

AMERICAN SOCIETY FOR TESTING AND MATERIALS

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USA STANDARD G24.18-1968
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Standard Specification for QUENCHED AND TEMPERED STEEL BOLTS AND STUDS¹



ASTM Designation: A 449 - 68

This Standard of the American Society for Testing and Materials is issued under the fixed designation A 449; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

Scope

1. This specification covers the chemical and mechanical requirements for quenched and tempered, medium carbon steel bolts and studs 3 in. and under in diameter for general applications where high strength is required.

Material and Manufacture

2. (a) Steel for bolts and studs shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

(b) The bolts and studs shall be heat treated by quenching in a liquid medium from above the transformation temperature and then tempering by reheating to a temperature of not less than 800 F.

(c) Threads of bolts and studs shall be rolled, cut, or ground.

Chemical Requirements

3. (a) The bolts and studs shall conform to the chemical composition specified in Table I.

¹ Under the standardization procedure of the Society, this specification is under the jurisdiction of the ASTM Committee A-1 on Steel, and is the direct responsibility of Subcommittee XXVI on Bolting. A list of committee members may be found in the ASTM Year Book.

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form to the chemical composition specified in Table I.

(b) Check analyses may be made by the purchaser from finished material representing each lot. The chemical composition thus determined shall conform to the requirements prescribed for check analysis in Table I.

Mechanical Requirements

4. (a) Bolts and studs shall not exceed the maximum hardness specified in Table II.

(b) Bolts and studs which are too short, or which have insufficient threads for tension testing, or which have drilled or undersize heads which are weaker than the threaded section shall not be subject to tension tests but shall meet or exceed the minimum hardness specified in Table II.

(c) Bolts and studs other than those accepted in Paragraph (b) shall be subjected to tension tests as specified in Paragraphs (d) and (e), and in Section 7.

(d) Bolts and studs 1½ in. and under in diameter shall meet the requirements for proof load or yield strength, and tensile strength specified in Tables III and IV respectively, in full size.

(c) Bolts and studs $1\frac{1}{4}$ in. and larger in diameter shall preferably meet the requirements for proof load or yield strength and tensile strength specified in Table III in full size. When equipment of sufficient capacity for such tests is not available, or if the length of the bolt or stud makes full size testing impractical, they shall meet the requirements for machined specimens specified in Table V.

TABLE I.—CHEMICAL COMPOSITION.

	Ladle Analysis	Check Analysis
Carbon, per cent.....	0.28 to 0.55	0.25 to 0.58
Manganese, min, per cent...	0.60	0.57
Phosphorus, max, per cent..	0.040	0.048
Sulfur, max, per cent.....	0.050	0.058

Dimensions

5. (a) Unless otherwise specified, the bolts shall be finished hexagon head with dimensions conforming to the latest issue of the USA Standard for Square and Hexagon Bolts and Screws (USAS B18.2.1-1965).

(b) Studs shall have dimensions conforming to those specified by the purchaser.

(c) Unless otherwise specified, threads shall be Coarse Thread Series as specified in the latest issue of the USA Standard for Unified Screw Threads (USAS B1.1-1960), and shall have Class 2A tolerances.

Methods of Test

6. (a) Bolts and studs shall be tested in accordance with Supplement III of the Methods and Definitions for Mechanical Testing of Steel Products (ASTM Designation: A 370).²

(b) The wedge test shall be applicable only to square and hexagon head bolts.

(c) Studs shall be tested by the Axial

Tension Method as described in Section F-2(b), Supplement III of Methods A 370.

Number of Tests and Retests

7. (a) 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

TABLE II.—HARDNESS REQUIREMENTS.

Bolt or Stud Diameter, in.	Hardness	
	Brinell Hardness Number	Rockwell C
$\frac{1}{4}$ to 1, incl.....	241 to 302	23 to 32
Over 1 to $1\frac{1}{2}$, incl...	223 to 285	19 to 30
Over $1\frac{1}{2}$ to 3, incl...	183 to 235	...

heats of steel are not identified in the finished product.

(b) 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.

(c) When testing on a lot basis is specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material of one type, that is, bolts or studs having the same nominal diameter and length offered for inspection at one time. From each lot, the number of tests for each specified property shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and less.....	1
Over 800 to 8 000, incl.....	2
Over 8 000 to 22 000, incl.....	3
Over 22 000.....	5

(d) Should any sample fail to meet the requirements of a specified test, double the original number of samples from

² 1969 Book of ASTM Standards, Part 4.

TABLE III.—TENSILE REQUIREMENTS FOR COARSE-THREAD FULL-SIZE BOLTS AND STUDS.

Bolt or Stud Diameter, in.	Threads per inch ^a	Stress Area, sq in. ^b	Tensile Load, min, lb ^c	Proof Load, Length Measurement Method, min, lb ^c	Alternate Proof Load, Yield Strength Method, (0.2 per cent Offset), min, lb ^c
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
1/4.....	20	0.0318	3 800	2 700	2 900
5/16.....	18	0.0524	6 300	4 450	4 800
3/8.....	16	0.0775	9 300	6 600	7 100
7/16.....	14	0.1063	12 750	9 050	9 800
1/2.....	13	0.1419	17 050	12 050	13 050
9/16.....	12	0.182	21 850	15 450	16 750
5/8.....	11	0.228	27 100	19 200	20 800
3/4.....	10	0.334	40 100	28 400	30 700
7/8.....	9	0.462	55 450	39 250	42 500
1.....	8	0.606	72 700	51 500	55 750
1 1/8.....	7	0.763	80 100	56 450	61 800
1 1/4.....	7	0.969	101 700	71 700	78 500
1 3/8.....	6	1.155	121 300	85 450	93 550
1 1/2.....	6	1.405	147 500	104 000	113 800
1 3/4.....	5	1.90	171 000	104 500	110 200
2.....	4 1/2	2.50	225 000	137 500	145 000
2 1/4.....	4 1/2	3.25	292 500	178 750	188 500
2 1/2.....	4	4.00	360 000	220 000	232 000
2 3/4.....	4	4.93	443 700	271 150	286 000
3.....	4	5.97	537 300	328 350	346 200

^a For 8 threads per inch in sizes 1 1/8 to 1 1/2 in., incl, stresses of 105,000 psi, 74,000 psi, and 81,000 psi shall be used for calculating the values in columns 4, 5, and 6 respectively.

^b Stress area calculated from the formula:

$$A_s = 0.7854 \left(D - \frac{0.9743}{n} \right)^2$$

where:

A_s = stress area,

D = nominal diameter, and

n = threads per inch.

^c Values tabulated are based on the following:

Bolt Size, in.	Column 4, psi	Column 5, psi	Column 6, psi
1/4 to 1, incl.....	120 000	85 000	92 000
1 1/8 to 1 1/2, incl.....	105 000	74 000	81 000
1 3/4 to 3, incl.....	90 000	55 000	58 000

the same lot shall be retested for the requirement(s) in which it failed. All the additional samples shall conform to the specification or the lot shall be rejected.

(e) If any test specimen shows defective machining, it may be discarded and another specimen substituted.

Workmanship

8. The bolts and studs shall be commercially smooth and free from burrs, laps, seams, cracks, and other injurious material or manufacturing defects which would make them unsuitable for the intended application.

TABLE IV.—TENSILE REQUIREMENTS FOR FINE-THREAD FULL-SIZE BOLTS AND STUDS.

Bolt or Stud Diameter, in.	Threads per inch	Stress Area sq in. ^a	Tensile Load, min, lb ^b	Proof Load, Length Measurement Method, min, lb ^b	Alternate Proof Load, Yield Strength Method, (0.2 per cent, Offset), min, lb ^b
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
$\frac{1}{4}$	28	0.0364	4 350	3 100	3 500
$\frac{5}{16}$	24	0.0580	6 950	4 950	5 350
$\frac{3}{8}$	24	0.0878	10 550	7 450	8 100
$\frac{7}{16}$	20	0.1187	14 250	10 100	10 900
$\frac{1}{2}$	20	0.1599	19 200	13 600	14 700
$\frac{9}{16}$	18	0.203	24 350	17 250	18 700
$\frac{5}{8}$	18	0.256	30 700	21 750	23 550
$\frac{3}{4}$	16	0.373	44 750	31 700	34 300
$\frac{7}{8}$	14	0.509	61 100	43 250	46 800
1.....	12	0.663	79 550	56 350	61 000
$1\frac{1}{8}$	12	0.856	89 900	63 350	69 350
$1\frac{1}{4}$	12	1.073	112 650	79 400	86 900
$1\frac{3}{8}$	12	1.315	138 100	97 300	106 500
$1\frac{1}{2}$	12	1.581	166 000	117 000	128 000

^a See footnote ^b below Table III.^b See footnote ^a below Table III.

TABLE V.—TENSILE REQUIREMENTS FOR SPECIMENS MACHINED FROM BOLTS AND STUDS.

Bolt or Stud Diameter, in.	Tensile Strength, min, psi	Yield Strength, min, psi	Elongation in 4D, min, per cent	Reduction of Area, min, per cent
$\frac{1}{4}$ to 1, incl.....	120 000	92 000	14	35
Over 1 to $1\frac{1}{2}$, incl....	105 000	81 000	14	35
Over $1\frac{1}{2}$ to 3, incl.....	90 000	68 000	14	35

Marking

9. Bolt heads shall be marked with 3 radial lines 120 deg apart and with a symbol identifying the manufacturer. Markings may be raised or depressed at the option of the manufacturer.

Inspection

10. (a) If the inspection described in Paragraph 7(b) is required by the pur-

chaser, it shall be specified in the inquiry and contract or order.

(b) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of manufacturer's works that concern the manufacture and testing of the material ordered. The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests (except check 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.

Rejection

11. Rejections based on requirements specified herein shall be reported to the manufacturer within 30 days after receipt of material by the purchaser.



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Standard Specification for STEEL CASTINGS FOR HIGHWAY BRIDGES¹

This Standard is issued under the fixed designation A 486; 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 steel castings for use as highway bridge components.

1.2 Three classes are covered as indicated. Selection will depend upon design, service conditions, and mechanical properties.

1.2.1 *Class 70*—Carbon cast steel of 70,000 psi (49.2 kgf/mm²) tensile strength that is weldable.

1.2.2 *Class 90*—Low-alloy cast steel of 90,000 psi (63.3 kgf/mm²) that is weldable under carefully controlled conditions.

1.2.3 *Class 120*—Low-alloy cast steel of 120,000 psi (84.4 kgf/mm²) tensile strength that is weldable under carefully controlled conditions.

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

2. Process

2.1 The steel may be made by any process capable of meeting chemical and mechanical requirements specified herein.

3. Heat Treatment

3.1 All castings shall receive a heat treatment proper to the class designation as follows:

3.1.1 *Class 70*—Normalize, or normalize and temper, or quench and temper.

3.1.2 *Class 90*—Normalize, or normalize and temper, or quench and temper.

3.1.3 *Class 120*—Quench and temper.

3.2 Definitions of heat treating terms shall be those listed in ASTM Definitions E 44, Terms Relating to Heat Treatment of Metals.²

3.3 Furnace temperatures for heat treatment shall be effectively controlled by pyrometers.

4. Chemical Requirements

4.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

5. Ladle Analysis

5.1 An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in Section 4 and the alloying elements intentionally added by the producer. The chemical composition thus determined shall conform to the requirements prescribed in Section 4 and shall be reported to the purchaser or his representative.

6. Mechanical Properties

6.1 Steel used for castings shall conform to the requirements as to mechanical properties prescribed in Table 2.

6.2 Tension tests and impact tests shall be prepared and performed from cast coupons in accordance with ASTM Methods and Definitions A 370, for Mechanical Testing of Steel Products.³

6.3 Steel castings for highway bridges may be required for service under moderately cold and cold conditions. When specified in the inquiry, contract, or order, the impact properties of the steel used for low-temperature service castings shall conform to the requirements prescribed in Table 3. The class, the

¹ This specification is under the jurisdiction of ASTM Committee A-1 on Steel, and is the direct responsibility of Subcommittee A01.18 on Steel Castings.

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² 1974 Annual Book of ASTM Standards, Part 2 and 1973 Annual Book of ASTM Standards, Part 31.

³ 1974 Annual Book of ASTM Standards, Parts 1, 2, 3, 4, and 5 and 1973 Annual Book of ASTM Standards, Part 31.

testing temperature, and the minimum impact value must be clearly stated in the inquiry and order.

6.4 Impact requirements for temperatures below -50°F (-46°C) may be specified in the contract or order when agreed upon between the manufacturer and the purchaser.

7. Number of Tests

7.1 One tension test specimen and three impact test specimens shall be made from each heat.

8. Retests

8.1 If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be reheat treated and retested.

9. Workmanship

9.1 The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

9.2 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method No. SP-55⁴ or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperatures are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 4.

9.3 When specified by the purchaser, magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of ASTM Reference Photographs E 125, for Magnetic Particle Indications on Ferrous Castings,⁵ of Degree 2 in sections up to 2 in. (50.8 mm) thick and of Degree 3 in sections over 2 in. thick shall be acceptable.

10. Repair by Welding

10.1 Repairs shall be made using procedures and personnel qualified in accordance with the requirements of ASTM Recommended Practice A 488, for Qualification of Procedures and Personnel for the Welding of Steel Castings.⁶

10.2 Repair welds shall conform to the same inspection standards as those required of the casting.

10.3 The deposited weld metal shall have hardness and other mechanical properties compatible with those of the parent metal.

11. Marking

11.1 Castings shall be marked for material identification with the ASTM symbols for the class of steel and an identification number.

12. Inspection

12.1 The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are 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.

13. Rejection

13.1 Any rejection based on tests made in accordance with this specification shall be reported to the manufacturer within 5 working days from the receipt of samples by the purchaser.

13.2 Material that shows injurious defects subsequent to its acceptance by the purchaser will be rejected, and the manufacturer shall be notified.

14. Rehearing

14.1 Samples tested in accordance with Section 6, that represent rejected material, shall be preserved for 2 weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

⁴ Quality Standard for Steel Castings for Valve, Flanges, and Fittings, and Other Components, available from the Manufacturers Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Drive, Arlington, Va. 22209.

⁵ 1973 Annual Book of ASTM Standards, Part 31.

⁶ 1974 Annual Book of ASTM Standards, Part 2.

TABLE 1 Chemical Requirements

	Composition, max percent		
	Class 70	Class 90 ^a	Class 120 ^a
Carbon	0.35	0.35	0.35
Manganese	0.90	^a	^a
Phosphorus	0.05	0.05	0.05
Sulfur	0.06	0.06	0.06
Silicon	0.80	^a	^a

^a The manganese, silicon, and other alloying elements which are added to obtain the mechanical properties specified shall be selected by the manufacturer.

TABLE 2 Mechanical Properties

	Class 70	Class 90	Class 120
Tensile strength, min, ksi (MPa)	70 (483)	90 (621)	120 (827)
Yield point, min, psi ksi (MPa)	36 (248)	60 (414)	95 (655)
Elongation in 2 in. (50.8 mm), min, percent	22	20	14
Reduction of area, min, percent	30	40	30
Charpy V-notch impact 70 F (21 C), min, ft·lb ^a	25	25	30

^a Values apply only to sections up to 2 in. (50.8 mm) thick.

TABLE 3 Impact Properties for Low-Temperature Service

Charpy V-Notch Impact	Class 70	Class 90	Class 120
0 deg F, min, ft·lb ^a	15	15	25
-50 deg F, min, ft·lb ^a	...	15	15

^a Values apply only to sections up to 2 in. (50.8 mm) thick.

TABLE 4 Minimum Preheat Temperatures

Class	Thickness, in. (mm)	Minimum Preheat Temperature, deg F (deg. C)
Class 70	1 (25.4) and under	50 (10)
	Over 1 (25.4)	175 (79)
Class 90	all	250 (121)
Class 120	all	300 (149)

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser on the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Radiographic Inspection

S1.1 Castings may be subject to radiographic inspection if notice of this requirement is in the inquiry and contract or order. Areas to be radiographed, number of castings made from the same pattern which shall be radiographed, and the standard of acceptability, as listed in ASTM Reference Radiographs E 446, for Steel Castings up to 2 in. in Thickness,⁵ shall be specified in the inquiry, contract, or order.

S2. Magnetic Particle Inspection

S2.1 Castings may be subject to magnetic

particle inspection if notice of this requirement is in the inquiry and contract or order. Areas to be inspected and the standards of acceptability, as listed in Reference Photographs E 125 or ASTM Methods E 138, Wet Magnetic Particle Inspection,⁵ shall be specified in the inquiry and contract or order. The magnetic particle inspection shall be made in accordance with Method E 109, Dry Powder Magnetic Particle Inspection,⁵ or Method E 138.

S2.2 When magnetic particle inspection is required for the castings all welds shall be inspected by the magnetic particle method in accordance with Method E 109.



S2.3 When radiographic inspection is required for the castings all welds shall be inspected by Method E 109, but radiographic inspection shall be required only of those

welds whose depth exceeds 20 percent of the wall thickness or whose area exceeds 10 in.² (64.5 cm²)/in. (25.4 mm) of wall thickness.

By publication of this standard no position is taken with respect to the validity of any patent rights in connection therewith, and the American Society for Testing and Materials does not undertake to insure anyone utilizing the standard against liability for infringement of any Letters Patent nor assume any such liability.



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**Standard Specification for
QUENCHED AND TEMPERED ALLOY STEEL BOLTS
FOR STRUCTURAL STEEL JOINTS¹**

This Standard is issued under the fixed designation A490; 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 reappraisal.

1. Scope

1.1 This specification covers the chemical and mechanical requirements of quenched and tempered alloy steel bolts, $\frac{1}{2}$ to $1\frac{1}{2}$ 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 Bolts² issued by the Research Council on Riveted and Bolted Structural Joints of The Engineering Foundation.

1.2 Suitable nuts are Grade 2H as described in ASTM Specification A 194, for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service,³ and Grade DH as described in ASTM Specification A 563, for Carbon Steel Nuts.⁴

1.3 Suitable plain hardened washers are quenched and tempered (noncarburized) washers as described in ASTM Specification A 325, for High Strength Bolts for Structural Steel Joints, Including Suitable Nuts and Plain Hardened Washers.⁴

1.4 This specification provides that heavy hex structural bolts and heavy hex nuts shall be furnished unless other dimensional requirements are stipulated in the purchase inquiry and order. Dimensions of washers are limited to those given in the Specification for Structural Joints Using A 325 or A 490 Bolts cited in 1.1.

2. Definitions

2.1 Surface discontinuities as covered by this specification are defined as follows:

2.1.1 *crack*—a clean crystalline break passing through the grain boundary without inclusion of foreign elements.

2.1.2 *seam or lap*—a noncrystalline break

through the metal which is inherent in the raw material.

2.1.3 *burst*—a break located at the periphery of the bolt head.

3. Materials and Manufacture

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

3.2 Bolts shall be heat treated by quenching in oil from above the transformation temperature and then tempering by reheating to a temperature of not less than 900°F (480°C). If heat treatment is performed by a subcontractor, the heat-treated material shall be returned to the manufacturer for testing.

3.3 Threads of bolts may be cut or rolled.

4. Chemical Requirements

4.1 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 1—Steel is classified as alloy steel by the American Iron and Steel Institute when the maximum of the range specified for the content of alloying elements exceeds one or more of the following limits: 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 commercial field of alloy steels: aluminum,

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 A01.26 on Bolting.

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² Published by the American Institute of Steel Construction, New York, N. Y.

³ 1974 Annual Book of ASTM Standards, Part 1.

⁴ 1974 Annual Book of ASTM Standards, Part 4.

boron, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying element added to obtain a desired alloying effect.

4.2 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 Table 1. Choice of alloy steel composition necessary to assure meeting the specified mechanical requirements shall be made by the bolt manufacturer, and shall be reported to the purchaser for information purposes only.

5. Mechanical Requirements

5.1 Bolts that are too short for tension testing shall have a hardness not less than the minimum hardness nor greater than the maximum hardness specified in Table 2 when tested in accordance with 8.1.

5.2 Bolts other than those too short for tension testing shall be subject to the tension tests as specified in 5.3, 5.4, and 5.5.

5.3 Bolts 1¼ in. and under in diameter shall be tested in full size and shall meet the requirements for tensile strength and proof load, or alternate proof load, specified in Table 3 when tested in accordance with 8.2 and 8.3.

5.4 When specified in the inquiry and purchase order, bolts 1½ in. and larger in diameter shall be tested in full size and shall meet loads based on the stress area and the unit stresses for tensile strength and proof load, or alternate proof load, specified in Table 3 when tested in accordance with 8.2 and 8.3.

5.5 Bolts 1¾ in. and larger in diameter which are not required to be tested in full size in accordance with 5.4 may be tested in full size at the manufacturer's option, and when so tested shall meet loads based on the stress area and the unit stresses for tensile strength and proof load, or alternate proof load, specified in Table 3 when tested in accordance with 8.2 and 7.3. When equipment of sufficient capacity for full-size tests is not available, bolts shall meet the requirements for machined test specimens specified in Table 4 when tested in accordance with 8.4.

5.6 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 ⅛ 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.

6. Dimensions

6.1 Unless otherwise specified, bolts shall conform to the dimensions for heavy hex structural bolts specified in the American National Standard for Square and Hex Bolts and Screws (ANSI B18.2.1).

6.2 Unless otherwise specified, nuts shall conform to the dimensions for heavy hex nuts specified in the American National Standard for Square and Hex Nuts (ANSI B18.2.2).

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

6.4 Dimensions of washers shall conform to those shown in the latest issue of the Specification for Structural Joints Using ASTM A 325 or A 490 bolts cited in 1.1.

7. Quality Assurance of Mechanical Requirements

7.1 Nuts and Washers:

7.1.1 The requirements of this specification for nuts and washers 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 materials are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

7.1.2 If the purchaser requires that additional tests be performed by the manufacturer to determine that the properties of nuts or washers in an individual shipment are in conformance with the requirements of this specification, the purchaser shall specify the testing requirements, including sampling plan and basis of acceptance, in the original inquiry and purchase order.

7.2 Bolts:

7.2.1 The manufacturer shall make sample inspections of every lot of bolts to ensure that

properties of bolts are in conformance with the requirements of this specification. All bolts shall be inspection tested prior to shipment in accordance with one of the two quality assurance procedures described in 7.3 and 7.4, respectively. The manufacturer shall have the option of which procedure will be followed when furnishing bolts to any single purchase order.

7.2.2 The purpose of a lot inspection testing program is to ensure that each lot conforms to the requirements of this specification and that delivered bolts are free of known defects. 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.

7.3 *Production Lot Method:*

7.3.1 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.

7.3.2 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.

7.3.3 The manufacturer shall make tests for proof load, tensile strength (wedge test), and hardness of each lot of bolts. Alternatively, in accordance with 5.5, tests may be tensile strength, yield strength, reduction of area, elongation, and hardness.

7.3.4 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

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

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

7.3.7 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.

7.4 *Shipping Lot Method:*

7.4.1 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.

7.4.2 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.

7.4.3 The manufacturer shall make tests for proof load, tensile strength (wedge test), and hardness of each lot of bolts. Alternatively, in accordance with 5.5 tests may be tensile strength, yield strength, reduction of area, elongation, and hardness.

7.4.4 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

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

7.4.6 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.

8. Methods of Test

8.1 Tests shall be conducted in accordance with Supplement III of ASTM Methods and Definitions A 370, for Mechanical Testing of Steel Products.⁵

8.2 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 A 370.

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

8.4 Machined specimens shall be tested in accordance with the method described in S11.1.7, Supplement III of A 370.

8.5 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.

9. Magnetic Particle and Visual Inspection for Surface Discontinuities

9.1 Bolts shall be examined by magnetic particle inspection for longitudinal discontinuities and transverse cracks, and shall meet an AQL of 0.25 when inspected in accordance with the sampling plan described in 9.4.

9.2 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 9.5.

9.3 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.

9.4 Longitudinal Discontinuities and Transverse Cracks:

9.4.1 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 ASTM Method E 109, for Dry Powder Magnetic Particle Inspection.⁶ (See Note 2.) The sample size shall be as specified for an AQL of 0.25 in Table 5. If any defectives are found during inspection by the man-

ufacturer 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 2—Magnetic particle inspection may be conducted in accordance with ASTM Method E 138, for Wet Magnetic Particle Inspection.⁶ For referee purposes Method E 109 shall be used.

9.4.2 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 3—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 specified limits.

9.5 Bursts:

9.5.1 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 5. If the number of defectives found during inspection by the manufacturer is greater than the acceptance number given in Table 5 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 5 for the sample size, the lot shall be subject to rejection.

9.5.2 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.

10. Inspection

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

⁵ 1974 Annual Book of ASTM Standards, Parts 1, 2, 3, 4, and 5, and 1973 Annual Book of ASTM Standards, Part 31.

⁶ 1973 Annual Book of ASTM Standards, Part 31.

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

11. Rejection

11.1 Unless otherwise specified, any rejection based on requirements specified herein shall be reported to the manufacturer within

30 working days from the receipt of the material by the purchaser.

12. Certification

12.1 *Nuts and Washers*—When specified on 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.

12.2 *Bolts*—When specified on the order the manufacturer shall furnish the test reports described in 7.3.7 or 7.4.6, depending on whether the bolts are furnished by the production lot or shipping lot method.

13. Marking

13.1 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.

TABLE 1 Chemical Requirements

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 Hardness Requirements for Bolts

Bolt Size, in.	Hardness Number			
	Brinell		Rockwell C	
	min	max	min	max
1/2 to 1 1/2, incl	302	341	32	36

TABLE 3 Tensile Requirements for Full-Size Bolts

Bolt Size, Threads per in. and Series Designation	Stress Area, ^a in. ² (cm ²)	Tensile Load, ^b lbf(kN)		Proof Load ^b , lbf (kN)	Alternate 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 4 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 5 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.⁷

^b Inspect all bolts in the lot if lot size is less than sample size.

⁷ MIL-STD-105D may be obtained from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

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**Standard Specification for
HOT-FORMED WELDED AND SEAMLESS CARBON
STEEL STRUCTURAL TUBING¹**

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 reappraisal.

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. Basis of Purchase

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 designation,

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, Cast Iron, Open Hearth Iron, and Wrought 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. Method of Test

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 1974 Annual Book of ASTM Standards, Part 12.

³ 1974 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 1 1/2 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 varia-

tion for straightness of structural tubing shall be 1/8 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 tolerance for twist, or variation with respect to axial alignment of the section for square, rectangular, or special shape structural tubing, shall be as prescribed in Table 9. Twist is measured 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.

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, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe 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 ASTM A 501.

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.

⁴ 1974 Annual Book of ASTM Standards, Part 1.

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 the U.S. Department of Commerce, *Simplified Practice Recommendation R247-62* (Packaging, Marking and Loading Methods for Steel Products for Domestic Shipment).⁵

17. Inspection

17.1 All tubing shall be subject to an inspection at the place of manufacture to assure conformance with the requirements of this specification.

17.2 The structural tubing shall be free from injurious defects and shall have a commercially smooth finish.

17.2.1 Surface imperfections shall be classed as injurious defects when their depth exceeds 15 percent of the wall thickness as stated in Tables 4, 5, or 6 and when the imperfections materially affect the appearance of the structural member, or when their length (measured in a transverse direction) and depth would materially reduce the total cross sectional area at any location.

17.2.2 Injurious defects having a depth not in excess of $33\frac{1}{3}$ percent of the wall thickness stated in Tables 4, 5, or 6 may be repaired by welding, subject to the following conditions:

17.2.2.1 The defect shall be completely removed by chipping or grinding to sound metal.

17.2.2.2 The repair weld shall be made using suitable coated electrodes.

17.2.2.3 The projecting weld metal shall be

removed to produce a workmanlike finish.

17.3 The ends of structural tubing, unless otherwise specified, shall be finished square cut, and the burr held to a minimum. The burr can be removed on the outside diameter, inside diameter, or both, as a supplementary requirement. When burrs are to be removed, it shall be specified in the purchase order.

17.4 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tensile tests shall be furnished.

18. Rejection

18.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined herein, 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 National Bureau of Standards, Office of Engineering Standards Services, Washington, D. C. 20234.

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 $\frac{1}{16}$ 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 $\frac{1}{32}$ in. of the specified thickness under $\frac{1}{16}$ in.

TABLE 3 Bend Test Requirements

Thickness of Material, in. (mm)	Ratio of Bend Diameter to Specimen Thickness
3/4 in. (19.0) and under	1/2
Over 3/4 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 Dimen- sions Across Flat Sides, in. (mm)	Weight per Foot, lb (kg/m)	Calculated Nominal Wall Thick- ness, in. (mm)
1 by 1 (25.4 by 25.4)	1.09 (1.62) 1.41 (2.10)	0.095 (2.41) 0.133 (3.38)
2 by 2 (50.8 by 50.8)	2.69 (4.00) 3.04 (4.52) 3.65 (5.44) 4.31 (6.41)	0.110 (2.79) 0.125 (3.18) 0.154 (3.91) 0.188 (4.78)
2 1/2 by 2 1/2 (63.5 by 63.5)	4.32 (6.43) 5.59 (8.32) 7.10 (10.56)	0.141 (3.58) 0.188 (4.78) 0.250 (6.35)
3 by 3 (76.2 by 76.2)	5.78 (8.60) 6.86 (10.21) 8.80 (13.09)	0.156 (3.96) 0.188 (4.78) 0.250 (6.35)
3 1/2 by 3 1/2 (88.9 by 88.9)	6.88 (10.24) 8.14 (12.11) 10.50 (15.62) 12.69 (18.88)	0.156 (3.96) 0.188 (4.78) 0.250 (6.35) 0.312 (7.92)
4 by 4 (101.6 by 101.6)	9.31 (13.85) 12.02 (17.89) 14.52 (21.61) 16.84 (25.06) 20.88 (31.07)	0.188 (4.78) 0.250 (6.35) 0.312 (7.92) 0.375 (9.52) 0.500 (12.70)
5 by 5 (127.0 by 127.0)	11.86 (17.65) 15.42 (22.94) 18.77 (27.93) 21.94 (32.65) 27.68 (41.19)	0.188 (4.78) 0.250 (6.35) 0.312 (7.92) 0.375 (9.52) 0.500 (12.70)
6 by 6 (152.4 by 152.4)	14.41 (21.44) 18.82 (28.00) 23.02 (34.25) 27.04 (40.28) 34.48 (51.31)	0.188 (4.78) 0.250 (6.35) 0.312 (7.92) 0.375 (9.52) 0.500 (12.70)
7 by 7 (177.8 by 177.8)	16.85 (25.07) 22.04 (32.80) 26.99 (39.16) 31.73 (47.21) 40.55 (60.34)	0.188 (4.78) 0.250 (6.35) 0.312 (7.92) 0.375 (9.52) 0.500 (12.70)
8 by 8 (203.2 by 203.2)	25.44 (37.85) 31.24 (46.49) 36.83 (54.80) 47.35 (70.46) 56.98 (84.79) 65.73 (97.81)	0.250 (6.35) 0.312 (7.92) 0.375 (9.52) 0.500 (12.70) 0.625 (15.88) 0.750 (19.05)
10 by 10 (254.0 by 254.0)	32.23 (47.96) 39.74 (59.13) 47.03 (69.98) 60.95 (90.69) 73.98 (110.08) 86.13 (128.16) 107.79 (160.39)	0.250 (6.35) 0.312 (7.92) 0.375 (9.52) 0.500 (12.70) 0.625 (15.88) 0.750 (19.05) 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 (76.2 by 50.8)	4.32 (6.43)	0.141 (3.58)
	5.59 (8.32)	0.188 (4.78)
	7.10 (10.56)	0.250 (6.35)
4 by 2 (101.6 by 50.8)	5.78 (8.60)	0.156 (3.96)
	6.86 (10.21)	0.188 (4.78)
	8.80 (13.09)	0.250 (6.35)
4 by 3 (101.6 by 76.2)	6.88 (10.24)	0.156 (3.96)
	8.14 (12.11)	0.188 (4.78)
	10.50 (15.62)	0.250 (6.35)
	12.69 (18.88)	0.312 (7.92)
5 by 3 (127.0 by 76.2)	9.31 (13.85)	0.188 (4.78)
	12.02 (17.89)	0.250 (6.35)
	14.52 (21.61)	0.312 (7.92)
	16.84 (25.06)	0.375 (9.52)
6 by 3 (152.4 by 76.2)	10.58 (15.74)	0.188 (4.78)
	13.72 (20.42)	0.250 (6.35)
	16.65 (24.78)	0.312 (7.92)
	19.39 (28.85)	0.375 (9.52)
6 by 4 (152.4 by 101.6)	11.86 (17.65)	0.188 (4.78)
	15.42 (22.94)	0.250 (6.35)
	18.77 (27.93)	0.312 (7.92)
	21.94 (32.65)	0.375 (9.52)
	27.68 (41.19)	0.500 (12.70)
7 by 5 (177.8 by 127.0)	14.41 (21.44)	0.188 (4.78)
	18.82 (28.00)	0.250 (6.35)
	23.02 (34.25)	0.312 (7.92)
	27.04 (40.28)	0.375 (9.52)
	34.48 (51.31)	0.500 (12.70)
8 by 4 (203.2 by 101.6)	14.41 (21.44)	0.188 (4.78)
	18.82 (28.00)	0.250 (6.35)
	23.02 (34.25)	0.312 (7.92)
	27.04 (40.28)	0.375 (9.52)
	34.48 (51.31)	0.500 (12.70)
8 by 6 (203.2 by 152.4)	16.85 (25.07)	0.188 (4.78)
	22.04 (32.80)	0.250 (6.35)
	26.99 (39.16)	0.312 (7.92)
	31.73 (47.21)	0.375 (9.52)
	40.55 (60.34)	0.500 (12.70)
10 by 6 (254.0 by 152.4)	25.44 (37.85)	0.250 (6.35)
	31.24 (46.49)	0.312 (7.92)
	36.83 (54.80)	0.375 (9.52)
	47.35 (70.46)	0.500 (12.70)

TABLE 6 Dimensions of Common Sizes of Round Structural Tubing

Nominal Size, in.	Outside Diameter, in. (mm)	Weight Per Foot, lb (kg/m)	Calculated Nominal Wall Thickness, in. (mm)
½	0.840 (21.3)	0.85 (1.26)	0.109 (2.77)
	0.840 (21.3)	1.09 (1.62)	0.147 (3.73)
¾	1.050 (26.7)	1.13 (1.68)	0.113 (2.87)
	1.050 (26.7)	1.47 (2.19)	0.154 (3.91)
1	1.315 (33.4)	1.34 (1.99)	0.104 (2.64)
	1.315 (33.4)	1.68 (2.50)	0.133 (3.38)
	1.315 (33.4)	2.17 (3.23)	0.179 (4.55)
1¼	1.660 (42.2)	1.81 (2.69)	0.110 (2.79)
	1.660 (42.2)	2.27 (3.38)	0.140 (3.56)
	1.660 (42.2)	3.00 (4.47)	0.191 (4.85)
1½	1.900 (48.3)	2.17 (3.23)	0.114 (2.90)
	1.900 (48.3)	2.72 (4.05)	0.145 (3.68)
	1.900 (48.3)	3.63 (5.41)	0.200 (5.08)
2	2.375 (60.3)	2.92 (4.34)	0.121 (3.07)
	2.375 (60.3)	3.65 (5.44)	0.154 (3.91)
	2.375 (60.3)	5.02 (7.48)	0.218 (5.54)
	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)
5	4.500 (114.3)	14.98 (22.29)	0.337 (8.56)
	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)
	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)
	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)
	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)
	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)
	14.000 (355.6)	72.09 (107.27)	0.500 (12.70)
	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)
	16.000 (406.4)	82.77 (123.16)	0.500 (12.70)
	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)
	18.000 (457.2)	93.45 (139.05)	0.500 (12.70)
	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)
	20.000 (508.0)	104.13 (154.91)	0.500 (12.70)
	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 spec- ified 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 per 3 ft of Length, in.	Maximum Twist in 1 m, 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

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Standard Specification for STEEL STRUCTURAL RIVETS¹

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 two grades of steel rivets in diameters from $\frac{1}{2}$ to $1\frac{1}{2}$ 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.

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

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 U.S. customary 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 ladle and product analysis requirements for chemical composition given in Table 1.

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.

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.³ Brinell hardness shall be measured at only one point. Rockwell hardness 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

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 A01.26 on Bolting.

Current edition effective Aug. 31, 1965. Originally issued 1964. Replaces A 502 – 64.

² Discontinued, see 1966 Book of ASTM Standards, Part 4.

³ 1974 Annual Book of ASTM Standards, Parts 1, 2, 3, 4, and 5, and 1973 Annual Book of ASTM Standards, Part 31.

Standard B18.4 for Large Rivets ($\frac{1}{2}$ Inch Nominal Diameter and Larger).

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

^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 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	
	Ladle Analysis percent	Product Analysis ^a percent	Ladle Analysis percent	Product Analysis percent
Carbon	0.13–0.25	0.11–0.27	0.19–0.30	0.16–0.33
Manganese	0.30–0.90	0.27–0.93	1.20–1.65	1.14–1.71
Phosphorus, max				
acid	0.06	0.070	0.06	0.070
basic	0.04	0.048	0.04	0.048
Sulfur, max	0.05	0.058	0.05	0.058
Silicon	...	...	0.10–0.30	0.08–0.32
Copper, when copper bearing steel is specified, min	0.20	0.18	0.20	0.18

^a Product analysis is not applicable to rivets made from rimmed steel or merchant quality bars.

TABLE 2 Hardness Requirements

	Grade 1		Grade 2	
	Min	Max	Min	Max
Rockwell, B	55	72	76	85
Brinell, 500-kg load, 10-mm ball	103	126	137	163

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		10.0	
		Ac-cept-ance ^a	Re-jec-tion ^b	Ac-cept-ance ^a	Re-jec-tion ^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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**Standard Specification for
HIGH-YIELD-STRENGTH, QUENCHED AND
TEMPERED ALLOY STEEL PLATE, SUITABLE FOR
WELDING¹**

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 4 in. (102 mm) and under intended primarily for use in welded bridges and other structures.

NOTE 1—All types are not available in a maximum thickness of 4 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 U.S. customary units are to be regarded as the standard.

2. General Requirements for Delivery

2.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of ASTM Specification A 6, for General Requirements for Delivery of 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 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 1/2 in. (0.80 mm) of the specified thickness under 1/6

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 29, 1974 and Aug. 30, 1974. Published November 1974. Originally published as A 514 – 64. Last previous edition A 514 – 70.

² 1974 Annual Book of ASTM Standards, Part 4.

³ 1974 Annual Book of ASTM Standards, Part 11.

TABLE 1 Chemical Requirements (Heat Analysis)

	Type A, % 1 1/4 (32.0 mm)	Type B, % 1 1/4 (32.0 mm)	Type C, % 1 1/4 (32.0 mm)	Type D, % 1 1/4 (32.0 mm)	Type E, % 4 (102 mm)	Type F, % 4 (102 mm)	Type G, % 2 (51.0 mm)	Type H, % 2 (51.0 mm)	Type J, % 1 1/4 (32 mm)	Type K, % 2 (51.0 mm)	Type L, % 2 (51.0 mm)	Type M, % 2 (51.0 mm)	Type N, % 3/4 (19.0 mm)	Type P, % 4 (102 mm)
Maximum Thickness, in. (mm)	1 1/4 (32.0 mm)	1 1/4 (32.0 mm)	1 1/4 (32.0 mm)	1 1/4 (32.0 mm)	4 (102 mm)	4 (102 mm)	2 (51.0 mm)	2 (51.0 mm)	1 1/4 (32 mm)	2 (51.0 mm)	2 (51.0 mm)	2 (51.0 mm)	3/4 (19.0 mm)	4 (102 mm)
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
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
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
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
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
Nickel	...	...	...	...	...	0.70– 1.00	...	0.30– 0.70	...	...	...	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
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
Vanadium	...	0.03– 0.08	...	...	...	0.03– 0.08	...	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	...	...	...	...	...	0.05– 0.15	...	...	...	...	...	0.05– 0.15	...
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.

TABLE 2 Tensile and Hardness Requirements

Thickness, in.	Ultimate Tensile Strength, ksi (MPa)	Yield Strength ^a min, ksi (MPa)	Elonga- tion in 2 in. or 50 mm ^b , min, %	Reduction of Area, min, %	Brinell Hardness Number ^c
To ¼, incl	110 (760) to 130 (895)	100 (690)	18	40 ^e	235 to 293
Over ¼ to 2½, incl ^d	110 (760) to 130 (895)	100 (690)	18	40 ^e , 50 ^e	235 to 293
Over 2½ to 4, incl	100 (690) to 130 (895)	90 (620)	17	50 ^e	229 to 293

^a Measured at 0.2 % offset or 0.5 % extension under load as described in Section 13, yield strength of Methods A 370.

^b Elongation not required to be determined for floor plate.

^c See Section 7.

^d Either the full thickness rectangular specimen of Fig. 4, Methods A 370 (see footnote *b* above), or the ½ in. (12.5 mm) diameter specimen, shown in Fig. 5 of Methods A 370, may be used for plates over ¼ in. to 1½ in. (19 to 40 mm) in thickness.

^e Measured on 1½ in. (40 mm) wide full thickness rectangular specimen as shown in Fig. 4 of Methods A 370. This is the only specimen to be used for thicknesses of ¼ in. (19 mm) and under. The elongation is measured in a 2 in. or 50 mm gage length which includes the fracture and which shows the greatest elongation.

^f Measured on ½ in. (12.5 mm) diameter specimen as shown in Fig. 5 of Methods A 370. This is the only specimen to be used for thicknesses over 1½ in. (40 mm). The specimen shall be taken so that the axis is midway, or as near midway as practicable, between the center and the surface.

TABLE 3 Bend Test Requirements

Material Thickness, in.	Ratio of Bend Diameter to Specimen Thickness ^a
1 and under	2
Over 1 to 2½, incl	3
Over 2½ to 4, incl	4

^a The above ratios apply to the bending performance of a test specimen only. This specimen is always taken in the longitudinal direction and usually has some edge preparation. Where plates are to be bent in a fabricating operation, more liberal bend radii must be used, particularly if this bend axis is in the unfavorable (longitudinal) direction.

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If not listed in the current combined Index, will appear in the next edition.

**Standard Specification for
PRESSURE VESSEL PLATES, ALLOY STEEL, HIGH-
STRENGTH, QUENCHED AND TEMPERED¹**

This Standard is issued under the fixed designation A 517; 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 specification² covers high-strength quenched and tempered alloy steel plates intended for use in fusion welded boilers and other pressure vessels.

1.2 This specification includes a number of grades as manufactured by different producers, but all having the same mechanical properties and general characteristics.

1.3 The maximum thickness of plates furnished under this specification shall be as follows:

Grade	Thickness
A, B, C, D, J	1.25 in. (32 mm)
G, H, K, L, M	2 in. (51 mm)
E, F, P	2.50 in. (64 mm)

1.4 Because of its critical alloy content and specialized properties, welding procedures are of fundamental importance and must be such as to not adversely affect the properties of the plate, especially in the heat affected zone. It is presupposed that all welding parameters shall be in accordance with approved methods capable of producing the desired properties in the finished structure.

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

2. Applicable Documents**2.1 ASTM Standard:**

A 20 Specification for General Requirements for Steel Plates for Pressure Vessels³

3. General Requirements and Basis of Purchase

3.1 Material supplied to this material specification shall conform to the latest issue of

Specification A 20. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

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

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

- 3.3.1 Vacuum treatment,
- 3.3.2 Additional or special tension testing,
- 3.3.3 Impact testing, and
- 3.3.4 Nondestructive examination.

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

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

4. Heat Treatment

4.1 All plates shall be heat treated by the material manufacturer by heating to not less

¹ This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel for Boilers and Pressure Vessels.

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² For ASME Boiler and Pressure Vessel Code applications see related Specification SA-517 in Section II of that Code.

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

than 1650°F (900°C), quenching in water or oil and tempering at not less than 1150°F (620°C) for not less than ½ h.

5. Chemical Requirements

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

6. Metallurgical Structure

6.1 *Austenitic Grain Size*—All steel shall have a fine austenitic grain size.

7. Mechanical Requirements

7.1 Tension Tests:

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

7.1.2 Test Methods:

7.1.2.1 The yield strength may be determined by the 0.2 % offset method or by the total extension under load of 0.5 % method.

7.1.2.2 For material ¾ in. (19 mm) and under in thickness, the test specimen shall be

the 1½ in. (38 mm) wide rectangular-test specimen.

7.1.2.3 For material over ¾ in. either the full thickness rectangular-test specimen or the ½ in. (12.5 mm) round-test specimen may be used.

7.1.2.4 When the 1½ in. (40 mm) wide rectangular-test specimen is used, the elongation is measured in a 2 in. or 50 mm gage length which includes the fracture.

7.2 Impact Properties Requirements:

7.2.1 Transverse Charpy V-notch impact test specimens shall have a lateral expansion opposite the notch of not less than 0.015 in. (0.38 mm).

7.2.2 The test temperature shall be agreed upon between the manufacturer and the purchaser, but shall not be higher than 32°F (0°C).

7.2.3 The values of energy absorption in foot-pounds force (or joules) and the fracture appearance in percent shear shall be recorded and reported for information.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

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

S1. Vacuum Treatment,
S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment
of Mechanical Test Coupons,
S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,
S7. High-Temperature Tension Test,
S8. Ultrasonic Examination,
S9. Magnetic Particle Examination, and
S14. Bend Test.

TABLE 1 Chemical Requirements

Elements	Composition, %												
	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 P
Carbon: Heat analysis Product analysis	0.15–0.21 0.13–0.23	0.15–0.21 0.13–0.23	0.10–0.20 0.08–0.22	0.13–0.20 0.11–0.22	0.12–0.20 0.10–0.22	0.10–0.20 0.08–0.22	0.15–0.21 0.13–0.23	0.12–0.21 0.10–0.23	0.12–0.21 0.10–0.23	0.10–0.20 0.08–0.22	0.13–0.20 0.11–0.22	0.12–0.21 0.10–0.23	0.12–0.21 0.10–0.23
	Manganese: Heat analysis Product analysis	0.80–1.10 0.75–1.15	0.70–1.00 0.65–1.05	1.10–1.50 1.05–1.55	0.40–0.70 0.36–0.74	0.40–0.70 0.36–0.74	0.60–1.00 0.55–1.05	0.80–1.10 0.75–1.15	0.95–1.30 0.90–1.35	0.45–0.70 0.41–0.74	1.10–1.50 1.05–1.55	0.40–0.70 0.36–0.74	0.45–0.70 0.41–0.74	0.45–0.70 0.41–0.74
Phosphorus, max Sulfur, max		0.035 0.040	0.035 0.040	0.035 0.040	0.035 0.040	0.035 0.040	0.035 0.040	0.035 0.040	0.035 0.040	0.035 0.040	0.035 0.040	0.035 0.040	0.035 0.040
	Silicon: Heat analysis Product analysis	0.40–0.80 0.34–0.86	0.20–0.35 0.18–0.37	0.15–0.30 0.13–0.32	0.20–0.35 0.18–0.37	0.20–0.35 0.18–0.37	0.15–0.35 0.13–0.37	0.50–0.90 0.44–0.96	0.20–0.35 0.18–0.37	0.20–0.35 0.18–0.37	0.15–0.30 0.13–0.32	0.20–0.35 0.18–0.37	0.20–0.35 0.18–0.37
Nickel: Heat analysis Product analysis		... ...	... ...	... ...	... ...	... ...	0.70–1.00 0.67–1.03	... ...	0.30–0.70 0.27–0.73	... ...	... ...	... ...	1.20–1.50 1.15–1.55	1.20–1.50 1.15–1.55
	Chromium: Heat analysis Product analysis	0.50–0.80 0.46–0.84	0.40–0.65 0.36–0.69	... ...	0.85–1.20 0.79–1.26	1.40–2.00 1.34–2.06	0.40–0.65 0.36–0.69	0.50–0.90 0.46–0.94	0.40–0.65 0.36–0.69	... ...	... ...	1.15–1.65 1.09–1.71	......	0.85–1.20 0.79–1.26
Molybdenum: Heat analysis Product analysis		0.18–0.28 0.15–0.31	0.15–0.25 0.12–0.28	0.20–0.30 0.17–0.33	0.15–0.25 0.12–0.28	0.40–0.60 0.36–0.64	0.40–0.60 0.36–0.64	0.40–0.60 0.36–0.64	0.20–0.30 0.17–0.33	0.50–0.65 0.46–0.69	0.45–0.55 0.42–0.58	0.25–0.40 0.22–0.43	0.45–0.60 0.41–0.64	0.45–0.60 0.41–0.64
	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 min	0.001–0.005	0.001–0.005	0.0015–0.005	0.001–0.005

TABLE 1 Continued

Elements	Composition, %											
	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G	Grade H	Grade J	Grade L	Grade M	Grade P
Vanadium:												
Heat analysis	...	0.03–0.08	...	^a	^a	0.03–0.08	...	0.03–0.08	...	^a	...	...
Product analysis	...	0.02–0.09	...	...	...	0.02–0.09	...	0.02–0.09	...	...	...	...
Titanium:												
Heat analysis	...	0.01–0.03	...	0.04–0.10	0.04–0.10	...	...	...	...	0.04–0.10	...	...
Product analysis	...	0.01–0.04	...	0.03–0.11	0.03–0.11	...	...	...	...	0.03–0.11	...	...
Zirconium:												
Heat analysis	0.05–0.15	...	...	...	...	...	0.05–0.15	...	...	...	...	...
Product analysis	0.04–0.16	...	...	...	...	...	0.04–0.16	...	...	...	...	...
Copper:												
Heat analysis	...	...	...	0.20–0.40	0.20–0.40	0.15–0.50	...	...	...	0.20–0.40	...	...
Product analysis	...	...	...	0.17–0.43	0.17–0.43	0.12–0.53	...	...	...	0.17–0.43	...	...

^a May be substituted for part or all of titanium content on a one for one basis.

TABLE 2 Tensile Requirements

Tensile strength, ksi (MPa)	115-135 (795-930)
Yield strength, min, ksi (MPa)	100 (690)
Elongation in 2 in. or 50 mm, min, %	16
Reduction of area, min, %:	
Rectangular specimens	35
Round specimens	45

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**Standard Specification for
STEEL SHEET, ZINC-COATED (GALVANIZED)
BY THE HOT-DIP PROCESS,
GENERAL REQUIREMENTS¹**

This Standard is issued under the fixed designation A 525; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This specification covers the general requirements for the delivery of steel sheet in coils and cut lengths, zinc-coated (galvanized) on continuous lines by the hot-dip process. Galvanized steel sheet is customarily available in commercial quality, lock-forming quality, drawing quality, drawing quality special killed, and physical (structural) quality, which are fully described in separate standards (Section 2). Galvanized steel sheet is produced to various zinc-coating designations, as shown in Table 1, designed to give coatings compatible with the service life required. Except for differential-coated sheet, the coating is always expressed as the total coating of both surfaces. Galvanized steel sheet can be produced with the following types of coatings:

- 1.1.1 Regular spangle,
- 1.1.2 Minimized spangle,
- 1.1.3 Iron-zinc alloy, and
- 1.1.4 Differential.

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

2. Applicable Documents

2.1 The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue in effect shall apply.

2.2 ASTM Standards:

- A 90 Tests for Weight of Coating on Zinc-Coated Iron or Steel Articles²
- A 361 Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, for Roofing²
- A 370 Mechanical Testing of Steel Products³

- A 444 Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, for Culverts and Underdrains²
 - A 446 Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Physical (Structural) Quality²
 - A 526 Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Commercial Quality²
 - A 527 Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Lock-Forming Quality²
 - A 528 Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Drawing Quality²
 - A 642 Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Drawing Quality, Special Killed²
 - D 2092 Recommended Practices for Preparation of Zinc-Coated Steel Surfaces for Painting⁴
 - E 376 Recommended Practice for Measuring Coating Thickness by Magnetic Field or Eddy-Current (Electromagnetic) Test Methods⁵
- 2.3 *Other Standards:*
- R 247 – 62, U.S. Department of Commerce

¹ This specification is under the jurisdiction of ASTM Committee A-5 on Metallic-Coated Iron and Steel Products.

Current edition approved Oct. 29, 1973. Published December 1973. Originally published as A 525 – 64 T. Last previous edition A 525 – 71.

² 1974 *Annual Book of ASTM Standards*, Part 3.

³ 1974 *Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, and 5, and 1973 *Annual Book of ASTM Standards*, Part 31.

⁴ 1974 *Annual Book of ASTM Standards*, Part 27.

⁵ 1974 *Annual Book of ASTM Standards*, Parts 3 and 27, and 1973 *Annual Book of ASTM Standards*, Part 31.

*Simplified Practice Recommendation, (Packaging, Marking and Loading Methods for Steel Products for Domestic Shipment)*⁶

3. Definitions

3.1 *regular spangle*—galvanized sheet coated on continuous lines to the coating designations prefixed “G” shown in Table 1. Regular spangles are the result of the unrestricted growth of zinc crystals during normal solidification.

3.2 *minimized spangle*—galvanized sheet obtained by treating the regular galvanized sheet during the solidification of the zinc to restrict the normal spangle formation. This product usually has a dull appearance not characterized by a high degree of uniformity, and dissimilarity from coil to coil is not unusual. Minimum spangle is normally produced in coating designations G 90 and lighter.

3.3 *iron-zinc alloy*—galvanized sheet produced by processing the steel through the galvanizing line to produce a completely alloyed coating. This product is not spangled, is normally dull gray in appearance, and is suitable for immediate painting without further treatment except normal cleaning (refer to Methods D 2092). The lack of ductility of the alloy coating may result in powdering of the coating during fabrication. Iron-zinc alloy coated sheet can be supplied in the three coating designations in Table 1 prefixed by the letter “A”. Coating Designation A 60 is commonly known as galvanized sheet.

3.4 *differential coated*—galvanized steel sheet having a specified coating weight on one surface and a significantly lighter coating weight on the other surface. The light-coated side may be iron-zinc alloy if specified.

3.5 *mill phosphatized*—galvanized sheet chemically processed by the producer to prepare the surfaces for immediate painting without further treatment except normal cleaning (refer to Methods D 2092). Since this is a surface treatment only, all other characteristics of the coating remain unchanged. This sheet is normally produced to all coating designations in Table 1.

3.6 *extra smooth or skin passed*—material produced by skin passing the galvanized sheet to impart a higher degree of smoothness than is normal to the as-coated product, as in the

case of critical painted surfaces. Extra smooth is normally furnished in coating Designations G 90 and A 60 and lighter only. If fluting or stretcher strains are a hazard, extra smooth or skin passed should be specified.

3.7 *chemical treatment*—a passivating chemical treatment normally applied to galvanized coatings to retard the formation of white oxide during shipment and storage. However, the inhibiting characteristics of the treatment are limited and if a shipment is received wet, the material should be used or dried immediately.

3.8 *oiling*—a coating applied to the galvanized sheet as produced, either alone or in addition to the chemical treatment for further insurance against white oxide. In the event a chemical treatment is undesirable because of further processing such as phosphatizing, an oil coating offers protection during shipment and storage.

4. General Requirements for Delivery

4.1 The requirements of the purchase order, the individual material specification, and this general specification shall govern in the sequence stated.

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

5. Manufacture

5.1 The base metal shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

6. Chemical Requirements

6.1 An analysis of each cast or heat (formerly ladle) of steel shall be made by the producer to determine the percentage of carbon, manganese, phosphorus, sulfur, copper (when specified), and any other elements specified or restricted by the applicable specification.

6.1.1 When requested, cast or heat (formerly ladle) analysis for elements listed or required shall be reported to purchaser or his representative.

⁶ Available from the National Bureau of Standards, Washington, D.C. 20234.

6.2 Product analysis (formerly check) may be made by the purchaser on finished material. The chemical analysis so determined shall not vary from the limits specified by more than the amounts in Table 2. The several determinations of any element shall not vary both above or below the specified range.

6.2.1 Capped or rimmed steels are not technologically suited to product analysis due to the nonuniform character of their chemical composition, and therefore, the tolerances in Table 2 do not apply. Product analysis is appropriate on these steels only when misapplication is apparent or when copper is specified.

6.2.2 Product analysis for phosphorus or sulfur is not technologically appropriate because of segregation of these elements in all types of steel. Product analysis is appropriate only when misapplication is apparent.

6.2.3 Samples for product analysis should be drillings through stripped areas in sufficient numbers to adequately represent the coil or lift. At least three pieces should be selected, but if the product of more than one mill lift or coil is involved, six pieces should be selected.

6.3 *Zinc Bath Analysis*—The bath metal used in continuous hot-dip galvanizing shall contain not less than 98 percent pure zinc.

NOTE 2—To control alloy formation and promote adhesion of the zinc coating with the steel base metal, the molten coating metal composition normally contains a percentage of aluminum usually in the range from 0.05 to 0.25. This aluminum is purposely supplied the molten coating bath, either as a specified ingredient in the zinc spelter or by the addition of a master alloy containing aluminum.

7. Mechanical Requirements

7.1 *Base Metal Tests:*

7.1.1 When base metal mechanical properties are required by the applicable specification they shall be determined by the methods described in Methods A 370.

7.1.2 In determining the base metal mechanical properties, base metal thickness should be measured after stripping the coating from the ends of the specimen contacting the grips of the tension testing machine, before testing.

7.1.3 For all qualities other than physical (structural) quality the bend test specimen shall be capable of being bent through 180 deg flat on itself in any direction without major cracking of the base metal on the outside of

the bent portion. For physical (structural) quality, the radius of bend is specified in Specification A 446. Base metal bend tests are not required of sheets intended for corrugated roofing or siding.

7.2 *Base Metal Test Specimens:*

7.2.1 Test specimens shall be prepared from finished material.

7.2.2 Specimens for base metal tension tests shall be taken longitudinal and shall be selected and machined to the standard rectangular tension test specimen with 2-in. gage length as outlined in Methods A 370.

7.2.3 Specimens for base metal bend tests shall be as free as possible of burrs. Filing or machining to remove burrs is permitted. If any specimen develops a flaw it shall be discarded and a new specimen substituted. Cracks of the base metal developing at the edge of the specimen or coarse grain developing at the line of the bend, shall be disregarded.

8. Coating Tests

8.1 *Weight of Coating:*

8.1.1 The weight of coating shall conform to the requirements for triple- and single-spot minimum checks prescribed in Table 1 for the specific coating designation. The weight of coating is the total amount on both sides of a sheet, expressed in ounces per square foot of sheet, except in the case of differential coating.

8.1.2 When purchaser wishes to make tests to ascertain compliance of this specification for coating weight on a lot of any specific item of galvanized sheet, the procedure to be employed is as outlined in Methods A 90 in conjunction with the sampling procedure provided in 8.1.3, 8.1.4, and 8.1.5.

8.1.3 *Triple-Spot Test*—The triple-spot test shall be made in accordance with the procedure of Methods A 90. The result shall consist of the average of determinations from the three specimens cut from the test sheet or sample piece as provided in 8.1.5. Material 18 in. (457 mm) and under is normally produced by slitting from wider width coils and therefore is subject to the single-spot test only. Material slit after leaving the producer's works is subject to the single-spot test only.

8.1.4 *Single-Spot Test*—The minimum check limit by the single-spot test shall be that

one of the triple-spot test bearing the lightest coating, or the purchaser may select a single specimen taken from any part of the test sheet providing it is taken within the boundaries outlined in 8.1.5. For material narrower than 2.25 in. (57 mm), the test specimen length shall be chosen to give an area of 5.06 in.² (3265 mm²).

8.1.5 Test specimens for coils and cut lengths coated in coils shall be taken from a sample piece approximately one ft (300 mm) in length by the as-coated width. For the triple-spot test, one specimen shall be cut from the middle of the width and one from each side not closer than 2 in. (51 mm) from the side edge.

8.1.6 *Coating Thickness Measurements with Magnetic Gages*—A reasonable estimate of weight of coating may be obtained by converting coating thickness measurements made with magnetic gages. An accuracy of ± 15 percent in determining the thickness may be realized by following the recommended practice for magnetic instruments described in Recommended Practice E 376. This test may be used as a basis for acceptance but rejection shall be governed by the weight of coating tests described in 8.1.1 through 8.1.5.

8.2 *Coating Bend Test:*

8.2.1 For all qualities other than physical (structural) quality the bend test specimens of coated metal designated by prefix “G” shall be capable of being bent through 180 deg in any direction without flaking of the coating on the outside of the bend only. The radius of the bend is determined by the number of pieces of the same thickness (or mandrel equivalent) as shown in Table 3. Flaking of coating within $\frac{1}{4}$ in. (6.4 mm) of the edge of the bend specimen shall not be cause for rejection. Bend tests are not required of sheets intended for corrugated roofing or siding.

8.2.2 For coating bend tests applicable to physical (structural) quality refer to Specification A 446.

8.2.3 Because of the characteristics of alloy coatings designated by prefix “A”, as explained in 3.3, coating bend tests are not applicable.

8.2.4 Coating bend test specimens shall be 2 to 4 in. (51 to 102 mm) wide. The specimen shall be cut not less than 2 in. (51 mm) from the edges of the test sheet.

9. Retests

9.1 If one test fails for either base metal or coating, two more tests shall be taken at random from the same lot of any specific item. Both retests must conform to the requirements of the specification; otherwise, the lot shall be rejected.

9.2 When the percent of elongation is less than the specified minimum and any part of the fracture is outside the middle half of the gage length as scribed before the test, the test shall be discarded and a retest shall be permitted.

10. Dimensions and Tolerances

10.1 All dimensions and tolerances applicable to galvanized sheet are contained in the Tables. The appropriate tolerance tables shall be identified in each individual specification.

11. Workmanship

11.1 Cut lengths shall have a workmanlike appearance and shall not have defects of a nature or degree for the grade and quality ordered that will be detrimental to the fabrication of the finished part.

11.2 Coils may contain some abnormal imperfections which render a portion of the coil unusable since the inspection of coils does not afford the producer the same opportunity to remove portions containing imperfections as in the case with cut lengths.

12. Product Information

12.1 Galvanized sheet of rimmed-type steels is subject to the phenomenon commonly known as aging when stored over a period of time. This will result in such surface disturbances as fluting and stretcher strains when fabricated. To minimize fluting, effective roller leveling must be performed immediately before fabrication or drawing quality, special killed steel, which ages at a slower rate, should be specified. To minimize stretcher straining, extra-smooth galvanized steel is required and it must be effectively roller leveled immediately prior to fabrication, otherwise extra-smooth drawing quality, special killed must be specified.

12.2 Galvanized sheet in coils is subject to coil “breaks” when coiled to a smaller inside diameter than is compatible to the thickness

of the sheet. To minimize this condition, sheet heavier than 0.0291 in. (0.74 mm) should be ordered with a minimum 24 in. (610 mm) inside diameter and a minimum of 20 in. (508 mm) for thinner material. In further processing, such as slitting, the material should not be rewound on a smaller inside diameter than received.

13. Packaging, Marking, and Loading

13.1 It is common practice to use the methods of packaging as listed in the latest revision of the U.S. Department of Commerce *Simplified Practice Recommendation R 247-62*, (Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipments).

13.2 Purchaser may specify other than 13.1.

13.3 Abrasion during transit may have an effect on the appearance of galvanized steel. This condition is minimized if the product is oiled.

14. Inspection

14.1 The producer shall afford the purchaser's inspector all reasonable facilities to

assure him that material is being produced in compliance with the specification. Unless otherwise specified, all inspection and tests, except product analysis, shall be made at the producer's works prior to shipment. Such inspection or sampling shall be made concurrently with the producer's regular inspection and test operations unless it causes interference with normal operations or is otherwise specified.

15. Rejection and Rehearing

15.1 Unless otherwise specified, any rejection shall be reported to the producer within a reasonable time after receipt of material by the purchaser.

15.2 Material that is reported to be defective subsequent to the acceptance at the purchaser's works shall be set aside, adequately protected, and correctly identified. The producer shall be notified as soon as possible so that an investigation may be initiated.

15.3 Samples that are representative of the rejected material shall be made available to the producer. In the event that the producer is dissatisfied with the rejection, he may request a rehearing.

TABLE 1 Weight of Coating
(Total Both Sides)

NOTE—The coating designation number is the term by which this product is specified. The weight of coating in ounces per square foot of sheet refers to the total coating on both surfaces. Because of the many variables and changing conditions that are characteristic of continuous galvanizing, the weight of zinc coating is not always evenly divided between the two surfaces of a galvanized sheet; neither is the zinc coating evenly distributed from edge to edge. However, it can normally be expected that not less than 40 percent of the single-spot check limit will be found on either surface.

Type	Coating Designation	Previous Coating Class	Minimum Check Limit Triple-Spot Test		Minimum Check Limit Single Spot Test	
			oz/ft ² (of sheet)	g/m ²	oz/ft ² (of sheet)	g/m ²
Regular	G 235	2.75	2.35	717	2.00	610
	G 210	2.50	2.10	640	1.80	549
	G 185	2.25	1.85	564	1.60	488
	G 165	2.00	1.65	503	1.40	427
	G 140	1.75	1.40	427	1.20	366
	G 115	1.50	1.15	351	1.00	305
	G 90	1.25 Commercial	0.90	275	0.80	244
	G 60	Light Commercial	0.60	183	0.50	152
	G 01	...	no minimum	...	no minimum	...
Alloyed	A 60	...	0.60	183	0.50	152
	A 40	...	0.40	122	0.30	91
	A 01	...	no minimum	...	no minimum	...

**TABLE 2 Tolerances for Product Analysis
(Formerly Check)**

Element	Limit, or Maximum of Specified Element, percent	Tolerance Over the Maximum Limit or Under the Minimum Limit	
		Under Minimum Limit	Over Maximum Limit
Carbon	To 0.15, incl	0.02	0.03
	Over 0.15 to 0.40, incl	0.03	0.04
	Over 0.40 to 0.80, incl	0.03	0.05
Manganese	To 0.60, incl	0.03	0.03
	Over 0.60 to 1.15, incl	0.04	0.04
	Over 1.15 to 1.65, incl	0.05	0.05
Phosphorus	...	...	0.01
Sulfur	...	...	0.01
Silicon	To 0.30, incl	0.02	0.03
	Over 0.30 to 0.60	0.05	0.05
Copper	...	0.02	...

TABLE 3 Coating Bend Tests^{a, b, c}
(Number of Pieces of Same Thickness Used in Coating Bend Test)

Coating Designation	Galvanized Sheet Thickness		
	0.1756 in. (4.46 mm) to 0.0748 in. (1.90 mm)	0.0747 in. (1.90 mm) to 0.0382 in. (0.97 mm)	0.0381 in. (0.97 mm) to 0.0131 in. (0.33 mm)
G 235	3		3 2
G 210	2		2 2
G 185	2		2 2
G 165	2		2 2
G 140	2	1	1 1
G 115	1	0	0 0
G 90	1	0	0 0
G 60	0	0	0 0
G 01	0	0	0 0

^a Spacing of the inside of the bend determines the severity of the test and is specified in this table by the number of pieces, of the same gage as tested, used to space the bend.

^b Bends may be made over mandrels of equivalent thickness with radius proportional to the thickness.

^c This table does not apply to physical (structural) quality and alloy coatings.

TABLE A List of Dimension and Tolerance Tables

Title	No.
Allowances in Width and Length (Hot-Dip Galvanized Cut Lengths Specified to Stretcher-Leveled Standard of Flatness, Not Resquared)	13
Camber Tolerances of Hot-Dip Galvanized Sheet	7
Camber Tolerance of Hot-Dip Galvanized Sheet in Widths 2 to 12 in. (51 to 305 mm) in Coils and Cut Lengths	16
Diameter Tolerances for Sheared Circles (Hot-Dip Galvanized Sheet)	8
Flatness Tolerances (Hot-Dip Galvanized Cut Lengths Over 12 in. in Width, Not Specified to Stretcher-Leveled Standard of Flatness)	11
Flatness Tolerances (Hot-Dip Galvanized Cut Lengths, Stretcher-Leveled Standard of Flatness)	12
Length Tolerances (Hot-Dip Galvanized Cut Lengths, Not Resquared)	6
Length Tolerances of Hot-Dip Galvanized Cut Lengths 2 to 12 in. (51 to 305 mm) in Width, Not Resquared	15
Hot-Dip Galvanized Sheet Gage Numbers and Thickness	17
Out-of-Square Tolerances (Hot-Dip Galvanized Cut Lengths, Not Resquared)	9
Resquared Tolerances (Resquared Hot-Dip Galvanized Cut Lengths)	10
Thickness Tolerances of Hot-Dip Galvanized Sheet	4
Width Tolerances of Hot-Dip Galvanized Sheet (Coils and Cut Lengths, Not Resquared)	5
Width Tolerances of Hot-Dip Galvanized Sheet (Coils and Cut Lengths, Not Resquared) 2 to 12 in. (51 to 305 mm) in Width	14

TABLE 4 Thickness Tolerances of Hot-Dip Galvanized Sheet

NOTE 1—Thickness is measured at any point across the width not less than $\frac{3}{8}$ in. (9.5 mm) from a side edge.
NOTE 2—Regardless of whether total thickness tolerance is specified equally or unequally, over and under, the total tolerance should be equal to twice the tabular tolerances.

Thickness Tolerances for Widths and Thicknesses, Over and Under, in.						
Specified Widths, in.	Specified Thickness, in.					
	0.1868 to 0.1009	0.1008 to 0.0748	0.0747 to 0.0605	0.0605 to 0.0426	0.0425 to 0.0232	0.0231 and thinner
To 32, incl.	0.008	0.007	0.006	0.005	0.004	0.003
Over 32 to 40, incl.	0.008	0.008	0.006	0.005	0.004	0.003
Over 40 to 60, incl.	0.009	0.008	0.006	0.005	0.004	0.003
Over 60 to 72, incl.	0.009	0.009	0.006	0.005	0.004	...

Thickness Tolerances for Widths and Thicknesses, Over and Under, (mm)						
Specified Widths, mm	Specified Thickness, (mm)					
	4.75 to 2.55	2.54 to 1.90	1.89 to 1.50	1.49 to 1.10	1.09 to 0.60	0.59 and thinner
To 815, incl.	0.21	0.18	0.15	0.13	0.10	0.08
Over 815 to 1015, incl.	0.21	0.21	0.15	0.13	0.10	0.08
Over 1015 to 1525, incl.	0.23	0.21	0.15	0.13	0.10	0.08
Over 1525 to 1825, incl.	0.23	0.23	0.15	0.13	0.10	...

TABLE 5 Width Tolerances of Hot-Dip Galvanized Sheet
(Coils and Cut Lengths, Not Resquared)

Specified Width, in. (mm)	Tolerance Over Specified Width, No Tolerance Under	
	in.	mm
Up to 30 (762), incl.	$\frac{1}{8}$	3
Over 30 (762) to 48 (1219), incl.	$\frac{3}{16}$	5
Over 48 (1219) to 60 (1524), incl.	$\frac{1}{4}$	6
Over 60 (1524) to 72 (1829), incl.	$\frac{5}{16}$	8

TABLE 7 Camber Tolerances of Hot-Dip Galvanized Sheet

NOTE—Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge. The camber tolerance for sheet in coils is 1 in. (25.4 mm) in any 20 ft (6.096 m), except as shown in Table 16. The camber tolerances for sheet in cut lengths, not resquared, are as shown.

Cut Lengths, ft (m)	Camber Tolerance	
	in.	mm
To 4 (1.219), incl.	$\frac{1}{8}$	3
Over 4 (1.219) to 6 (1.829), incl.	$\frac{3}{16}$	5
Over 6 (1.829) to 8 (2.438), incl.	$\frac{1}{4}$	6
Over 8 (2.438) to 10 (3.048), incl.	$\frac{5}{16}$	8
Over 10 (3.048) to 12 (3.658), incl.	$\frac{3}{8}$	10
Over 12 (3.658) to 14 (4.267), incl.	$\frac{1}{2}$	13
Over 14 (4.267) to 16 (4.877), incl.	$\frac{5}{8}$	16
Over 16 (4.877) to 18 (5.486), incl.	$\frac{3}{4}$	19
Over 18 (5.486) to 20 (6.096), incl.	$\frac{7}{8}$	22
Over 20 (6.096) to 30 (9.144), incl.	1 $\frac{1}{4}$	32
Over 30 (9.144) to 40 (12.192), incl.	1 $\frac{1}{2}$	38

TABLE 6 Length Tolerances
(Hot Dip Galvanized Cut Lengths Not Resquared)

Specified Length, in. (mm)	Tolerance Over Specified Length, No Tolerance Under	
	in.	mm
Over 12 (305) to 30 (762), incl.	$\frac{1}{8}$	3
Over 30 (762) to 60 (1524), incl.	$\frac{1}{4}$	6
Over 60 (1524) to 96 (2438), incl.	$\frac{1}{2}$	13
Over 96 (2438) to 120 (3048), incl.	$\frac{3}{4}$	19
Over 120 (3048) to 156 (3962), incl.	1	25
Over 156 (3962) to 192 (4877), incl.	1 $\frac{1}{4}$	31
Over 192 (4877) to 240 (6096), incl.	1 $\frac{1}{2}$	38
Over 240 (6096)	1 $\frac{3}{4}$	44

TABLE 8 Diameter Tolerances for Sheared Circles
(Hot-Dip Galvanized Sheet)

Specified Thickness, in. (mm)	Tolerance Over Specified Diameter, in. (mm), No Tolerance Under		
	Diameters, in. (mm)		
	Under 30 in. (762 mm)	30 in. to 48 in. (762 mm) to 48 in. (1219 mm)	Over 48 in. (1219 mm)
0.1009 and thicker (2.563)	$\frac{1}{8}$ (3.2)	$\frac{3}{16}$ (4.8)	$\frac{1}{4}$ (6.4)
0.1008 to 0.0606 (2.562) to (1.539)	$\frac{3}{32}$ (2.4)	$\frac{5}{32}$ (4.0)	$\frac{7}{32}$ (5.6)
0.0605 and thinner (1.538)	$\frac{1}{16}$ (1.6)	$\frac{1}{8}$ (3.2)	$\frac{3}{16}$ (4.8)



TABLE 9 Out-of-Square Tolerances
(Hot-Dip Galvanized Cut Lengths Not Resquared)

Out-of-square is the greatest deviation of an end edge from a straight line at right angles to a side and touching one corner. It is also obtained by measuring the difference between the diagonals of the cut length. The out-of-square deviation is one half of that difference. The tolerance for cut lengths of all thicknesses and all sizes is $\frac{1}{16}$ in. in each 6 in. (1.5 mm/152 mm) of width or fraction thereof.

TABLE 10 Resquared Tolerances
(Resquared Hot-Dip Galvanized Cut Lengths)

When cut lengths are specified resquared, the width and length are not less than the dimensions specified. The individual tolerance for over-width, over-length, camber, or out-of-square should not exceed $\frac{1}{16}$ in. (1.5 mm) for cut lengths up to and including 48 in. (1.219 m) in width and up to and including 120 in. (3.048 m) in length, nor $\frac{1}{8}$ in. (3 mm) for wider or longer cut lengths.

TABLE 11 Flatness Tolerances
(Hot-Dip Galvanized Cut Lengths Over 12 In. (305 mm) In Width, Not Specified to Stretcher-Leveled Standard of Flatness)

NOTE 1—This table does not apply to physical (structural) quality.

NOTE 2—This table also applies to sheet cut to length from coils by the consumer when adequate flattening measures are performed.

Specified Thickness, in. (mm)	Specified Width, in. (mm)	Flatness Tolerances, in. (mm) (Maximum Deviation From a Horizontal Flat Surface)
0.0486 (1.234) and thicker	To 36 (914), incl	$\frac{1}{4}$ (6)
	Over 36 (914) to 60 (1524), incl	$\frac{3}{8}$ (10)
	Over 60 (1524) to 72 (1829), incl	$\frac{5}{8}$ (16)
0.0485 (1.233) and thinner	To 36 (914), incl	$\frac{3}{8}$ (10)
	Over 36 (914) to 60 (1524), incl	$\frac{5}{8}$ (16)
	Over 60 (1524) to 72 (1829), incl	$\frac{7}{8}$ (22)

TABLE 12 Flatness Tolerances
(Hot-Dip Galvanized Cut Lengths to Stretcher-Leveled Standard of Flatness)

Specified Thickness, in. (mm)	Specified Width, in. (mm)	Specified Length, in. (mm)	Flatness Tolerance, in. (mm) (Maximum Deviation from a Horizontal Flat Surface)
0.0322 (0.8178) and thicker	To 48 (1219), incl Wider or longer sheet	To 120 (3048), incl	$\frac{1}{8}$ (3)
			$\frac{1}{4}$ (6)
0.0321 (0.8177) to 0.0195 (0.4953), incl	To 36 (914), incl Wider or longer sheet	To 120 (3048), incl	$\frac{1}{4}$ (6)
			$\frac{3}{8}$ (10)

TABLE 13 Allowance in Width and Length
(Hot-Dip Galvanized Cut Lengths Specified to Stretcher-Leveled Standard of Flatness, Not Resquared)

Specified Length, in. (mm)	Allowances Over Specified Dimensions		
	Width, in. (mm)	Length, in. (mm)	
		Specified: "Grip or entry marks outside specified length."	Specified: "Grip or entry marks inside specified length."
To 120 (3048), incl	$\frac{3}{4}$ (19)	4 (102)	3 (76)
Over 120 (3048) to 156 (3962), incl	1 (25)	4 (102)	3 (76)
Over 156 (3962)	$1\frac{1}{4}$ (32)	5 (127)	4 (102)

TABLE 14 Hot-Dip Galvanized Sheet Width Tolerances
(Coils and Cut Lengths, Not Resquared Sheet, 2 to 12 in.
(51 mm to 305 mm) in Width)

Specified Thickness, in. (mm)	Tolerances Over and Under Specified Width, in. (mm)		
	2 to 6 (51 to 152), incl	Over 6 to 9 (152 to 229), incl	Over 9 to 12 (229 to 305), incl
0.0821 to 0.0681 (2.09 to 1.73)	0.012 (0.305)	0.016 (0.406)	0.032 (0.813)
0.0680 to 0.0142 (1.73 to 0.36)	0.008 (0.203)	0.016 (0.406)	0.032 (0.813)

TABLE 15 Hot-Dip Galvanized Sheet Length Tolerances
(Cut Length 2 to 12 in. (51 to 305 mm) in Width, Not
Resquared)

Specified Thickness, in. (mm)	Tolerance Over Specified Length, No Under Tolerance, in. (mm)		
	24 to 60 (0.61 to 1.52), incl	Over 60 to 120 (1.52 to 3.05), incl	Over 120 to 240 (3.05 to 6.10), incl
2 to 12 (51 to 305), incl	½ (13)	¾ (19)	1 (25)

**TABLE 16 Hot-Dip Galvanized Sheet in Coils, Camber
Tolerances**

Sheet in Widths 2 to 12 in. (51 to 305 mm), incl ¼ in. (6.35 mm) in any 8 ft. (2.44 m)

**TABLE 17 Galvanized Sheet Gage Numbers and
Thicknesses^a**

Galvanized Sheet Gage No.	Thickness Equivalent for Galvanized Sheet Gage No., in.	Thickness Equivalent for Galvanized Sheet Gage No., mm
8	0.1681	4.270
9	0.1532	3.891
10	0.1382	3.510
11	0.1233	3.132
12	0.1084	2.753
13	0.0934	2.372
14	0.0785	1.994
15	0.0710	1.803
16	0.0635	1.613
17	0.0575	1.461
18	0.0516	1.311
19	0.0456	1.158
20	0.0396	1.006
21	0.0366	0.9296
22	0.0336	0.8534
23	0.0306	0.7772
24	0.0276	0.7010
25	0.0247	0.6274
26	0.0217	0.5512
27	0.0202	0.5131
28	0.0187	0.4750
29	0.0172	0.4369
30	0.0157	0.3988
31	0.0142	0.3607
32	0.0134	0.3404

^a This table for information only. As stated in 4.2, the product is ordered to decimal thickness only; not to gage number.

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AMERICAN SOCIETY FOR TESTING AND MATERIALS

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Standard Specification for DUCTILE IRON CASTINGS¹

This Standard is issued under the fixed designation A 536; 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 castings made of ductile iron, also known as spheroidal or nodular iron, which is defined as cast iron with the graphite substantially spheroidal in shape and essentially free of other forms of graphite.

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

2. Chemical Requirements

2.1 It is the intent of this specification to subordinate chemical composition to mechanical properties; however, any chemical requirements may be specified by agreement between the manufacturer and the purchaser.

3. Tensile Properties

3.1 The iron as represented by the test specimens shall conform to the requirements as to tensile properties prescribed in Table 1.

3.2 The yield strength prescribed in Table 1 shall be determined at 0.2 percent offset by the offset method, see ASTM Methods E 8, Tension Testing of Metallic Materials.² Other methods may be used by mutual consent of manufacturer and purchaser.

4. Test Coupons

4.1 The separately cast test coupons from which the tension test specimens are machined shall be cast to the size and shape shown in Fig. 1 or 2. The size of coupon cast to represent the casting shall be at the option of the purchaser. In case no option is expressed, the manufacturer shall make the choice.

4.2 The test coupons shall be poured from the same ladle or heat as the castings they represent.

4.3 Test coupons shall be subjected to the same thermal treatment as the castings they represent.

5. Tension Test Specimens

5.1 The standard round tension test specimen with a 2-in. or 50-mm gage length shown in Fig. 3 shall be used, except when the ½-in. (12.7-mm) Y-block coupon is used. In this case, either of the test specimens shown in Fig. 4 shall be satisfactory.

6. Number of Tests

6.1 The number of representative coupons poured and tested shall be established by the manufacturer, unless otherwise agreed upon with the purchaser.

6.2 In the case of the Y-block, the section shall be cut from the block as shown in Fig. 5. If any tension test specimen shows obvious defects, another may be cut from the same test block or from another test block representing the same metal.

7. Heat Treatment

7.1 The 60-40-18 grade will normally require a full ferritizing anneal. The 120-90-02 and the 100-70-03 grades generally require a quench and temper or a normalize and temper heat treatment. The other two grades can be met either as-cast or by heat treatment.

¹This specification is under the jurisdiction of the ASTM Committee A-4 on Iron Castings.

Current edition approved August 29, 1972. Published October 1972. Originally published as A 536 - 65T. Last previous edition A 536 - 71.

²Annual Book of ASTM Standards, Part 31.

8. Workmanship and Finish

8.1 The castings shall be smooth, free from injurious defects, and shall conform substantially to the dimensions of the drawing or pattern supplied by the purchaser.

9. Inspection

9.1 The manufacturer shall afford the inspector representing the purchaser free entry and reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. Unless otherwise specified, all tests and inspection shall be made at the place of manufacture prior to shipment,

and shall be so conducted as not to interfere unnecessarily with the operation of the works.

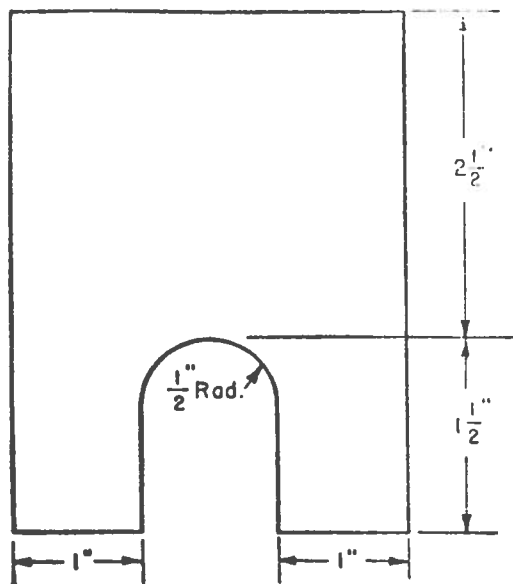
10. Certification

10.1 When agreed upon in writing by the purchaser and the seller, a certification shall be made the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the seller, accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

TABLE 1 Tensile Requirements^a

	Grade 60-40-18	Grade 65-45-12	Grade 80-55-06	Grade 100-70-03	Grade 120-90-02
Tensile strength, min, psi	60 000	65 000	80 000	100 000	120 000
Tensile strength, min, MPa	414	448	552	689	827
Yield strength, min, psi	40 000	45 000	55 000	70 000	90 000
Yield strength, min, MPa	276	310	379	483	621
Elongation in 2 in. or 50 mm, min, percent	18	12	6.0	3.0	2.0

^a In choosing the five grades of ductile iron as defined in the scope, the subcommittee studied a great deal of test data obtained from a wide variety of commercial iron in both the as-cast and the heat-treated conditions. These five grades fit the general pattern and are popular for some producers and consumers. On the other hand, there are many other combinations of minimum ultimate strength, yield strength, and percent elongation that are equally valid and useful for the intended purpose: For instance, 80-60-03 is a very popular grade where a great amount of ductility is not necessary. Also 60-45-10 and 60-42-10 are annealed grades that have been used satisfactorily by the pipe industry. Grade 70-50-05 as-cast ductile iron is used extensively for pipe fittings for water and other liquids. Grades other than the five shown can be agreed upon between the consumer and producer and made to meet all the other requirements of this standard.

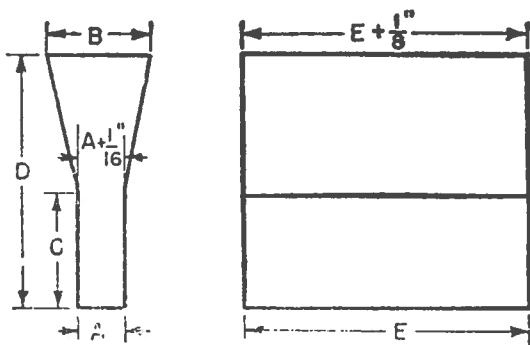


Metric Equivalents

in.	mm	in.	mm
1/2	12.7	1 1/2	38.1
1	25.4	2 1/2	63.5

NOTE—The length of the keel block shall be 6 in. (152 mm).

FIG. 1 Keel Block for Test Coupons.

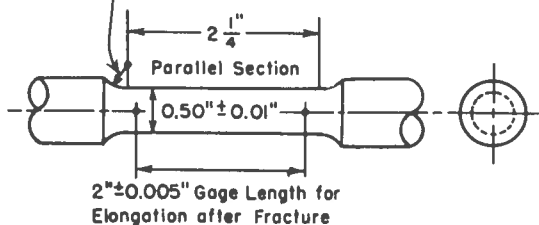


"Y" Block Size

Dimensions	For Castings of Thickness Less Than 1/2 in. (13 mm)		For Castings of Thickness 1/2 in. (13 mm) to 1 1/2 in. (38 mm)		For Castings of Thickness of 1 1/2 in. (38 mm) and Over	
	in.	mm	in.	mm	in.	mm
A	1/2	13	1	25	3	75
B	1 1/2	40	2 1/2	50	5	125
C	2	50	3	75	4	100
D	4	100	6	150	8	200
E	7	175	7	175	7	175
	approx	approx	approx	approx	approx	approx

FIG. 2 Y-Blocks for Test Coupons.

Minimum Radius Recommended
3/8 in., but not less than 1/8 in.
Permitted

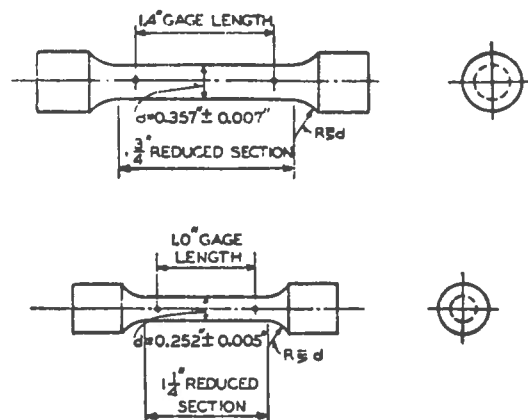


Metric Equivalents

in.	mm	in.	mm
0.005	0.13	0.50	12.7
0.10	2.5	2	50.8
1/8	3.2		
3/8	9.5	2 1/4	57.2

NOTE—The gage length and fillets shall be as shows, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. (0.08 to 0.13 mm) larger in diameter than the center.

FIG. 3 Standard Round Tension Test Specimen with 2-in. or 50-mm Gage Length.

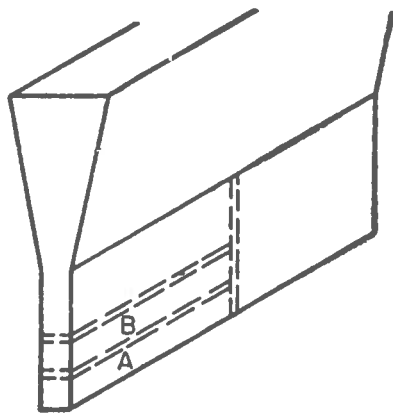


Metric Equivalents

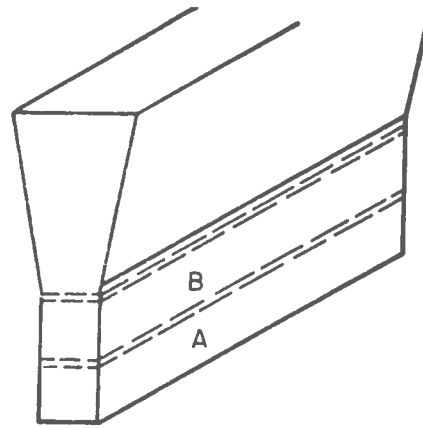
in.	mm	in.	mm
0.005	0.13	1.0	25.4
0.007	0.18	1 1/4	31.8
0.252	6.40	1.4	35.6
0.357	9.07	1 3/4	44.4

NOTE—If desired, the length of the reduced section may be increased to accommodate an extensometer.

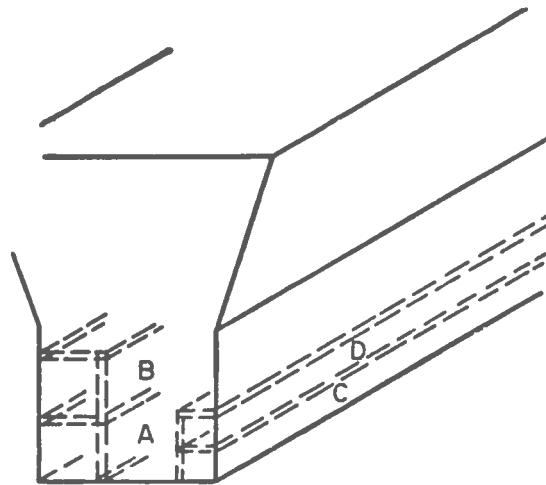
FIG. 4 Examples of Small-Size Specimens Proportional to Standard 1/2-in. (12.7-mm) Round Specimen.



(a) 1/2-in. (12.7-mm) Y-Block—Two blanks for 0.252-in. (6.40-mm) diameter test specimens.



(b) 1-in. (25.4-mm) Y-Block—Two blanks for 0.50-in. (12.7-mm) diameter tension test specimens.



(c) 3-in. (76.2-mm) Y-Block—Two blanks for 0.50-in. (12.7-mm) diameter tension test specimens.

FIG. 5 Sectioning Procedure for Y-Blocks.

APPENDIX

A1. Y-BLOCK SELECTION

A1.1 As a general guide for selection of the proper Y-block, the tabulation in Table A1, based on cooling rates, shows, for various test coupons,

the equivalent geometric shapes with various dimensions.

TABLE A1 Equivalent Geometric Shapes Corresponding to Y-Blocks

Y-Block Size, in. (mm)	Infinite Plate Thickness, in. (mm)	Round Diameter, in. (mm)	Cube Edge, in. (mm)
½ (12.7)	0.5 (12.7)	1.2 (30.5)	1.75 (44.4)
1 (25.4)	0.9 (22.9)	1.75 (44.4)	2.75 (69.8)
3 (76.2)	1.6 (40.6)	3.1 (78.7)	4.8 (121.9)

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**Standard Specification for
HIGH-STRENGTH LOW-ALLOY COLUMBIUM-
VANADIUM STEELS OF STRUCTURAL QUALITY¹**

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.

1. Scope

1.1 This specification covers six grades of high-strength low-alloy structural steel shapes, plates, sheet piling, and bars. Grades 42, 45, and 50 are intended for riveted, bolted, or welded construction of bridges, buildings, and other structures. Grades 55, 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 U.S. customary units are to be regarded as the standard.

2. Applicable Documents

2.1 ASTM Standard:

A 6, Specification for General Requirements for Delivery of 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 July 29, 1974, and Aug. 30, 1974. Published November 1974. Originally published as A 572 – 66. Last previous edition A 572 – 74.

² 1974 Annual Book of ASTM Standards, Part 4.

Elements	Heat Analysis, %
Columbium ^a	0.005–0.05 ^b
Vanadium	0.01–0.15
Columbium ^a (0.05 max, %) plus vanadium ^c	0.02–0.15
Nitrogen ^d (with vanadium)	0.015 max

^a Columbium when added either singly or in combination with vanadium shall be restricted to plate or bar thickness of ½ in. (13 mm) max and to shapes of Table A Group 1 of Specification A 6, unless killed steel is furnished.

^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 ⅝ 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 ⅛ in. (0.8 mm) of the specified thickness or diameter below ⅝ in.

6.2 *Bending Properties*—The longitudinal bend test specimens shall withstand 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 4.

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.

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
45	45 000	310	2	50.8	all	all
50 ^a	50 000	345	2	50.8	1, 2, 3, and 4	all
55	55 000	380	1 ½	38.1	1, 2, 3, and 4 up to 426 lb/ft (639 kg/m), incl	all
60 ^a	60 000	415	1 ¼	31.8	1 and 2	not available
65	65 000	450	1 ¼	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 Steel² 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 Thick- ness, or Distance Between Parallel Faces, in. (mm)	Grade	Carbon, max, %	Manganese, ^b max, %	Phosphorus, max, %	Sulfur, max, %	Silicon ^c	
						Plates to 1 1/2-in. (38.1 mm) Thick, Shapes to 426 lb/ft (639 kg/m) Sheet Piling, and Bars ^d	Plates Over 1 1/2- in. (38.1 mm) Thick
						max, %	range, %
6 (152)	42	0.21	1.35	0.04	0.05	0.30	0.15-0.30
2 (51)	45	0.22	1.35	0.04	0.05	0.30	0.15-0.30
2 (51)	50	0.23	1.35	0.04	0.05	0.30	0.15-0.30
1 1/2 (38.1)	55	0.25	1.35	0.04	0.05	0.30	...
1 1/4 (31.8)	60	0.26	1.35	0.04	0.05	0.30	...
> 1/2 - 1 1/4 (12.7-31.8)	65	0.23	1.65	0.04	0.05	0.30	...
≤ 1/2 (12.7)	65	0.26	1.35	0.04	0.05	0.30	...

^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 3/8 in. (9.5 mm) in thickness; a minimum of 0.50 % (0.45 % product analysis) shall be required for plates 3/8 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 0.30 % by heat analysis must be negotiated.

^d Bars over 1 1/2 in. (38.1 mm) in diameter, thickness, or distance between parallel faces, shall be made by a killed steel practice.

TABLE 3 Tensile Requirements

Grade	Yield Point, min		Tensile Strength, min		Minimum Elongation, ^{a,b} %	
	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
45	45 000	310	60 000	415	19	22
50	50 000	345	65 000	450	18	21
55	55 000	380	70 000	485	17	20
60	60 000	415	75 000	520	16	18
65	65 000	450	80 000	550	15	17

^a Elongation not required to be determined for floor plate.

^b For wide flange shapes over 426 lb/ft elongation in 2 in. (50 mm) of 19 % minimum applies.

TABLE 4 Bend Test Requirements

Thickness of Material, in. (mm)	Ratio of Bend Diameter to Thickness of Specimen ^a					
	Grade 42	Grade 45	Grade 50	Grade 55	Grade 60	Grade 65
3/4 (19.0), and under	1	1	1	1 1/2	2	2 1/2 ^b
Over 3/4 to 1 (19.0 to 25.4), incl	1 1/2	1 1/2	1 1/2	2	2 1/2	3
Over 1 to 1 1/2 (25.4 to 38.1), incl	2	2	2 1/2	3	3	3 1/2
Over 1 1/2 to 2 (38.1 to 51), incl	2 1/2	2 1/2 ^c	3 ^c	3 1/2 ^c	...	...
Over 2 to 4 (51 to 102), incl	3	...	...	...	...	...
Over 4 to 6 (102 to 152), incl	4	...	...	...	...	...

^a The above ratios apply to the bending performance of a test specimen only. This specimen is always taken in the longitudinal direction and usually has some edge preparation. Where plates are to be bent in a fabricating operation, more liberal bend radii must be used, particularly if this bend axis is in the unfavorable (longitudinal) direction.

^b 1/2 in. (13 mm) max, specimen thickness.

^c Applicable to webs of structural shapes.

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**Standard Specification for
HIGH-STRENGTH LOW-ALLOY STRUCTURAL STEEL
WITH 50 000 PSI MINIMUM YIELD POINT TO 4 IN.
THICK¹**

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 saving 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), incl, 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 U.S. customary units are to be regarded as the standard.

2. General Requirements for Delivery

2.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of ASTM Specification A 6, for General Requirements for Delivery of 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 Properties

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 $\frac{5}{16}$ in. (7.9 mm) in thickness or diameter, as represented by the test specimen, a deduction of 1.25 percentage points from the percentage of elongation in 8 in. or 200 mm specified in Table 2 shall be made for each decrease of $\frac{1}{32}$ in. (0.8 mm) of the specified thickness or diameter below $\frac{5}{16}$ in. (7.9 mm).

6. Bending Properties

6.1 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 based on the thickness of the specimen as prescribed in Table 3.

¹ This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

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² 1974 Annual Book of ASTM Standards, Part 4.

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	0.10–0.19	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	0.90–1.25	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	0.15–0.30	0.15–0.30	0.15–0.30	0.50–0.90	0.15–0.30	0.30 max	0.25–0.70	0.25–0.75	0.30–0.50
Nickel	...	0.25–0.50	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	0.50–0.75	...	0.30 max	0.50–1.00	0.10–0.25	...
Molybdenum	...	...	...	...	0.10–0.25	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

	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 ^d
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 ^{a, b}	...	...	18 ^a
Elongation in 2 in. or 50 mm, min, %	21 ^b	21 ^b	21 ^b	21 ^c

^a See 5.2.

^b Elongation not required to be determined for floor plate.

^c For wide flange shapes over 426 lb/ft elongation in 2 in. of 18 % minimum applies.

^d See Specification A 6.

TABLE 3 Bend Test Requirements

Thickness of Material, in. (mm)	Ratio of Bend Diameter to Thickness of Specimen
To ¾ (19.1), incl	1
Over ¾ to 1 (19.1 to 25.4), incl	1 ½
Over 1 to 1 ½ (25.4 to 38.1), incl	2
Over 1 ½ to 2 (38.1 to 50.8 mm), incl	2 ½
Over 2 to 8 (50.8 to 203.2 mm), incl	3

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**Standard Specification for
HOT-FORMED WELDED AND SEAMLESS HIGH-
STRENGTH LOW-ALLOY STRUCTURAL TUBING¹**

This Standard is issued under the fixed designation A 618; 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 hot-formed welded and seamless high-strength low-alloy square, rectangular, round, or special shape structural tubing for welded, riveted, or bolted construction of bridges and buildings and for general structural purposes. When the steel is used in welded construction, the welding procedure shall be suitable for the steel and the intended service.

1.2 When enhanced corrosion resistance is desired for Grades I and III, copper limits may be specified.

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

2. Basis of Purchase

2.1 Orders for material under this specification shall include the following as required to describe the material adequately:

- 2.1.1 Quantity (feet or number of lengths),
- 2.1.2 Grade (Tables 1 and 2),
- 2.1.3 Material (round, square, or rectangular tubing),
- 2.1.4 Method of manufacture (seamless, butt welded, or hot-stretch-reduced electric-resistance welded),
- 2.1.5 Size (outside diameter and nominal wall thickness for round tubing and the outside dimensions and calculated nominal wall thickness for square and rectangular tubing),
- 2.1.6 Length (specific or random, see 7.2),
- 2.1.7 End condition (see 8.2),
- 2.1.8 Burr removal (see 8.2),
- 2.1.9 Certification (see 11.1),
- 2.1.10 ASTM designation,
- 2.1.11 End use, and
- 2.1.12 Special requirements.

3. Manufacture

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

3.2 The tubing shall be made by the seamless, furnace-butt welded (continuous-welded), or hot-stretch-reduced electric-resistance-welded process.

4. Chemical Requirements

4.1 When subjected to the heat and product analysis, respectively, the steel shall conform to the requirements prescribed in Table 1.

4.1.1 For Grade I, the choice and use of alloying elements, combined with carbon, manganese, and sulfur within the limits prescribed in Table 1 to give the mechanical properties prescribed in Table 2, shall be made by the manufacturer and included and reported in the heat analysis for information purposes only to identify the type of steel applied.

4.1.2 The chemistry may be such as to provide copper-bearing steel having enhanced corrosion resistance of twice the atmospheric corrosion resistance of plain carbon steel.

4.1.3 The copper limits of Grade I are subject to negotiation and shall be indicated in the purchase order.

4.1.4 When Grade III is required for enhanced corrosion resistance, copper limits may be specified and the minimum content shall be 0.20 percent by heat analysis and

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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0.18 percent by product analysis.

4.2 Heat Analysis—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.

4.3 Product Analysis:

4.3.1 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. 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, Cast Iron, Open-Hearth Iron, and Wrought Iron for Determination of Chemical Composition.² The chemical composition thus determined shall conform to the requirements specified in Table 1 for product analysis.

4.3.2 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.

5. Mechanical Requirements

5.1 Tensile Properties:

5.1.1 The material, as represented by the test specimen, shall conform to the requirements prescribed in Table 2.

5.1.2 Elongation may be determined on a gage length of either 2 in. (or 50 mm) or 8 in. (200 mm) at the manufacturer's option.

5.1.3 For material under $\frac{5}{16}$ in. (7.94 mm) in thickness, a deduction from the percentage elongation of 1.25 percentage points in 8 in. specified in Table 2 shall be made for each decrease of $\frac{1}{32}$ in. (0.79 mm) of the specified thickness under $\frac{5}{16}$ in. (7.94 mm).

5.2 Bend Test—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.

5.3 Number of Tests—Two tension and two bend tests, as specified in 5.4.2, and 5.4.3, shall be made from tubing representing each heat. However, if tubing from one heat differs in the ordered nominal wall thickness, one tension test and one bend test shall be made from both the heaviest and lightest wall thicknesses processed.

5.4 Test Specimens:

5.4.1 The test specimens required by this specification shall conform to those described in the latest issue of ASTM Methods and Definitions A 370, for the Mechanical Testing of Steel Products.³

5.4.2 The tension test specimen shall be taken longitudinally from a section of the finished tubing, at a location 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.

5.4.3 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. (1.59 mm).

5.5 Methods of Test:

5.5.1 The yield point shall be determined in accordance with one of the alternatives described in Methods A 370.

5.5.2 The bend test shall be made on square or rectangular tubing manufactured in accordance with this specification.

6. Retests

6.1 If the results of the mechanical tests representing any heat do not conform to a

² 1974 Annual Book of ASTM Standards, Part 12.

³ 1974 Annual Book of ASTM Standards, Parts 1, 2, 3, 4, 5, and 10.

requirement, as specified in 5.1 and 5.2, 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.

6.2 In case of failure on retest to meet the requirements of 5.1 and 5.2, 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.

7. Dimensions and Permissible Variations

7.1 The dimensions of square, rectangular, round, and special shape structural tubing to be ordered under this specification shall be subject to prior negotiation with the manufacturer. The dimensions agreed upon shall be indicated in the purchase order.

7.2 Permissible Variations:

7.2.1 Outside Dimensions:

7.2.1.1 For round tubing 2 in. and over in nominal diameter, the outside diameter shall not vary more than ± 1 percent from the specified outside diameter. For sizes 1½ in. (38.1 mm) and under, the outside diameter shall not vary more than ¼ in. (0.40 mm) over and more than ½ in. (0.79 mm) under the specified outside diameter.

7.2.1.2 The specified dimensions, measured across the flats at positions at least 2 in. (50.8 mm) from either end of square and rectangular tubing and including an allowance for convexity and concavity, shall not exceed the plus and minus tolerance shown in Table 4.

7.2.2 *Mass*—The mass of structural tubing shall not be less than the specified value by more than 3.5 percent. The mass tolerance shall be determined from individual lengths or for round tubing sizes 4½ in. (114 mm) in outside diameter and under and square and rectangular tubing having a periphery of 14 in. (356 mm) and under shall be determined from masses of the customary lifts produced by the mill. On round tubing sizes over 4½ in. in outside diameter and square and rectangular tubing having a periphery in excess of 14 in. the mass tolerance is applicable to the

individual length.

7.2.3 *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 (9.8 to 13.4 m), in multiple lengths, and in definite cut lengths (Section 2). When cut lengths are specified for structural tubing, the length tolerances shall be in accordance with Table 5.

7.2.4 *Straightness*—The permissible variation for straightness of structural tubing shall be ⅛ in. times the number of feet of total length divided by 5 (2.08 mm times length in meters).

7.2.5 *Squareness of Sides*—For square or rectangular structural tubing, adjacent sides may deviate from 90 deg by a tolerance of ± 2 deg, max.

7.2.6 *Radius of Corners*—For square or rectangular structural tubing, the radius of any outside corner of the section shall not exceed 3 times the specified wall thickness.

7.2.7 Twist:

7.2.7.1 The tolerance for twist, or variation with respect to axial alignment of the section for square, rectangular, or special shape structural tubing, shall be as prescribed in Table 6.

7.2.7.2 Twist is measured 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. The difference in the height of the corners shall not exceed the values in Table 6.

8. Workmanship and Quality Levels

8.1 The structural tubing shall be free from injurious defects and shall have a commercially smooth finish.

8.1.1 Surface imperfections shall be classed as injurious defects when their depth exceeds 15 percent of the specified wall thickness and when the imperfections materially affected 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.

8.1.2 Injurious defects having a depth not in excess of 33⅓ percent of the wall thickness may be repaired by welding, subject to the following conditions:

8.1.2.1 The defect shall be completely removed by chipping or grinding to sound metal.

8.1.2.2 The repair weld shall be made using suitable coated electrodes.

8.1.2.3 The projecting weld metal shall be removed to produce a workmanlike finish.

8.2 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 the burrs are to be removed, it shall be specified in the purchase order.

9. Packaging, Marking, and Loading

9.1 Except as noted in 9.2, 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 wall thickness; steel grade; and this specification number designation.

9.2 For structural tubing 1½ in. (38.1 mm) and under in nominal size or the greatest cross sectional dimension less than 2 in. (50.8 mm), the information listed in 9.1 may be marked on a tag securely attached to each bundle.

9.3 When specified in the order, contract, etc., packaging, marking, and loading shall be in accordance with the procedures recommended by the U.S. Department of Commerce, *Simplified Practice Recommendation R247-62* (Packaging, Marking, and Loading Methods for Steel Products for Domestic

Shipment).⁴

10. Inspection

10.1 All tubing shall be subject to an inspection at the place of manufacture to assure conformance with the requirements of this specification.

11. Certification

11.1 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.

12. Rejection

12.1 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 herein, 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.

12.2 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.

⁴ Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402.

TABLE 1 Chemical Requirements

Element	Composition, percent					
	Grade I		Grade II		Grade III	
	Heat	Product	Heat	Product	Heat	Product
Carbon, max	0.22	0.26	0.22	0.26	0.23	0.27
Manganese	1.25 max	1.30 max	0.85–1.25	1.30 max	1.35 max	1.40 max
Phosphorus, max	...	...	0.04	0.05	0.04	0.05
Sulfur, max	0.05	0.063	0.05	0.063	0.05	0.06
Silicon, max	...	...	0.30	0.33	0.30	0.35
Copper, min	...	...	0.20	0.18	...	...
Vanadium, min	...	...	0.02	0.01	0.02 ^a	0.01

^a For Grade III, columbium may be used in conformance with the following limits: 0.005 percent, min (heat) and 0.004 percent, min (product).

TABLE 2 Tensile Requirements

	Grade I		Grade II		Grade III	
Tensile strength, min, ksi (MPa)	70	(483)	70	(483)	65	(448)
Yield point, min, ksi (MPa)	50	(345)	50	(345)	50	(345)
Elongation in 2 in. or 50 mm, min, percent	22		22		20	
Elongation in 8 in. or 200 mm, min, percent	19		18		18	

TABLE 3 Bend Test Requirements

Thickness of Material, in. (mm)	Ratio of Bend Diameter to Specimen Thickness
3/4 (19.05) and under	1
Over 3/4 to 1 (19.05 to 25.4), incl	1 1/2
Over 1 (25.4)	2

TABLE 4 Outside Dimension Tolerances for Square, Rectangular, and Special Shape Structural Tubing

Largest Outside Dimension Across Flats, in. (mm)	Tolerance Plus and Minus, in. (mm)
2 1/2 (63.5) and under	0.020 (0.51)
Over 2 1/2 to 3 1/2 (63.5 to 88.9), incl	0.025 (0.64)
Over 3 1/2 to 5 1/2 (88.9 to 139.7), incl	0.030 (0.76)
Over 5 1/2 (139.7)	1 percent

TABLE 5 Cut Length Tolerances for Structural Tubing

	22 ft (6.71 m) and Under		Over 22 to 44 ft (6.71 to 13.42 m), incl	
	Over	Under	Over	Under
Length tolerance for specified cut lengths, in. (mm)	1/2 (12.7)	1/4 (6.35)	3/4 (19.05)	1/4 (6.35)

TABLE 6 Twist Tolerances for Square, Rectangular, or Special Shape Structural Tubing

Specified Dimension of Longest Outside Side, in. (mm)	Maximum Twist per 3 ft of Length, in.	Maximum Twist per Meter of Length, mm
1 1/2 (38.1) and under	0.050	1.39
Over 1 1/2 to 2 1/2 (38.1 to 63.5), incl	0.062	1.72
Over 2 1/2 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 (203.2)	0.112	3.11

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**Standard Specification for
SAMPLING PROCEDURE FOR IMPACT TESTING OF
STRUCTURAL STEEL¹**

This Standard is issued under the fixed designation A 673; 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 establishes the procedure for longitudinal Charpy V-notch testing of structural steel and contains two frequencies of testing. The impact properties of steel can vary within the same heat and piece, be it as rolled, control rolled or heat treated. The purchaser should, therefore, be aware that testing of one plate, bar, or shape does not provide assurance all plates, bars, or shapes of the same heat as processed will be identical in toughness with the product tested. Normalizing or quenching and tempering the product will reduce the degree of variation.

1.2 This specification is intended to supplement specifications for structural steel when so specified.

1.3 This specification does not necessarily apply to all product specifications; therefore, the producer should be consulted for energy absorption levels and minimum testing temperatures that can be expected or supplied.

1.4 Two frequencies of testing (P and H) are prescribed.

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

2. Applicable Documents

2.1 ASTM Standard:

A 370, Methods and Definitions for Mechanical Testing of Steel Products.²

3. Basis of Purchase

3.1 The inquiry and order shall indicate the following:

3.1.1 The frequency of testing, (P) or (H).

3.1.2 The test temperature to be used.

3.1.3 The absorbed energy (ft·lbf (J)) requirements.

3.1.4 Condition of material: as rolled, stress relieved, normalized, normalized and stress relieved, or quenched and tempered.

4. Tests

4.1 An impact test shall consist of three specimens taken from a single test coupon or test location, the average of which shall comply with the specified minimum with not more than one value below the specified minimum, but in no case below either two thirds of the specified minimum or 5 ft·lbf (7 J), whichever is greater (see Methods A 370).

4.2 The specimen for plates and bars shall be taken adjacent to the tension test specimen and the specimen for shapes shall be taken from the end of a shape at a point one third the distance from the outer edge of the flange or leg to the web or heel of the shape (see Figs. 1 and 2).

4.2.1 The longitudinal axis of the specimen shall be parallel to the final direction of rolling of the plate or parallel to the major axis of the shape.

4.2.2 The center longitudinal axis of the specimen shall be located as near as practicable mid-way between the surface and the

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.

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² 1974 Annual Book of ASTM Standards, Parts 1, 2, 3, 4, 5, and 10.

center of the material thickness and the length of the notch shall be perpendicular to the rolled surface of the material.

4.3 The impact energy values obtained on sub-size specimens shall not be less than shown in Table 1, which are proportional to energy values required for the full-size specimen.

5. Frequency of Testing

5.1 *Frequency (H) Heat Testing for Plates, Shapes, and Bars*—One Charpy V-notch impact test (a set of three specimens) shall be made for each 50 tons (45 Mg) of the same type of product in the same condition, that is, as rolled or heat treated produced on the same mill from each heat of steel. The impact tests shall be taken from different as-rolled or heat-treated pieces of the thickest or largest diameter produced unless there are insufficient pieces of the thickest or largest diameter material produced to comply with the number of tests required, in which case the testing shall proceed to the next thickest or next largest diameter piece produced. An as-rolled piece is the unit piece rolled from a slab, plate, bloom, or direct from an ingot.

5.2 *Frequency (P) Piece Testing:*

5.2.1 *Plates*—One Charpy V-notch impact test (a set of three specimens) shall be made from each as-rolled or as heat-treated plate.

5.2.2 *Shapes*—One Charpy V-notch impact test (a set of three specimens) shall be made from each 5 tons (45 Mg) of material produced on the same mill of the same nominal size, excluding length, from each heat of steel. If single pieces exceed 5 tons in weight, then each piece shall be tested. If the shapes are heat treated, one test shall be taken from each heat of the same nominal size, excluding length, in each furnace lot.

5.2.3 *Bars*—One Charpy V-notch impact test (a set of three specimens) shall be made for each 5 tons (45 Mg) of the same heat and same diameter or thickness if the material is furnished as rolled or is heat treated in a continuous-type furnace. For material heat treated in a non-continuous furnace, one test shall be taken from each heat of the same bar diameter or thickness for each furnace charge.

6. Heat Treatment

6.1 The material shall be heat treated when specified on the purchase order.

6.2 When the plates are to be supplied in the as-rolled condition the manufacturer at his option may heat treat the plates by normalizing or stress relieving or normalizing and stress relieving to meet the desired toughness properties.

6.3 When the fabricator elects to perform the required heat treatment or fabricates by hot forming instead of heat treating, the plates shall be accepted on the basis of mill tests made on full-thickness specimens heat treated in accordance with the purchaser's order requirements. If the heat treatment temperatures are not indicated on the purchase order, the manufacturer shall heat treat the specimens under conditions he considers appropriate for grain refinement and to meet the toughness requirements. The plate manufacturer shall inform the purchaser of the procedure followed in treating the specimens at the mill.

7. Retests

7.1 If more than one value is below the specified minimum average or the greater of 5 ft·lbf (7 J) or two thirds of the specified minimum, a retest of three additional specimens shall be made, each of which must have a value equal to or exceeding the specified minimum.

7.2 If the required energy values are not obtained upon retest, the material may at the option of the manufacturer be heat treated in the case of as-rolled material or reheat treated in the case of heat-treated material.

7.3 After heat treatment or reheat treatment a set of three specimens shall be tested and qualified in the same manner for the original material.

7.4 If the impact test fails for the thickest product tested when testing to Frequency (H) that material shall be rejected and the next thickest material tested to qualify the heat in accordance with 4.1. At the option of the producer retests may be made on the rejected material in which case each piece shall be accepted or rejected on the basis of the results of its own test.

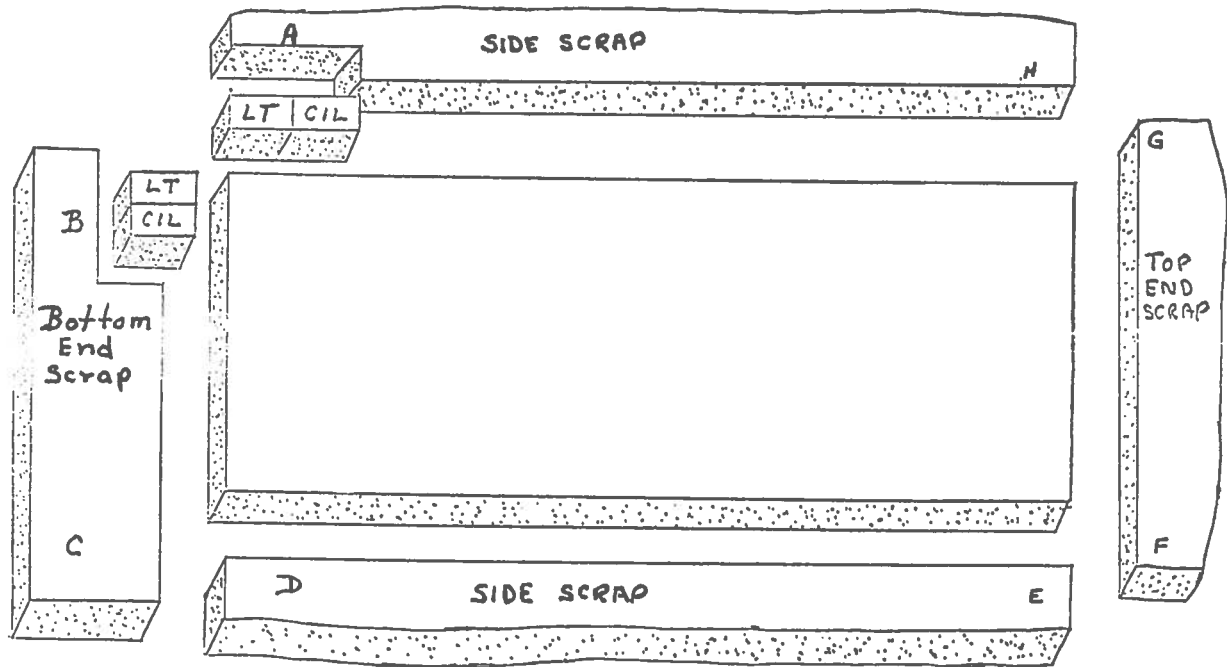
8. Test Reports

8.1 When test reports are required by the purchase order, the report shall show the results of each test required by the specification.

8.2 The thickness of the product tested may not necessarily be the same as an individual ordered thickness when (H) heat testing is ordered.

TABLE 1 Equivalent Absorbed Energy for Various Specimen Sizes

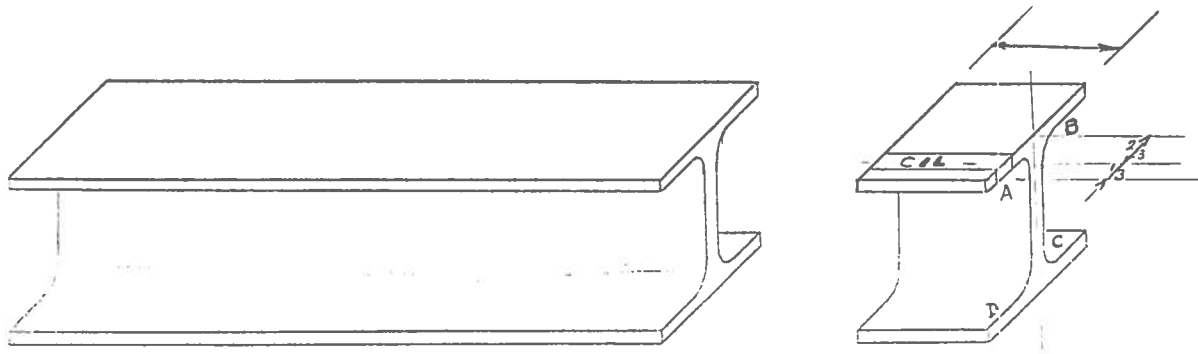
Full Size, 10 by 10 mm, ft · lbf (J)	$\frac{3}{4}$ Size, 10 by 7.5 mm, ft · lbf (J)	$\frac{2}{3}$ Size, 10 by 6.6 mm, ft · lbf (J)	$\frac{1}{2}$ Size, 10 by 5 mm, ft · lbf (J)	$\frac{1}{3}$ Size, 10 by 3.3 mm, ft · lbf (J)	$\frac{1}{4}$ Size, 10 by 2.5 mm, ft · lbf (J)
20 (27)	16 (21)	13 (18)	10 (14)	7 (10)	5 (7)
15 (20)	12 (16)	10 (14)	8 (11)	5 (7)	4 (5)
13 (18)	10 (14)	9 (12)	7 (10)	5 (7)	4 (5)
12 (16)	10 (14)	9 (12)	7 (10)	4 (5)	3 (4)
10 (14)	8 (11)	7 (10)	5 (7)	3 (4)	3 (4)
7 (10)	6 (8)	5 (7)	4 (5)	2 (3)	2 (3)



NOTE 1—CIL = charpy impact longitudinal, LT = longitudinal tensile.

NOTE 2—Tests may be cut at position A, B, C, D, E, F, G, or H.

FIG. 1 Plate Test Location.



NOTE 1—CIL = charpy impact longitudinal.

NOTE 2—Test coupon for impact specimens may be taken from locations A, B, C, or D as shown laid out at location A.

FIG. 2 Shape Test Location.

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Standard Specification for STRUCTURAL STEEL FOR BRIDGES¹

This Standard is issued under the fixed designation A 709; 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 carbon and high-strength, low-alloy steel for structural shapes, plates, and bars and quenched and tempered alloy steel for structural plates intended for use in bridges. Five grades are available in three strength levels (36, 50, and 100). Grades 50W and 100W have enhanced atmospheric corrosion resistance (see 12.1). Product availability is shown in Table 2.

1.2 All steels covered by this specification are weldable. It is presupposed that welding procedures will be suitable for the steel being welded and its intended use.

1.3 Supplementary requirements are available but shall apply only when specified by the purchaser at the time of ordering.

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

2. Applicable Documents

2.1 ASTM Standards:

A 6, Specification for General Requirements for Delivery of Rolled Steel Plates, Shapes, Sheet Piling and Bars for Structural Use²

A 370, Methods and Definitions for Mechanical Testing of Steel Products³

A 435, Specification for Straight-Beam Ultrasonic Examination of Steel Plates for Pressure Vessels²

A 673, Specification for Sampling Procedure for Impact Testing of Structural Steel²

E 112, Estimating the Average Grain Size of Metals⁴

3. General Requirements for Delivery

3.1 Steel furnished to this specification shall

conform, except as noted in 3.2, to the applicable requirements of the current edition of Specification A 6. These include the permissible variations in dimension and weight, test specimens, method of test, quality, repair by welding, inspection and testing, retests, rejections, packaging, marking, and loading.

3.2 When the requirements of this specification (including supplementary requirements when specified) conflict with, or are more restrictive than those of Specification A 6, the requirements of this specification shall govern.

4. Basis of Purchase

4.1 The inquiry and order shall indicate the following:

4.1.1 ASTM designation and date of issue,

4.1.2 Product (plates, shapes, or bars),

4.1.3 Grade, including suffixes, if any,

4.1.4 Dimension or size designation,

4.1.5 Quantity (number of pieces), and

4.1.6 Supplementary requirement, if any.

5. Manufacture

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

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.

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² Annual Book of ASTM Standards, Part 4.

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

⁴ Annual Book of ASTM Standards, Part 11.

troslag remelting (ESR) or vacuum-arc remelting (VAR) is permitted.

5.2 Grades 36 and 50 steel shall be made of other than rimmed or capped steel.

5.3 Grade 50W shall be made to a killed fine grain practice.

5.4 Grades 100 and 100W steel shall be killed fine grain (ASTM No. 5 or finer) as determined in accordance with Methods E 112, specifically Plate IV.

6. Heat Treatment

6.1 Grades 100 and 100W steel shall be heat treated by the manufacturer to conform to the tensile and hardness requirements of Table 2 by heating to not less than 1600°F (870°C), quenching in water or oil, and tempered at not less than 1100°F (590°C). The heat-treating temperatures shall be reported on the test certificates.

7. Chemical Requirements

7.1 The heat analysis shall conform to the requirements of 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, except as specified in 7.3.

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

7.4 The purchaser at the time of ordering may request that the manufacturer advise the range of any alloying elements that will be present (see Table 1, Note 2).

8. Tensile Requirements

8.1 The steel as represented by the test specimens shall conform to the requirements of Table 2.

8.2 For steel under ⅝ in. (8 mm) in thickness, a deduction from the percentage of elongation as specified in Table 2, of 1.25 % shall be made for each decrease of ⅛ in. (0.8 mm) of the specified thickness below ⅝ in. This deduction shall not exceed 3 %.

8.3 Shapes less than 1 in.² (645 mm²) in cross section and bars, other than flats, less than ½ in. (13 mm) in thickness or diameter

need not be subjected to tension tests by the manufacturer.

9. Brinell Hardness Requirements (Grades 100 and 100W Steel Only)

9.1 Each heat-treated plate or a specimen cut from a heat-treated plate, from which no tension test is taken, shall be subjected to a Brinell hardness test in accordance with Methods and Definitions A 370. The Brinell hardness so measured shall conform to the requirements shown in Table 2.

10. Test Specimens and Number of Tension Tests

10.1 For Grades 36, 50, and 50W, location and condition, number of tests, and preparation of test specimens shall meet the requirements of Specification A 6.

10.2 The following requirements which are in addition to those of Specification A 6 shall apply only to Grades 100 and 100W steel:

10.2.1 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, all of these pieces shall be full thickness, and shall be similarly and simultaneously heat treated with the steel. 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.

10.2.2 After final heat treatment of the plates, one longitudinal tension test specimen shall be taken from one corner of at least two plates treated in each lot. If a lot consists of only one plate, then only one tension test specimen shall be taken.

10.2.3 A lot shall consist of plates from the same heat and thickness, same prior condition and heat treatment but shall not exceed 15 tons (13.6 Mg) in weight except when a single plate is heat treated.

NOTE 2—The term "plate" identifies the "plate as heat treated."

11. Retests

11.1 Grades 36, 50, and 50W may be retested in accordance with Specification A 6.

11.2 Grades 100 and 100W plate subjected to Brinell hardness tests and that 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.

11.3 The manufacturer may reheat treat Grades 100 and 100W plate that fail to meet the mechanical property requirements of this specification. All mechanical property tests shall be repeated when the material is reheat treated.

12. Atmospheric Corrosion Resistance

12.1 Steels meeting this specification pro-

vide two levels of atmospheric corrosion resistance:

12.1.1 Steel grades without suffix provide a level of atmospheric corrosion resistance typical of carbon steel without copper.

12.1.2 Steel grades with suffix "W" provide a level of atmospheric corrosion resistance approximately equal to at least four times that provided by carbon steel without copper.

13. Marking

13.1 Material shall be marked with specification and grade. In addition the marking requirements of Specification A 6 are applicable.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Fine Grain Practice

S1.1 Grades 36 and 50 steel shall be made to a killed steel fine grain practice.

S2. Transverse Tension Test Specimens

S2.1 Tension test specimens from plates shall be taken transverse to the final direction of rolling instead of longitudinal specimens. Transverse test specimens shall meet the tensile and yield requirements of Table 2, except that the elongation requirements of Table 2 (whether modified by 8.2 or not) shall be reduced by 2 % and the reduction of area requirements of Table 2 shall be reduced by 5 %.

S3. Frequency of Tension Tests

S3.1 The purchaser may specify additional tension testing as follows:

S3.1.1 *Plate*—One tension test shall be made from each as-rolled or as-heat treated plate.

S3.1.2 *Structural Shapes*—One tension test shall be made from each 5 tons (4.5 Mg) of material produced on the same mill of the same nominal size, excluding length, from each heat of steel. If single pieces exceed 5 tons in weight then each piece shall be tested. If shapes are heat treated, one test shall be taken from each

heat of the same nominal size, excluding length, in each furnace lot.

S3.1.3 *Bars*—One tension test shall be made from each 5 tons (4.5 Mg) of the same heat and same diameter or thickness if the material is furnished as-rolled or is heat treated in a continuous-type furnace. For material heat treated in a noncontinuous furnace, one test shall be taken from each heat of the same bar diameter or thickness for each furnace charge.

S4. Charpy V-Notch Impact Tests

S4.1 Charpy V-notch tests (CVN) shall be conducted in accordance with the requirements of Specification A 673. Where this supplement is specified, the suffix "T" followed by the numeral 1, 2, or 3 depending upon the testing zone used shall be added to the grade designation when marking the steel. Frequency of testing: "H" for Grades 36T, 50T, and 50WT, and "P" for Grades 100T and 100WT. The testing zones are those chosen by the American Association of State Highway and Transportation Officials (AASHTO) and are in relationship to the lowest ambient temperature expected for that area. Impact test requirements shall be in accordance with Table 3.

S4.2 Charpy V-notch impact tests shall be

conducted in accordance with Specification A 673 except that orientation of test bars (whether longitudinal or transverse to the direction of final rolling), the test temperature, and the required acceptance criteria shall be as agreed upon between the purchaser and the manufacturer. The absorbed energy shall be reported in accordance with the procedures provided in Methods A 370.

S5. Atmospheric Corrosion Resistance

S5.1 When specified, the manufacturer shall

supply to the purchaser evidence of atmospheric corrosion resistance satisfactory to the purchaser.

S5.2 When specified, the material shall contain a minimum of 0.20 % copper, for improved atmospheric corrosion resistance over that of carbon steel without copper.

S6. Ultrasonic Examination

S6.1 Plates shall be ultrasonically examined in accordance with the requirements of Specification A 435.

TABLE 1 Chemical Requirements (Heat Analysis)

NOTE 1—When grain refining is inferred or required, the steel shall contain, in the percentages listed, at least one of the following grain-refining elements, and their use shall be reported to the purchaser:

Aluminum, total	0.015 % min
Columbium ^a	0.015–0.060 %
Vanadium ^b	0.02–0.10 %
Titanium	0.02–0.10 %

^a Columbium when added either singularly or in combination with vanadium shall be restricted to plate or bar thickness of ½ in. (13 mm) max and to shapes of Table A Group 1 of Specification A 6, unless killed steel is furnished.

^b 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.

If these elements are used in combination, at least one of them must be present in the steel in the minimum quantity specified.

NOTE 2—The choice and use of alloying elements, combined with carbon, manganese, phosphorus, and sulfur within the limits prescribed to conform to the tensile and mechanical properties or to enhance the atmospheric corrosion resistance, or both, may vary by manufacturer. Elements commonly added include: boron, chromium, copper, molybdenum, nickel, silicon, vanadium, titanium, and zirconium. The alloys used shall be reported to the purchaser (see 7.4).

NOTE 3—Grades 36, 50, 50W, 100, and 100W are equivalent to A 36, A 572, A 588, and A 514 respectively. When the supplementary requirements are specified they exceed the requirements of Specifications A 36, A 572, A 588, and A 514.

Grade	Classification	Thickness, in. (mm)	Elements Present, %			
			Carbon	Manganese	Phosphorus, max	Sulfur, max
36	carbon steel shapes ^{a,b} carbon steel plates ^{a,c}	all	0.26 max	...	0.04	0.05
		to ¾ (19)	0.25 max	...	0.04	0.05
		greater than ¾ to 1½ (19 to 38), incl	0.25 max	0.80–1.20	0.04	0.05
		greater than 1½ to 2½ (38 to 64), incl	0.26 max	0.80–1.20	0.04	0.05
		greater than 2½ to 4 (64 to 120), incl	0.27 max	0.85–1.20	0.04	0.05
	carbon steel bars ^b	over 4 (102)	0.29 max	0.85–1.20	0.04	0.05
		to ¾ (19)	0.26 max	...	0.04	0.05
		greater than ¾ to 1½ (19 to 38), incl	0.27 max	0.60–0.90	0.04	0.05
		greater than 1½ to 4 (38 to 102)	0.28 max	0.60–0.90	0.04	0.05
		over 4	0.29 max	0.60–0.90	0.04	0.05
50	HSLA steel ^d	to 2 (51)	0.23 max	1.35 max	0.04	0.05
50W	HSLA steel	to 4 (102)	0.20 max ^c	1.35 max ^c	0.04	0.05
100 and 100W	alloy steel	to 4 (102)	0.10–0.21	0.40–1.50	0.035	0.04

^a Manganese content of 0.85–1.35 % and silicon content of 0.15–0.30 % is required for shapes over 426 lb/ft (634 kg/m).

^b Manganese content may be 1.35 % max when notch toughness is specified.

^c When normalized the maximum ladle carbon may be 0.22 % and the maximum manganese may be 1.40 %.

^d Silicon content of 0.15–0.30 % is required for plates over 1½ in. (38 mm) in thickness.



TABLE 2 Tensile and Hardness Requirements

Grade	Availability		Tensile Properties							Brinell Hardness Number
	Plate Thickness, in. (mm)	Structural Shapes	Yield Point/ Strength, ^a min, ksi (MPa)	Tensile Strength, ksi (MPa)	Minimum Elongation, %				Reduction of Area, min, %	
					Plates and Bars		Shapes			
					in 8 in. or 200 mm	in 2 in. or 50 mm	in 8 in. or 200 mm	in 2 in. or 50 mm		
36	to 8 (204), incl	to 426 lb/ft (634 kg/m)	36 (250)	58-80 (400-550)	20	23	20	21	...	...
	over 8 (204)	over 426 lb/ft (634 kg/m)	36 (250)	58 min (400)	...	...	20	19	...	...
50	to 2 (51), incl	groups 1, 2, 3, and 4	32 (220)	58 min (400)	20	23	...	...	...	...
50W	to 4 (102), incl	groups 1, 2, 3, 4, and 5	50 (345)	65 min (450)	18	21	18	21 ^a	...	...
100 and 100W	to 2 1/2 (64), incl	...	50 (345)	70 min (485)	18	21	21	18 ^c	...	...
			100 (700) ^a	110-130 (775-915)	...	18	...	...	40 ^d -50 ^e	228-269
100 and 100W	over 2 1/2 to 4 (64 to 102)	...	90 (635) ^a	100-130 (700-915)	...	17	...	...	50 ^f	212-269

^a Measured at 0.2 % offset or 0.5 % extension under load as described in Section 13 on yield strength of Methods A 370.^b Elongation in 2 in. or 50 mm: 19 % for shapes over 426 lb/ft (634 kg/m).^c Applies only to wide flange shapes over 426 lb/ft (634 kg/m).^d Measured on 1 1/2-in. (38-mm) wide full thickness rectangular specimen as shown in Fig. 4 of Methods A 370. This is the only specimen to be used for thickness of 1/4 in. (19 mm) and under. The reduction in area is measured in a 2-in. or 50-mm gage length that includes the fracture and that shows the greatest elongation.^e Measured on a 1/2-in. (13-mm) diameter specimen as shown in Fig. 6 of Methods A 370. This is the only specimen to be used for thicknesses over 1 1/2 in. (38 mm). The specimen shall be taken so that the axis is midway, or as near midway as practicable, between the center and the surface.

TABLE 3 Impact Test Requirements

Grade	Thickness, in. (mm)	Impact Test Requirements, Minimum Average Energy, ft-lbf (J), and Testing Temperature, °F (°C)					
		Zone 1		Zone 2		Zone 3	
		ft-lbf (J)	°F (°C)	ft-lbf (J)	°F (°C)	ft-lbf (J)	°F (°C)
36T	to 4 (102), incl	15 (20)	70 (21)	15 (20)	40 (4)	15 (20)	10 (−12)
50T ^a , 50WT ^a	to 2 (51), incl	15 (20)	70 (21)	15 (20)	40 (4)	15 (20)	10 (−12)
50WT ^a	over 2 to 4 (51 to 102), incl	20 (27)	70 (21)	20 (27)	40 (4)	20 (27)	10 (−12)
100T, 100WT	to 2½ (64), incl	25 (34)	30 (−1)	25 (34)	0 (−18)	25 (34)	−30 (−34)
100T, 100WT	over 2½ to 4 (64 to 102), incl	35 (47)	30 (−1)	35 (47)	0 (−18)	35 (47)	−30 (−34)

^a If the yield point of the material exceeds 65 ksi (450 MPa), the testing temperature for the minimum average energy required shall be reduced by 15°F (8°C) for each increment or fraction of 10 ksi (70 MPa) above 65 ksi.

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