1.8.1 Description of recommended maintenance procedures for hydraulic and pneumatic systems and components.

13.1.9 List of parts used in the assembly of the ride or device, or drawings showing component parts and their use.

13.1.10 Recommended procedures to be followed in the event of an extended period of non-operation or storage, or both.

13.1.11 Description of recommended assembly and disassembly techniques and procedures, pertaining to specific components, as deemed necessary by the manufacturer.

13.1.12 Recommended restrictions and special procedures, lubricants, materials, or equipment that may be necessary because of environmental conditions.

13.1.13 Other recommendations known to the manufacturer and specific to certain serial numbered rides or devices.

14. Manufacturer Supplemental Bulletin Requirements

14.1 Supplemental notification bulletins delivered by the manufacturer of an amusement ride or device to the owner/operator that were not provided at the time of sale and contain new information or newly recommended inspections or testing, or both, shall be consistent with the following criteria in order to carry the force and effect of this practice:

14.1.1 Modifications, procedures, testing, or inspections shall conform to Practices F 770, F 1193, and F 2291.

14.1.2 Modifications, procedures, testing, and inspections shall be reasonable, ethical, and consistent with the general manufacturing practices within the industry.

14.1.3 Supplemental notification bulletins when used shall have a page header that contains the following information, when available:

14.1.3.1 The name, address and telephone number of the issuing entity,

14.1.3.2 The date the bulletin is released,

14.1.3.3 The date the bulletin takes effect,

14.1.3.4 The period the bulletin recommends for completion,

14.1.3.5 The name of the original ride or device manufacturer,

14.1.3.6 The name of the ride or device,

14.1.3.7 The model number of the ride or device,

14.1.3.8 The serial numbers of the affected rides or devices,

14.1.3.9 The applicable dates of manufacture for the affected rides or devices,

14.1.3.10 A number that uniquely identifies the bulletin,

14.1.3.11 The number of the superseded bulletin, where applicable, and

14.1.3.12 The page number and number of total pages.

14.1.4 The first page shall contain, in large bold upper case letters, one of the following titles:

14.1.4.1 "SAFETY ALERT" for notifications that recommend immediate action (see Fig. A1.1),

14.1.4.2 "SERVICE BULLETIN" for notifications that do not recommend immediate action but do recommend future action (see Fig. A1.2), and

14.1.4.3 "NOTIFICATION" for notifications that do not necessarily recommend future action but are primarily for promulgation of information (see Fig. A1.3).

14.1.5 The first page shall contain a summary of the information contained in the body of the bulletin.

14.1.6 The first page shall summarize the reason(s) that prompted the release of the bulletin.

14.1.7 The first page shall list the recommended action to be taken, for example: Inspection, modification, part replacement, new parts, nondestructive testing, procedural change, manual revision, operational revision, etc.

14.1.8 The remainder of the first page and any supplemental pages shall contain text detailing the information being promulgated. Drawings and diagrams may be used for clarification where applicable.

14.1.9 The supplemental notification bulletin, when printed, shall be in black ink on white paper. The following colored ink may be used to print titles:

14.1.9.1 Red—for safety alert,

14.1.9.2 Blue—for service bulletins, and

14.1.9.3 Green—for notifications.

14.1.10 The supplemental notification bulletins shall follow the format provided in Annex A1.

15. Inspection Requirements

15.1 The manufacturer of an amusement ride or device shall provide the owner/operator with a written inspection procedure to be delivered with the ride or device. The document shall outline the inspections as contained in Practices F 1193 and F 770.

15.1.1 Any changes in the procedure prescribed in 15.1 deemed essential by the manufacturer due to information not available to the manufacturer at the time of delivery shall be communicated to all known owner/operators.

15.2 All inspections, whether recommended at the time of sale or subsequently, shall meet the following criteria:

15.2.1 Inspections are such that shall have been satisfactorily performed by the manufacturer.

15.2.2 Inspections are ones in which the ride or device or element can reasonably be expected to pass during the expected design life of the ride, device or element, assuming that recommended maintenance procedures have been followed; and

15.2.3 Inspections are reasonable and are such that the owner/operator can reasonably be expected to be competent to perform or cause to be performed.

15.3 Upon notification from an owner/operator of an incident involving a critical component, the manufacturer of an amusement ride or device shall promptly evaluate this information and disseminate his findings to the original owner/operator, along with any pertinent recommendations, to all known owner/operators.

16. Used Ride or Device Information Requirements (from Specification F 1950)

16.1 The original manufacturer of the used amusement ride or device being sold shall make available, upon request by the purchaser, owner, operational, and maintenance information along with updates, if any.

16.2 The original manufacturer of the used amusement ride or device being sold shall make available to the purchaser information regarding any major modifications made to the ride or device that the manufacturer authorized or otherwise performed on the ride or device.

17. Keywords

17.1 amusement rides and devices; inspection; manufacturing; quality assurance; welding

ANNEX

(Mandatory Information)

A1. SUPPLEMENTARY NOTIFICATION BULLETINS FORMAT

Issuing Entity Logo	Issuing Entity : Name Address City,State Zip Country Phone Fax E-mail Or Web Site	Bulletin No.: Release Date: Effective Date: Supercedes: Completion Date: Page: 1 of 1

SAFETY ALERT

Ride Manufacturer:	Affected Production Dates:
Ride Name:	Affected Serial Nos.:
Model Number:	
Abstract Of Issue:	
Reason For Release:	
Action To Be Taken:(Inspection, Modification, Replacement, NDT, Order Parts, Manual Revision, Procedural Change, etc.)	
Detail Of Issue: (Text/Drawings/Schematics)	

FIG. A1.1 Safety Alert Bulletin

Issuing Entity Logo	Issuing Entity : Name Address City,State Zip Country Phone Fax E-mail Or Web Site	Bulletin No.: Release Date: Effective Date: Supercedes: Completion Date: Page: 1 of 1

SERVICE BULLETIN

Ride Manufacturer:	Affected Production Dates:
Ride Name:	Affected Serial Nos.:
Model Number:	
Abstract Of Issue:	
Reason For Release:	
Action To Be Taken:(Inspection, Modification, Replacement, NDT, Order Parts, Manual Revision, Procedural Change, etc.)	
Detail Of Issue: (Text/Drawings/Schematics)	

FIG. A1.2 Service Bulletin

Issuing Entity Logo	Issuing Entity : Name Address City,State Zip Country Phone Fax E-mail Or Web Site	Bulletin No.: Release Date: Effective Date: Supercedes: Completion Date: Page: 1 of 1

NOTIFICATION

Ride Manufacturer:	Affected Production Dates:
Ride Name:	Affected Serial Nos.:
Model Number:	

Abstract Of Issue:

Reason For Release:

Action To Be Taken:(Inspection, Modification, Replacement, NDT, Order Parts, Manual Revision, Procedural Change, etc.)

Detail Of Issue:
(Text/Drawings/Schematics)

FIG. A1.3 Notification Bulletin

Issuing Entity Logo	Issuing Entity : Name Address City,State Zip Country Phone Fax E-mail Or Web Site	Bulletin No.: Release Date: Effective Date: Supercedes: Completion Date: Page: 2 of 2
Ride Manufacturer:	Affected Production Dates:	
Ride Name:	Affected Serial Nos.:	
Model Number:		
Detail Of Issue Continued:(Text/Drawings/Schematics)		

FIG. A1.3 Notification Bulletin *(continued)*

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.

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WASHINGTON, D.C.

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.

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]	Plates Over 1½-in. (38.1 mm) Thick and Shapes Over 426 lb/ft (634 kg/m)
						max, %	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		Tensile Strength, min		Minimum Elongation,[b,c,d] %	
	psi	MPa	psi	MPa	in 8 in. or 200 mm	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.

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.

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WASHINGTON, D.C.

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.

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.

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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.

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[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.

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[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

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.

Document Name: ASTM A615: Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

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

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OFFICE OF THE FEDERAL REGISTER
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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 ⅝ 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*:

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[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.

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[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

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
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.

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.

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.

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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.

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[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							
		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 percent 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							
		Nominal Dimensions[A]			Deformation Requirements, mm		
Bar Designation No.[B]	Nominal Weight, kg/m	Diameter, mm	Cross Sectional Area, cm^2	Perimeter, mm	Maximum Average Spacing	Minimum Average Height	Maximum Gap (Chord of 12½ percent 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.

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.

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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.

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[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							
		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
SI Units							
		Nominal Dimensions[A]			Deformation Requirements, mm		
Bar Designation No.[B]	Nominal Weight, kg/m	Diameter, mm	Cross-Sectional Area, cm^2	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	4d	4d
6	5d	5d
7, 8	5d	6d
9, 10, 11	5d	8d

CERTIFICATE

By Authority Of
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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.

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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.

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[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.

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)

CERTIFICATE

By Authority Of
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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.

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

APPROVED

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

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,

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[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)