As of 4/81 This chapter has be discarded although it may be useful as reference - all items are not through up-to-date.

I/5
ASTM Specifications for Structural Steel

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AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St., Philadelphia, Pa. 19103

Specifications for:

Designation: A 6 – 74

American National Standard G24.4
American National Standards Institute

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1916 Race St., Philadelphia, Pa., 19103

Standard Specification for GENERAL REQUIREMENTS FOR DELIVERY OF ROLLED STEEL PLATES, SHAPES, SHEET PILING, AND BARS FOR STRUCTURAL USE[1]

This Standard is issued under the fixed designation A 6; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

This specification has been approved by the Department of Defense for listing in the DoD Index of Specifications and Standards. Future proposed revisions should be coordinated with the Federal Government through the Army Materials and Mechanics Research Center, Watertown, Mass. 02172.

1. Scope

1.1 This specification[2] covers a group of common requirements which, unless otherwise specified in the purchase order or in an individual specification, apply to rolled steel plates, shapes, sheet piling, and bars under each of the following specifications issued by the American Society for Testing and Materials:

ASTM Designation[3]	Title of Specification
	Carbon Steel
A 36	Structural Steel
A 113	Structural Steel for Locomotives and Cars
A 131	Structural Steel for Ships
A 283	Low and Intermediate Tensile Strength Carbon Steel Plates of Structural Quality
A 284	Low and Intermediate Tensile Strength Carbon-Silicon Steel Plates for Machine Parts and General Construction
A 328	Steel Sheet Piling
A 529	Structural Steel with 42,000 psi (290 MPa) Minimum Yield Point (½ in. (12.7 mm) Maximum Thickness)
A 573	Structural Carbon Steel Plates of Improved Toughness
A 678	Quenched and Tempered Carbon Steel Plates for Structural Applications
	High-Strength and High-Strength Low-Alloy Steel
A 242	High-Strength Low-Alloy Structural Steel
A 440	High-Strength Structural Steel
A 441	High-Strength Low-Alloy Structural Manganese Vanadium Steel
A 572	High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality
A 588	High-Strength Low-Alloy Structural Steel with 50,000 psi Minimum Yield Point to 4 in. Thick
A 633	Normalized High-Strength Low-Alloy Structural Steel
A 656	High-Strength Low-Alloy, Hot-Rolled, Structural Vanadium-Aluminum-Nitrogen Steel
A 690	High-Strength Low-Alloy Steel H-Piles and Sheet Piling for Use in Marine Environments
	Alloy Steel
A 514	High-Yield Strength, Quenched and Tempered Alloy Steel Plate Suitable for Welding
A 699	Low-Carbon Manganese-Molybdenum-Columbium Alloy Steel Plates, Shapes, and Bars

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

2. Description of Terms

2.1 *Plates*—Flat hot-rolled steel classified as follows:

2.1.1 *When Ordered to Thickness:*

2.1.1.1 Over 8 in. in width and 0.230 in. or over in thickness.

2.1.1.2 Over 48 in. in width and 0.180 in. or over in thickness.

2.1.2 *When Ordered to Weight/ft²:*

2.1.2.1 Over 8 in. in width and 9.62 lb/ft², or heavier.

2.1.2.2 Over 48 in. in width and 7.53 lb/ft², or heavier.

2.1.2.3 Slabs, sheet bars and skelp, though frequently falling in the foregoing size ranges, are not classed as plates.

2.2 *Structural-Size Shapes*—Rolled flanged sections having at least one dimension of the cross-section 3 in. or greater. Structural shape size groupings used for tensile property classification are listed in Table A.

2.3 *Sheet Piling*—Steel sheet piling consists

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys, and is the direct responsibility of Subcommittee A01.02 on Structural Steel.

Current edition approved Aug. 30, 1974. Published November 1974. Originally published as A 6 – 49 T. Last previous edition A 6 – 73.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-6 in Section II of that Code.

[3] *1974 Annual Book of ASTM Standards*, Part 4.

of rolled sections which can be interlocked, forming a continuous wall when individual pieces are driven side by side.

2.4 *Bars*—Rounds, squares, and hexagons, of all sizes; flats 1¾4 in. (0.2031 in.) and over in specified thickness, not over 6 in. in specified width; and flats 0.230 in. and over in specified thickness, over 6 to 8 in., incl, in specified width.

2.5 *Bar Size Shapes*—Rolled flanged sections having a maximum dimension of the cross section less than 3 in.

3. Heat Analysis

3.1 An analysis of each heat shall be made by the producer to determine the percentage of carbon, manganese, phosphorus, sulfur and of any other elements specified or restricted by the applicable specification. This analysis shall be made from a test sample preferably taken during the pouring of the heat. The heat analysis shall be reported to the purchaser or his representative and shall conform to the heat analysis requirements of the applicable specification.

4. Product Analysis

4.1 The purchaser may analyze finished material representing each heat. Sampling shall be in accordance with ASTM Method E 59, Sampling Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron for Determination of Chemical Composition.[4] The chemical composition thus determined shall conform to the requirements of the product specification subject to the product analysis tolerances in Tables B, C, D, or E as applicable. If a range is specified, the determinations of any element in a heat may not vary both above and below the specified range. Rimmed or capped steel is characterized by a lack of homogeneity in its composition, expecially for the elements carbon, phosphorus, and sulphur; therefore, the limitations for these elements shall not be applicable unless misapplication is clearly indicated.

4.1.1 *Plates, Structural Size Shapes, and Sheet Piling:*

4.1.1.1 Carbon steel shall be subject to the tolerances in Table B.

4.1.1.2 High-strength and high-strength low-alloy steel shall be subject to the tolerances in Table B for carbon, manganese, phosphorus, sulfur, silicon, and copper (only when copper is specified as 0.20 percent, min), and to the tolerances in Table C for other elements (including copper when a range is specified).

4.1.1.3 Alloy steel shall be subject to the tolerances in Table C.

4.1.2 *Bars and Bar Size Shapes:*

4.1.2.1 Carbon steel shall be subject to the tolerances in Table D.

4.1.2.2 High-strength and high-strength low-alloy steel shall be subject to the tolerances in Table D for carbon, manganese, phosphorus, sulfur, silicon, and copper (only when copper is specified as 0.20 percent, min) and to the tolerances in Table E for alloying elements (including copper when a range is specified).

5. Permissible Variations in Dimensions or Weight[5]

5.1 One cubic inch of rolled steel shall be assumed to weigh 0.2833 lb (0.1285 kg).

5.2 *Plates*—The permissible variations for dimensions shall not exceed the applicable limits in Tables 1 to 16 inclusive.

5.3 *Structural-Size Shapes*—The cross sectional area or weight of each structural-size shape shall not vary more than 2.5 percent from the theoretical or specified amounts. The permissible variations from dimensions for structural-size shapes shall not exceed the applicable limits in Tables 17 to 26 inclusive.

5.4 *Sheet Piling*—The weight of each steel sheet pile shall not vary more than 2.5 percent from the theoretical or specified weight. The length of each steel sheet pile shall not vary more than 5 in. over, and shall not be less than the length specified.

5.5 *Bars and Bar Size Shapes*—The variations from nominal dimensions of hot-rolled bars and bar size shapes shall not exceed the applicable limits in Tables 27 to 36 inclusive.

6. Test Specimens

6.1 *Location and Condition:*

6.1.1 Test specimens shall be prepared for testing from the material in its delivered condition except that test specimens for heat-treated material may be from a separate piece

[4] *1974 Annual Book of ASTM Standards*, Part 12.

[5] See Index of Tables of Permissible Variations at end of text.

of full thickness or full section from the same heat similarly treated.

6.1.2 Test specimens shall be taken longitudinally and except as specified in 6.3, shall be the full thickness or full section of the material as delivered.

6.1.3 Test specimens shall be selected from the webs of beams, channels, and zees, from the legs of angles and bulb angles, and from the stems of rolled tees.

6.1.4 Tension and bend test specimens for bars to be used for pins and rollers less than 3 in. in diameter shall be taken so that the axis is midway, if practicable, between the center and the surface. Tension and bend test specimens for pins and rollers 3 in. and over in diameter should be taken so that the axis is 1 in. from the surface.

6.1.5 Test specimens for plates shall be taken from a corner of the plate.

6.2 *Number of Tests*—Two tension and two bend tests shall be made from each heat and each strength gradation, where applicable. However, for material 2 in. and under in thickness, when the material from one heat, and strength gradation, differs ⅜ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled in that strength gradation regardless of weight represented. For material over 2 in. thick, when the material from heat and strength differs 1 in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled in that strength gradation that is more than 2 in. thick regardless of the weight represented.

6.3 *Preparation:*

6.3.1 Tension test specimens for material under ¾ in. (19 mm) in thickness may conform to the requirements of Fig. 4 of Methods and Definitions A 370, for Mechanical Testing of Steel Products.[6] Tension test specimens for material ¾ in. and over in thickness or diameter may conform to the requirements of either Fig. 4 or 5 of A 370, except that tension test specimens for alloy steel plates over 1½ in. (38 mm) in thickness, and for bars to be used for pins and rollers, shall conform to the requirements of Fig. 5 of A 370. When the 0.500-in. (13-mm) diameter specimen (Fig. 5 of A 370) is used, the axis of the specimen shall be located as near as practical midway between the center of thickness and the top or bottom surface of the plate.

6.3.2 Tension test specimens for material over 1½ in. in thickness or diameter, except bars to be used for pins and rollers and alloy steel plates, may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.

6.3.3 Except as provided in 6.3.4 and 6.3.5, bend test specimens for shapes, flats, and plates shall be at least 1¼ in. in width, with both edges parallel, and may be machined, sheared, or gas-cut.

6.3.4 Bend test specimens for alloy steel plates over ¾ in. in thickness and for other material over 1½ in. in thickness or diameter, except bars to be used for pins and rollers, may be machined to a thickness or diameter of at least ¾ in. or to 1 by ½ in. in section. When the test is made on a specimen of reduced thickness, the rolled surface shall be on the outer curve of the bend.

6.3.5 Bend test specimens for bars to be used for pins and rollers shall be 1 by ½ in. in cross section.

6.3.6 The sides of the bend test specimens may have the corners rounded to a radius not over 1/16 in. for specimens 2 in. and under in thickness, and not over ⅛ in. for specimens over 2 in. in thickness.

7. Methods of Test

7.1 All tests shall be conducted in accordance with ASTM Methods and Definitions A 370,[6] for Mechanical Testing of Steel Products.

8. Quality

8.1 *General*—The material shall be free from injurious defects and shall have a workmanlike finish.

8.2 *Plate Conditioning:*

8.2.1 Plates may be conditioned by the manufacturer for the removal of imperfections or depressions on the top and bottom surfaces by grinding, provided the area ground is well faired without abrupt changes in contour and the grinding does not reduce

[6] *1974 Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, 5, and 10.

the thickness of the plate by (*1*) more than 7 percent under the nominal thickness for plates ordered to weight per square foot, but in no case more than ⅛ in. or, (*2*) below the permissible minimum thickness for plates ordered to thickness in inches.

8.2.2 Plates may have imperfections on the top and bottom surfaces removed by chipping, grinding or arc-air gouging and then depositing weld metal (see Section 9), subject to the following limiting conditions:

8.2.2.1 The chipped, ground or gouged area shall not exceed 2 percent of the area of the surface being conditioned.

8.2.2.2 After removal of any imperfections preparatory to welding, the thickness of the plate at any location must not be reduced by more than 30 percent of the nominal thickness of the plate. (Specification A 131 restricts the reduction in thickness to 20 percent maximum.)

8.2.3 The edges of plates may be conditioned by the manufacturer to remove injurious imperfections by grinding, chipping, or arc-air gouging and welding (see Section 9). Prior to welding, the depth of depression measured from the plate edge inward shall be limited to the thickness of the plate, with a maximum depth of 1 in.

8.3 *Structural Size Shapes, Bar Size Shapes, and Steel Sheet Piling Conditioning:*

8.3.1 These products may be conditioned by the manufacturer for the removal of injurious imperfections or surface depressions by grinding, or chipping and grinding, provided the area ground is well faired without abrupt changes in contour and the depression does not extend below the rolled surface by more than (*1*) 1/32 in., for material less than ⅜ in. in thickness, (*2*) 1/16 in., for material ⅜ in. to 2 in. inclusive in thickness, or (*3*) ⅛ in., for material over 2 in. in thickness.

8.3.2 Imperfections that are greater in depth than the limits previously listed, may be removed and then weld metal deposited (see Section 9), subject to the following limiting conditions:

8.3.2.1 The total area of the chipped or ground surface of any piece prior to welding shall not exceed 2 percent of the total surface area of that piece.

8.3.2.2 The reduction of thickness of the material resulting from removal of imperfections prior to welding, shall not exceed 30 percent of the nominal thickness at the location of the imperfection nor shall the depth of depression prior to welding exceed 1¼ in. in any case except as noted in 8.3.2.3.

8.3.2.3 The toes of angles, beams, channels, and zees and the stems and toes of tees may be conditioned by grinding, chipping, or arc-air gouging and welding (see Section 9). Prior to welding, the depth of depression, measured from the toe inward, shall be limited to the thickness of the material at the base of the depression, with a maximum depth limit of ½ in.

8.3.2.4 The interlock of any sheet piling section may be conditioned by welding (see Section 9) and grinding to correct or build up the interlock at any location not to exceed 2 percent of the total surface area.

8.4 *Bar Conditioning:*

8.4.1 Bars may be conditioned by the manufacturer for the removal of imperfections by grinding, chipping, or some other means, provided the conditioned area is well faired and the affected sectional area is not reduced by more than the permissible variations prescribed in the applicable tables of Section 5.

8.4.2 Imperfections which are greater in depth than the limitations of 8.4.1 may be removed by chipping or grinding and then depositing weld metal (see Section 9), subject to the following limiting conditions:

8.4.2.1 The total area of the chipped or ground surface of any piece, prior to welding, shall not exceed 2 percent of the total surface area of the piece.

8.4.2.2 The reduction of sectional dimension of a round, square, or hexagon bar, or the reduction in thickness of a flat bar, resulting from removal of an imperfection, prior to welding, shall not exceed 5 percent of the nominal dimension or thickness at the location of the imperfection.

8.4.2.3 For the edges of flat bars, the depth of the conditioning depression prior to welding shall be measured from the edge inward and shall be limited to a maximum depth equal to the thickness of the flat bar or ½ in., whichever is less.

9. Repair by Welding

9.1 *Carbon and High-Strength Low-Alloy Steels:*

9.1.1 All welding on carbon and high-strength low-alloy steels shall be performed by competent welders using low hydrogen welding electrodes conforming to the proper series of and the latest issue of AWS Specification A 5.1, for Mild Steel Covered Arc—Welding Electrodes or AWS Specification A 5.5, for Low—Alloy Steel Covered Arc—Welding Electrodes.[7] The electrodes shall be protected from moisture during storage and use.

9.1.2 The manufacturer shall establish and follow documented welding procedures which are appropriate for the material being welded.

9.2 *Alloy Steel:*

9.2.1 When so specified in the purchase order, prior approval for repair by welding shall be obtained from the purchaser.

9.2.2 The manufacturer shall establish and follow the documented welding procedures which are appropriate for the material being welded. When specified on the purchase order, such procedures shall be subject to the approval by the purchaser. The welding operators shall be competent to follow such procedures.

9.2.3 After removal of any imperfections and prior to welding, the cavity shall be examined by a magnetic particle method or a liquid penetrant method to ensure that the imperfection has been completely removed. When magnetic particle examination is employed, the cavity shall be examined parallel and normal to the length of the cavity.

9.2.4 Electrodes shall be protected from moisture during storage and use.

9.2.5 Electrodes and base metal shall be free of hydrogen-producing contaminants such as oil, grease, or other organic materials. The base metal shall be maintained in a dry condition during welding.

9.2.6 For material in its heat-treated condition, all welding shall be performed using either the shielded metal-arc (SMA) or gas metal-arc (GMA) process. For SMA welding, low hydrogen electrodes conforming to the latest edition of AWS Specification A 5.5 shall be employed. The electrodes shall be selected to provide weld-metal deposits compatible with the minimum specified base metal properties. Moisture content shall not exceed the tolerable level for the steel being welded. For GMA welding, any composition that provides weld-metal deposits compatible with the minimum specified base metal properties may be employed. Gases used for shielding shall be of welding quality. When weld repairs by either process are to be post-weld heat treated, special care must be exercised in selection of electrodes to avoid those compositions which embrittle as a result of such heat treatment.

9.2.7 The heat-affected zone of quenched and tempered alloy steels may be affected adversely by excessive heat input or excessive preheating, or both. Similarly, insufficient preheat and heat input in the welding of quenched and tempered alloy steels may result in undesirable defects. Therefore, suitable combinations of heat input and preheat (including interpass temperature) shall be employed.

9.2.8 For material which is to be quenched and tempered after repair-welding, electrodes for SMA or GMA welding shall be selected to provide weld deposits whose mechanical properties after heat treatment meet the requirements of the base metal.

9.2.9 Repairs on material that is subsequently thermally treated at the mill shall be examined after heat treatment; repairs on material that is not subsequently thermally treated at the mill shall be examined no sooner than 48 h after welding. In either case the repaired area shall be examined by one of the methods and in the same manner prescribed in 9.2.3.

9.2.10 The location of weld repairs shall be marked on the finished piece.

9.3 *Repair Quality*—The welds and adjacent heat affected zone shall be sound and free of cracks, the weld metal being thoroughly fused to all surfaces and edges without undercutting or overlap. Any visible cracks, porosity, lack of fusion, or undercut in any layer shall be removed prior to deposition of the succeeding layer. Weld metal shall project at least $\frac{1}{16}$ in. above the rolled surface after welding, and the projecting metal shall be removed by chipping or grinding, or both, to

[7] Available from American Welding Society, 2501 North West 7th St., Miami, Fla. 33125.

make it flush with the rolled surface, and to produce a workmanlike finish.

9.4 *Inspection of Repair*—The manufacturer shall maintain an inspection program to inspect the work to see that:

9.4.1 Imperfections have been completely removed,

9.4.2 The limitations specified above have not been exceeded,

9.4.3 Established welding procedures have been followed, and

9.4.4 Any weld deposit is of acceptable quality as defined above.

10. Marking

10.1 *Plates*—Each plate shall be steel die stamped, marked, or stenciled in one place with heat number, manufacturer's name, brand, or trade mark, size and thickness; except that unless otherwise specified, such marking in the case of secured lifts of plates 3/8 in.[8] and under in thickness of all sizes, and of plates 36 in. and under in width in all thicknesses, may be steel die stamped, marked or stenciled on only the top piece of each lift, or may be shown on a substantial tag attached to each lift. See also 10.5.

10.2 *Structural Size Shapes and Bar Size Shapes*—Structural size shapes shall be marked with the heat number, size of section, length, and mill identification marks on each piece. Either the manufacturer's name, brand, or trade mark shall be shown in raised letters at intervals along the length. Small structural shapes and bar size shapes with the greatest cross-sectional dimension not greater than 6 in. (152 mm) may be bundled for shipment with each lift marked or tagged showing the previously listed identification. See also 10.5.

10.3 *Steel Sheet Piling*—Carbon steel sheet piling shall be marked with the heat number, manufacturer's name, brand, or trade mark, size of section, length, and mill identification marks on each piece.

10.4 *Bars*—Bars in secured lifts shall be identified with a tag showing customer's order number, grade or specification, size, length, weight of lift, and heat number. Bars are not required to be die-stamped.

10.5 *Specification Identification*—In addition to the requirements of 10.1 or 10.2 each plate, shape or lift, when ordered to Specifications A 242, A 283 (Grade D only), A 440, A 441, A 514, A 529, A 572, A 588 and A 633 shall be marked with the applicable specification number. Color identification shall be applied as stated in 10.5.1, 10.5.2, and 10.5.3.

10.5.1 *Plates*—When specified by the purchaser, each plate (except for plates in secured lifts) shall be marked with the color designated in 10.5.3 along one edge or on the rolled surface within 12 in. of the heat number identification. Plates in secured lifts may have the color identification marked with a vertical stripe for the full height of the lift. Each plate in the lift shall be marked by this stripe. Color markings shall be distinct and of sufficient size to be clearly visible.

10.5.2 *Shapes*—Each structural shape or lift shall be marked with the color designated in 10.5.3 on one cut end or across the rolled face of one flange or leg, adjacent to one cut end. Color markings shall be distinct and of sufficient size to be clearly visible.

10.5.3 *Colors*—The following color system shall be used to identify the individual specifications:

A 242	blue
A 283 (Grade D)	orange
A 440	brown
A 441	yellow
A 514	red
A 529	black
A 572 Grade 42	green and white
A 572 Grade 45	green and black
A 572 Grade 50	green and yellow
A 572 Grade 55	green and brown
A 572 Grade 60	green and gray
A 572 Grade 65	green and blue
A 588	blue and yellow
A 633 Grades A and B	orange and black
A 633 Grades C and D	orange and blue
A 633 Grade E	orange and white
A 656	yellow and white
A 678 Grade A	red and white
A 678 Grade B	red and black
A 678 Grade C	red and yellow
A 690	blue and red
A 699 Class 1	white and blue
A 699 Class 2	white and brown
A 699 Class 3	white and black
A 699 Class 4	white and pink

10.6 *Heat Treatment Identification:*

10.6.1 Material that is eventually required to be heat treated by the material specification, but that is released on the basis of heat-treated test specimens, shall be identified with the

[8] For material specified for bridge construction 5/16 in. applies instead of 3/8 in. as given in this paragraph.

letter "G" following the specification designation.

10.6.2 Material that is given, at the mill, the full heat-treatment required by the material specification, shall be identified with the letters "MT" following the specification designation.

11. Inspection and Testing

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

12. Retests

12.1 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

12.2 If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than ¾ in. from the center of the gage length of a 2-in. specimen or is outside the middle half of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

12.3 If the results on an original tensile specimen are within 2000 psi of the required tensile strength, within 1000 psi of the required yield point, or within 2 percentage units of the required elongation, a retest shall be permitted on one random specimen from the heat or lot. If the results on this retest specimen meet the specified requirements, the heat or lot will be accepted.

12.4 If a bend specimen fails due to conditions of bending more severe than required by the specification, a retest shall be permitted, either on a duplicate specimen or on a remaining portion of the failed specimen.

12.5 Alloy steel plates are subject to the additional retest requirements contained in the material specification.

12.6 If a sheared or gas-cut bend test specimen fails due to conditions associated with the sheared or gas-cut edges, a retest shall be permitted on a duplicate machined specimen.

13. Rejection

13.1 Unless otherwise specified, any rejection based on product analysis made in accordance with the material specification shall be reported to the manufacturer within five working days from receipt of samples by the purchaser.

13.2 Samples that represent rejected material shall be preserved for 2 weeks from the date 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.

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

14. Test Reports

14.1 When test reports are required by the purchase order, the report shall show the results of each test required by the material specification, except that only one test need be reported when the amount of material from a heat in a shipment is less than 10 tons, or when the shipment consists of a single piece weighing more than 10 tons and when the thickness variations described in 6.2 are not exceeded.

14.2 The thickness of the product tested may not necessarily be the same as an individual ordered thickness since it is the heat that is tested rather than each ordered item.

15. Packaging, Marking, and Loading

15.1 Packaging, marking, and loading for shipment shall be in accordance with those procedures recommended by the U.S. Department of Commerce in its *Simplified Practice Recommendation R 247–62* (Packaging, Marking and Loading Methods for Steel Products for Domestic Shipment).[9]

[9] Available from the Clearinghouse for Federal Scientific Information, 5285 Port Royal Road, Springfield, Va. 22151.

TABLE A Structural Shape Size Groupings for Tensile Property Classification

Structural Shape	Group 1	Group 2	Group 3	Group 4	Group 5
W Shapes	W24 × 55, 61 W21 × 44, 49 W18 × 45 to 60 incl W18 × 35, 40 W16 × 26 to 50 incl W14 × 22 to 53 incl W12 × 14 to 58 incl W10 × 11.5 to 45 incl W8 × 10 to 48 incl W6 × 8.5 to 25 incl W5 × 16 to 18.5 incl W4 × 13	W36 × 135 to 194 incl W33 × 118 to 152 incl W30 × 99 to 210 incl W27 × 84 to 177 incl W24 × 68 to 160 incl W21 × 55 to 142 incl W18 × 64 to 114 incl W16 × 58 to 96 incl W14 × 61 to 136 incl W12 × 65 to 106 incl W10 × 49 to 112 incl W8 × 58 to 67 incl	W36 × 230 to 300 incl W33 × 200 to 240 incl W14 × 142 to 211 incl W12 × 120 to 190 incl	W14 × 219 to 550 incl	W14 × 605 to 730 incl
M Shapes	to 35 lb/ft incl	over 35 lb/ft			
S Shapes	to 35 lb/ft incl	over 35 lb/ft			
HP Shapes		to 102 lb/ft incl	over 102 lb/ft		
American Standard Channels (C)	to 21 lb/ft incl	over 21 lb/ft			
Miscellaneous Channels (MC)	to 28.5 lb/ft incl	over 28.5 lb/ft			
Angles (structural and bar size) (L Shapes)	to ½ in. incl	over ½ to ¾ in. incl	over ¾ in.		

NOTE 1—Structural tees from W, M, and S shapes fall in the same group as the structural shape from which they are cut.
NOTE 2—1 lb/ft = 1.48816 kg/m.

TABLE B Product Analysis Tolerance Carbon and High-Strength Low-Alloy[a] Steel Plates, Structural Size Shapes, Sheet Piling

Element	Upper Limit, or Maximum of Specified Range, percent	Tolerances, percent	
		Under min limit	Over max limit
Carbon	to 0.15, incl	0.02	0.03
	over 0.15 to 0.40, incl	0.03	0.04
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		—	0.010
Sulfur		—	0.010
Silicon	to 0.30 incl	0.02	0.03
	over 0.30 to 1.00 incl	0.05	0.05
Copper	under, minimum only	0.02	—

[a] For product analysis on alloy elements in high-strength low-alloy steels see Table C.

TABLE C Product Analysis Tolerances—Alloy Steel Plates

Element	Limit, or Maximum of Specified Element, percent	Tolerance Over Maximum Limit or Under Minimum Limit, percent
Carbon	to 0.30, incl	0.02
Manganese	to 0.90, incl	0.04
	over 0.90 to 2.10, incl	0.05
Phosphorus	over, max only	0.01
Sulfur	to 0.060 and over, max only	0.01
Silicon	to 0.40, incl	0.02
	over 0.40 to 2.20, incl	0.06
Nickel	to 1.00 incl	0.03
	over 1.00 to 2.00, incl	0.05
Chromium	to 0.90, incl	0.04
	over 0.90 to 2.10, incl	0.06
Molybdenum	to 0.20, incl	0.01
	over 0.20 to 0.40, incl	0.03
	over 0.40 to 1.15, incl	0.04
Copper	to 1.00, incl	0.03
	over 1.00 to 2.00, incl	0.05
Titanium	to 0.10, incl	0.01[a]
Vanadium	to 0.10, incl	0.01[a]
	over 0.10 to 0.25, incl	0.02
	minimum value only specified, check under min	0.01
Boron	not applicable	
Columbium	to 0.10, incl	0.01[a]
Zirconium	to 0.15, incl	0.03
Nitrogen	to 0.030 incl	0.005

[a] If the minimum of the range is 0.01 percent, the under tolerance is 0.005 percent.

TABLE D Product Analysis Tolerances, Carbon and High-Strength Low-Alloy[a] Steel Bars, and Bar Size Shapes

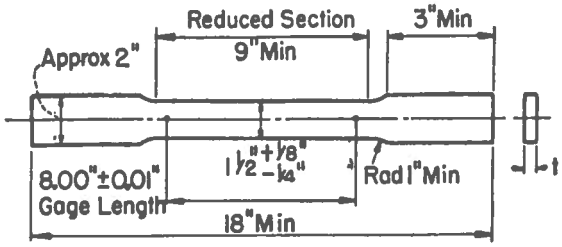
Element	Limit or Maximum of Specified Range, percent	Tolerance Over Maximum Limit or Under Minimum Limit, percent
Carbon	to 0.25, incl	0.02
	over 0.25 to 0.55, incl	0.03
Manganese	to 0.90, incl	0.03
	over 0.90 to 1.65, incl	0.06
Phosphorus	over, maximum only	0.008
Sulfur	over, maximum only	0.008
Silicon	to 0.35, incl	0.02
	over 0.35 to 0.60, incl	0.05
Copper	under, minimum only	0.02

[a] For product analysis on alloy elements in high-strength low-alloy steels, see Table E.

TABLE E Product Analysis Tolerances, Alloy Steel Bars and Bar Size Shapes

Element	Limit, or Maximum of Specified Range, percent	Tolerance Over Maximum or Under Minimum Limits, percent
Nickel	to 1.00, incl	0.03
	over 1.00 to 2.00, incl	0.05
Chromium	to 0.90, incl	0.03
	over 0.90 to 2.10, incl	0.05
Molybdenum	to 0.20 incl	0.01
	over 0.20 to 0.40, incl	0.02
Copper	to 1.00, incl	0.03
	over 1.00 to 2.00, incl	0.05
Titanium	to 0.10, incl	0.01[a]
Vanadium	to 0.10, incl	0.01[a]
	over 0.10 to 0.25, incl	0.02
Columbium	to 0.10, incl	0.01[a]
Zirconium	to 0.15, incl	0.03
Nitrogen	to 0.030 incl	0.005

[a] If the minimum of the range is 0.01 percent, the under tolerance is 0.005 percent.



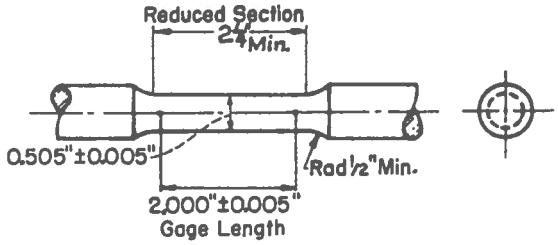
NOTE 1—When necessary, a narrower specimen may be used but the reduced portion shall be not less than 1 in. in width.

NOTE 2—The dimension "t" is the thickness of the test specimen as provided for in the applicable material specifications.

NOTE 3—The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center with the ends not more than 0.010 in. wider than the center.

NOTE 4—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.

FIG. 1 Standard Rectangular Tension Test Specimen with 8-in. Gage Length.



NOTE 1—The gage length and fillets shall be as shown, 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.

NOTE 2—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 0.005 in. larger in diameter than the center.

FIG. 2 Standard Round-Tension Test Specimen with 2-in. Gage Length.

Index to Tables of Permissible Variations.

TABLE 1 Permissible Variations in Thickness and Weight for Rectangular Sheared Plates and Universal Mill Plates 15 in. and Under in Thickness When Ordered to Thickness (Applies to All Specifications Listed in Section 1).

NOTE 1—Permissible overweight for lots of circular and sketch plates shall be 1¼ times the amounts in this table.
NOTE 2—Permissible variations in overweight for single plates shall be 1⅓ times the amounts in this table.
NOTE 3—Permissible overweight for single circular and sketch plates shall be 1⅔ times the amounts in this table.
NOTE 4—The adopted standard density for rolled steel is 0.2833 lb/in.[3]

Specified Thickness, in.[b]	Permissible Excess in Average Weight of Lots[a] for Widths Given in Inches, Expressed in Percentages of Nominal Weights										
	48 and under	Over 48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 132, excl	132 to 144, excl	144 to 168, excl	168 and over
To ¼, excl	6.0	7.0	8.0	8.5	10.5	12.0	14.0	16.0	18.5	...	...
¼ to 5/16, excl	6.0	6.0	7.0	8.0	8.5	10.5	12.0	14.0	16.5	19.5	...
5/16 to ⅜, excl	5.0	6.0	6.0	7.0	8.0	8.5	10.5	12.0	15.0	17.0	...
⅜ to 7/16, excl	4.5	5.0	6.0	6.0	7.0	8.0	8.5	10.5	13.0	15.0	17.0
7/16 to ½, excl	4.0	4.5	5.0	6.0	6.0	7.0	8.0	8.5	11.0	13.0	15.0
½ to ⅝, excl	4.0	4.0	4.5	5.0	6.0	6.0	7.0	8.0	9.5	11.0	13.0
⅝ to ¾, excl	4.0	4.0	4.0	4.5	5.0	6.0	6.0	7.0	8.0	9.0	11.0
¾ to 1, excl	3.5	4.0	4.0	4.0	4.5	5.0	6.0	6.0	7.0	8.0	9.5
1 to 2, excl	3.5	3.5	4.0	4.0	4.0	4.5	5.0	6.0	6.0	7.0	8.0
2 to 3, excl	3.5	3.5	3.5	4.0	4.0	4.5	5.0	6.0	6.0	6.5	7.0
3 to 4, excl	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.0	4.5	5.0
4 to 6, excl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5	4.0
6 to 8, excl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5
8 to 10, excl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5
10 to 12, excl	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
12 to 15, incl	2.5	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0

[a] The term "lot" means all the plates of each tabular width and thickness group represented in each shipment.
[b] Permissible variation under specified thickness, 0.01 in.

TABLE 2 Permissible Variations in Thickness for Rectangular Mill and Universal Mill Plates Over 2 in. in Thickness (Applies to Alloy Steel Specifications Only).

NOTE 1—Tolerance under specified thickness, 0.01 in.
NOTE 2—These tolerances only apply when the thickness is measured ⅜ in. from the longitudinal edges of plates.
NOTE 3—For overweight tolerances which limit the overall thickness of the plate, see Table 1.

Specified Thickness, in.	Variations over Specified Thickness for Widths Given, in.					
	To 36, excl	36 to 60, excl	60 to 84, excl	84 to 120, excl	120 to 132, excl	132 and over
Over 2 to 3, excl	1/16	3/32	7/64	⅛	⅛	9/64
3 to 4, excl	5/64	3/32	7/64	⅛	⅛	9/64
4 incl	3/32	⅛	9/64	9/64	5/32	11/64

TABLE 3 Permissible Variations in Weight for Rectangular Sheared Plates and Universal Mill Plates 612.0 lb/ft² and Under When Ordered to Weight.

NOTE 1—Permissible variation in overweight for lots of circular and sketch plates shall be 1¼ times the amounts in this table.
NOTE 2—Permissible variations in overweight for single plates shall be 1⅓ times the amounts in this table.
NOTE 3—Permissible variations in overweight for single circular and sketch plates shall be 1⅔ times the amounts in this table.
NOTE 4—The adopted standard density for rolled steel is 0.2833 lb/in.³

Specified Weights, lb/ft²	Permissible Variation in Average Weight of Lots[a] for Widths Given in Inches, Expressed in Percentage of the Specified Weights per Square Foot																					
	48 and under		Over 48 to 60, excl		60 to 72, excl		72 to 84, excl		84 to 96, excl		96 to 108, excl		108 to 120, excl		120 to 132, excl		132 to 144, excl		144 to 168, excl		168 and over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
To 10, excl	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	9.0	3.0	11.0	3.0	13.0	3.0	...	...	...	...
10 to 12.5, excl	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.5	3.0	7.0	3.0	8.0	3.0	9.0	3.0	12.0	3.0	...	...
12.5 to 15.0, excl	4.0	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	8.0	3.0	11	3.0	...	...
15 to 17.5, excl	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.0	3.0	9.0	3.0	10	3.0
17.5 to 20, excl	3.5	2.5	3.5	2.5	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	8.0	3.0	9.0	3.0
20 to 25, excl	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	7.0	3.0	8.0	3.0
25 to 30, excl	3.0	2.5	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	6.5	3.0	7.0	3.0
30 to 40, excl	3.0	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.5	3.5	2.5	4.0	3.0	4.5	3.0	6.0	3.0	6.5	3.0
40 to 81.6, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	4.0	3.0	5.5	3.0	6.0	3.0
81.6 to 122.4, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0
122.4 to 163.2, excl	2.5	1.5	2.5	1.5	2.5	1.5	2.5	1.5	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	3.0	2.0	3.5	2.0
163.2 to 244.8, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0	3.5	1.0
244.8 to 326.4, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0
326.4 to 408.0, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0
408.0 to 489.6, excl	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0
489.6 to 612.0, excl	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0

[a] The term "lot" means all the plates of each tabular width and weight group represented in each shipment.

TABLE 4 Permissible Variations in Width and Length for Sheared Plates 1½ In. and Under in Thickness; Length Only of Universal Mill Plates 2½ In. and Under in Thickness (Applies to All Specifications Listed in Section 1)

Specified Dimensions, in.		Variations over Specified Width and Length[a] for Thicknesses, in., and Equivalent Weights, lb/ft², Given							
		To ⅜, excl		⅜ to ⅝, excl		⅝ to 1, excl		1 to 2, incl[b]	
Length	Width	To 15.3, excl		15.3 to 25.5, excl		25.5 to 40.8, excl		40.8 to 81.6, incl	
		Width	Length	Width	Length	Width	Length	Width	Length
To 120, excl	To 60, excl	⅜	½	7/16	⅝	½	¾	⅝	1
	60 to 84, excl	7/16	⅝	½	11/16	⅝	⅞	¾	1
	84 to 108, excl	½	¾	⅝	⅞	¾	1	1	1⅛
	108 and over	⅝	⅞	¾	1	⅞	1⅛	1⅛	1¼
120 to 240, excl	To 60, excl	⅜	¾	½	⅞	⅝	1	¾	1⅛
	60 to 84, excl	½	¾	⅝	⅞	¾	1	⅞	1¼
	84 to 108, excl	9/16	⅞	11/16	15/16	13/16	1⅛	1	1⅜
	108 and over	⅝	1	¾	1⅛	⅞	1¼	1⅛	1⅜
240 to 360, excl	To 60, excl	⅜	1	½	1⅛	⅝	1¼	¾	1½
	60 to 84, excl	½	1	⅝	1⅛	¾	1¼	⅞	1½
	84 to 108, excl	9/16	1	11/16	1⅛	⅞	1⅜	1	1½
	108 and over	11/16	1⅛	⅞	1¼	1	1⅜	1¼	1¾
360 to 480, excl	To 60, excl	7/16	1⅛	½	1¼	⅝	1⅜	¾	1⅝
	60 to 84, excl	½	1¼	⅝	1⅜	¾	1½	⅞	1⅝
	84 to 108, excl	9/16	1¼	¾	1⅜	⅞	1½	1	1⅞
	108 and over	¾	1⅜	⅞	1½	1	1⅝	1¼	1⅞
480 to 600, excl	To 60, excl	7/16	1¼	½	1½	⅝	1⅝	¾	1⅞
	60 to 84, excl	½	1⅜	⅝	1½	¾	1⅝	⅞	1⅞
	84 to 108, excl	⅝	1⅜	¾	1½	⅞	1⅝	1	1⅞
	108 and over	¾	1½	⅞	1⅝	1	1¾	1¼	1⅞
600 to 720, excl	To 60, excl	½	1¾	⅝	1⅞	¾	1⅞	⅞	2¼
	60 to 84, excl	⅝	1¾	¾	1⅞	⅞	1⅞	1	2¼
	84 to 108, excl	⅝	1¾	¾	1⅞	⅞	1⅞	1⅛	2¼
	108 and over	⅞	1¾	1	2	1⅛	2¼	1¼	2½
720 and over	To 60, excl	9/16	2	¾	2⅛	⅞	2¼	1	2¾
	60 to 84, excl	¾	2	⅞	2⅛	1	2¼	1⅛	2¾
	84 to 108, excl	¾	2	⅞	2⅛	1	2¼	1¼	2¾
	108 and over	1	2	1⅛	2⅜	1¼	2½	1⅜	3

[a] Permissible variation under specified width and length, ¼ in.

[b] Permissible variations in length apply also to Universal Mill plates up to 12 in. in width for thicknesses over 2 to 2½ in., incl., except for alloy steel up to 1¾ in. thick.

TABLE 5 Permissible Variations in Width for Mill Edge Plates in Coils and Cut Lengths for Plates Produced on Strip Mills (Not Applicable to Alloy Steel).

Specified Width, in.	Variations over Specified Width, in.[a,b]
To 14, excl	7/16
14 to 17, excl	1/2
17 to 19, excl	9/16
19 to 21, excl	5/8
21 to 24, excl	11/16
24 to 26, excl	13/16
26 to 28, excl	15/16
28 to 35, excl	1 1/8
35 to 50, excl	1 1/4
50 to 60, excl	1 1/2
60 to 65, excl	1 5/8
65 to 70, excl	1 3/4
70 to 80, excl	1 7/8
80 and over	2

[a] No permissible variation under specified width.
[b] These variations do not apply to the uncropped ends of mill-edge plates in coils.

TABLE 6 Permissible Variations in Rolled Width for Universal Mill Plates 15 in. and Under in Thickness (Applies to All Specifications Listed in Section 1).

Specified Width, in.	Variations over Specified Width[a] for Thickness, in., or Equivalent Weights, lb/ft,[2] Given					
	To 3/8, excl	3/8 to 5/8, excl	5/8 to 1, excl	1 to 2, incl	Over 2 to 10, incl	Over 10 to 15, incl
	To 15.3, excl	15.3 to 25.5, excl	25.5 to 40.8, excl	40.8 to 81.6, incl	81.6 to 408.0, incl	408.0 to 612.0, incl
Over 8 to 20, excl	1/8	1/8	3/16	1/4	3/8	1/2
20 to 36, excl	3/16	1/4	5/16	3/8	7/16	9/16
36 and over	5/16	3/8	7/16	1/2	9/16	5/8

[a] Permissible variation under specified width, 1/8 in.

TABLE 7 Permissible Variations in Diameter for Sheared Circular Plates 1 in. and Under in Thickness (Applies to All Specifications Listed in Section 1).

Specified Diameters, in.	Permissible Variations over Specified Diameter for Thicknesses Given, in.[a]		
	To 3/8, excl	3/8 to 5/8, excl	5/8 to 1, incl
To 32, excl	1/4	3/8	1/2
32 to 84, excl	5/16	7/16	9/16
84 to 108, excl	3/8	1/2	5/8
108 to 130, excl	7/16	9/16	11/16
130 and over	1/2	5/8	3/4

[a] No permissible variations under specified diameter.

TABLE 8 Permissible Variations in Diameter for Gas-Cut Circular Plates (Not Applicable to Alloy Steel).

Specified Diameter, in.	Variations over Specified Diameter for Thicknesses Given, in.[a]					
	to 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	3/8	3/8	1/2	1/2	5/8	3/4
32 to 84, excl	3/8	1/2	1/2	5/8	3/4	7/8
84 to 108, excl	1/2	9/16	5/8	3/4	7/8	1
108 to 130, excl	1/2	9/16	11/16	7/8	1	1 1/8
130 and over	5/8	3/4	7/8	1	1 1/8	1 1/4

[a] No permissible variation under specified diameter.

TABLE 9 Permissible Variations in Width and Length for Rectangular Plates When Gas Cutting is Specified or Required (Applies to Alloy Steel Specifications Only).

NOTE 1—Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, in.	Variations Over for All Specified Widths or Lengths, in.[a]
To 2, excl	3/4
2 to 4, excl	1
4, incl	1 1/8

[a] These variations may be taken all under or divided over and under, if so specified.

TABLE 10 Permissible Variations in Width and Length for Rectangular Plates When Gas Cutting is Specified or Required (Not Applicable to Alloy Steel).

NOTE 1—Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, in.	Variations Over for All Specified Widths or Lengths, in.[a]
To 2, excl	1/2
2 to 4, excl	5/8
4 to 6, excl	3/4
6 to 8, excl	7/8
8 to 15, incl	1

[a] These variations may be taken all under or divided over and under, if so specified.

TABLE 11 Permissible Variations in Diameter for Gas-Cut Circular Plates (Applies to Alloy Steel Specifications Only).

Specified Diameter, in.	Variations over Specified Diameter for Thicknesses Given, in.[a]					
	to 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	1/2	1/2	3/4	3/4	1	1
32 to 84, excl	1/2	5/8	7/8	1	1 1/8	1 1/4
84 to 108, excl	5/8	3/4	1	1 1/8	1 1/4	1 3/8
108 to 130, incl	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2

[a] No permissible tolerance under specified diameter.

TABLE 12 Permissible Camber[a] for Carbon, Alloy, and High-Strength Low-Alloy Universal Mill Plates and Alloy and High-Strength Low-Alloy Sheared Special-Cut or Gas-Cut Rectangular Plates

Thickness, in.	Specified Weights, lb/ft²	Widths, in.	Camber Tolerances for Thicknesses and Widths Given
To 2, incl	to 81.6, incl	all	1/8 in. × (no. of feet of length/5)
Over 2 to 15, incl	81.6 to 612.0, incl	to 30, incl	3/16 in. × (no. of feet of length/5)
Over 2 to 15, incl	81.6 to 612.0, incl	over 30	1/4 in. × (no. of feet of length/5)

[a] Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE 13 Permissible Camber for Sheared Plates and Gas-Cut Rectangular Plates, All Thicknesses (Applies to Carbon Steel Only).

Maximum permissible camber, in. = 1/8 in. × (number of feet of length/5)

TABLE 14 Permissible Variations From Flatness for Carbon Steel Rectangular Sheared Plates, Universal Mill Plates, and Circular and Sketch Plates (Applies to Carbon Steel Only).

NOTE 1—When the longer dimension is under 36 in., the permissible variation should not exceed ¼ in. When the longer dimension is from 36 to 72 in., incl, the permissible variation should not exceed 75 percent of the tabular amount for the specified width, but in no case less than ¼ in.

NOTE 2—These variations apply to plates which have a specified minimum tensile strength of not more than 60,000 psi, or compatible chemistry or hardness. The limits in the table are increased 50 percent for plates specified to a higher minimum tensile strength or compatible chemistry or hardness.

NOTE 3—This table and these notes cover the permissible variations for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

Specified Thickness, in.	Specified Weight, lb/ft²	Permissible Variations from a Flat Surface for Specified Widths, in.[a,b]										
		To 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and Over
To ¼, excl	To 10.2, excl	9/16	¾	1 5/16	1¼	1⅜	1½	1⅝	1¾	1⅞	...	...
¼ to ⅜, excl	10.2 to 15.3, excl	½	⅝	¾	1 5/16	1⅛	1¼	1⅜	1½	1⅝	...	...
⅜ to ½, excl	15.3 to 20.4, excl	½	9/16	⅝	⅝	¾	⅞	1	1⅛	1¼	1⅞	2⅛
½ to ¾, excl	20.4 to 30.6, excl	7/16	½	9/16	⅝	⅝	¾	1	1	1⅛	1½	2
¾ to 1, excl	30.6 to 40.8, excl	7/16	½	9/16	⅝	⅝	⅝	¾	⅞	1	1⅜	1¾
1 to 2, excl	40.8 to 81.6, excl	⅜	½	½	9/16	9/16	⅝	⅝	⅝	1 1/16	1⅛	1½
2 to 4, excl	81.6 to 163.2, excl	5/16	⅜	7/16	½	½	½	½	9/16	⅝	⅞	1⅛
4 to 6, excl	163.2 to 244.8, excl	⅜	7/16	½	½	9/16	9/16	⅝	¾	⅞	⅞	1
6 to 8, excl	244.8 to 326.4, excl	7/16	½	½	⅝	1 1/16	¾	⅞	⅞	1	1	1
8 to 10, excl	326.4 to 408.0, excl	½	½	⅝	1 1/16	¾	1 3/16	⅞	1 5/16	1	1	1
10 to 12, excl	408.0 to 489.6, excl	½	⅝	¾	1 3/16	⅞	1 5/16	1	1	1	1	1
12 to 15, incl	489.6 to 612.0, incl	⅝	¾	1 3/16	⅞	1 5/16	1	1	1	1	1	...

[a] *Flatness Variations for Length*—The longer dimension specified is considered the length, and permissible variations in flatness along the length should not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

[b] *Flatness Variations for Width*—The flatness variations across the width should not exceed the tabular amount for the specified width.

TABLE 15 Permissible Variations From Flatness for High-Strength Low-Alloy and Alloy Steel Rectangular Sheared Plates, Universal Mill Plates, and Circular and Sketch Plates, Hot Rolled or Thermally Treated (Not Applicable to Carbon Steel).

NOTE 1—When the longer dimension is under 36 in., the variation should not exceed ⅜ in. When the larger dimension is from 36 to 72 in. incl, the variation should not exceed 75 percent of the tabular amount for the specified width.

NOTE 2—This table and notes cover the tolerances for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

Specified Thickness, in.	Specified Weights, lb/ft²	Flatness Tolerances for Specified Widths, in.[a,b]										
		To 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and Over
To ¼, excl	To 10.2 excl	1 3/16	1⅛	1⅜	1⅞	2	2¼	2⅜	2⅝	2¾	...	...
¼ to ⅜, excl	10.2 to 15.3 excl	¾	1 5/16	1⅛	1⅜	1¾	1⅞	2	2¼	2⅜	...	...
⅜ to ½, excl	15.3 to 20.4 excl	¾	⅞	1 5/16	1 5/16	1⅛	1 5/16	1½	1⅜	1⅞	2¾	3⅛
½ to ¾, excl	20.4 to 30.6 excl	⅝	¾	1 3/16	⅞	1	1⅛	1¼	1⅜	1⅝	2¼	3
¾ to 1, excl	30.6 to 40.8 excl	⅝	¾	⅞	⅞	1 5/16	1	1⅛	1 5/16	1½	2	2⅝
1 to 2, excl	40.8 to 81.6 excl	9/16	⅝	¾	1 3/16	⅞	1 5/16	1	1	1	1⅝	2¼
2 to 4, excl	81.6 to 163.2 excl	½	9/16	1 1/16	¾	¾	¾	¾	⅞	1	1¼	1⅝
4 to 6, excl	163.2 to 244.8 excl	9/16	1 1/16	¾	¾	⅞	⅞	1 5/16	1⅛	1¼	1¼	1½
6 to 8, excl	244.8 to 326.4 excl	⅝	¾	¾	1 5/16	1	1⅛	1¼	1 5/16	1½	1½	1½
8 to 10, excl	326.4 to 408.0 excl	¾	1 3/16	1 5/16	1	1⅛	1¼	1 5/16	1⅜	1½	1½	1½
10 to 12, excl	408.0 to 489.6 excl	¾	1 5/16	1⅛	1¼	1 5/16	1⅜	1½	1½	1½	1½	1½
12 to 15, incl	489.6 to 612.0 incl	⅞	1	1 3/16	1 5/16	1⅜	1½	1½	1½	1½	1½	1½

[a] *Flatness Variations for Length*—The longer dimension specified is considered the length, and variations from a flat surface along the length should not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

[b] *Flatness Variations for Width*—The flatness variation across the width should not exceed the tabular amount for the specified width.

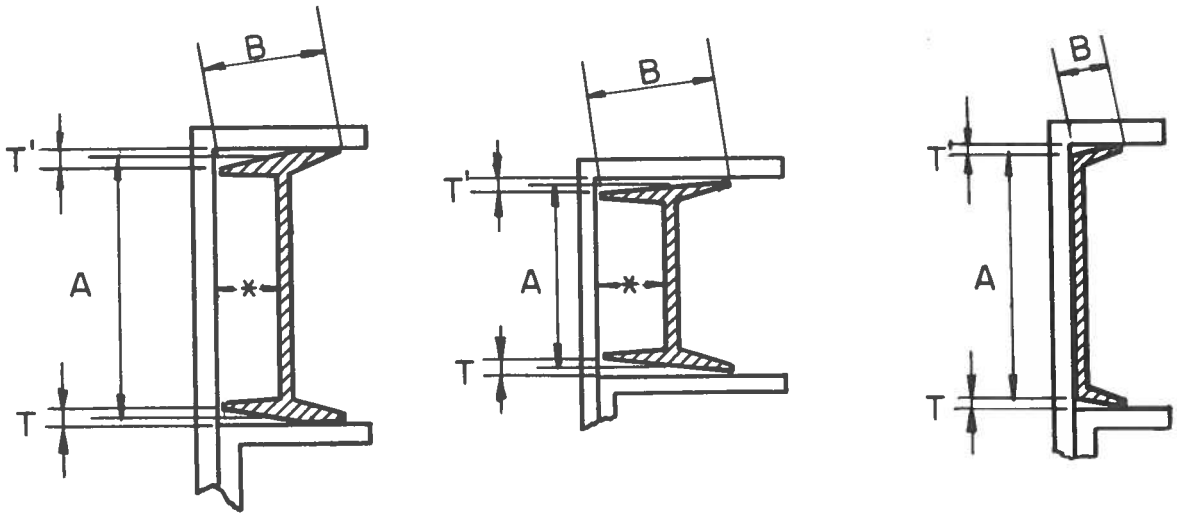
TABLE 16 Permissible Variations in Waviness for Rectangular Plates, Universal Mill Plates, and Circular and Sketch Plates

NOTE—Waviness denotes the maximum deviation of the surface of the plate from a plane parallel to the surface of the point of measurement and contiguous to the surface of the plate at each of the two adjacent wave peaks, when the plate is resting on a flat horizontal surface, as measured in an increment of less than 12 ft (3.66 m) of length.

The waviness tolerance is a function of the flatness tolerance as obtained from Table 14 or 15 as appropriate.

Flatness Tolerance, in., from Tables 14 or 15	Waviness Tolerance, in., When Number of Waves in 12 ft is						
	1	2	3	4	5	6	7
5/16	5/16	1/4	3/16	1/8	1/8	1/16	1/16
3/8	3/8	5/16	3/16	3/16	1/8	1/16	1/16
7/16	7/16	5/16	1/4	3/16	1/8	1/8	1/16
1/2	1/2	3/8	5/16	3/16	3/16	1/8	1/16
9/16	9/16	7/16	5/16	1/4	3/16	1/8	1/8
5/8	5/8	1/2	3/8	1/4	3/16	1/8	1/8
11/16	11/16	1/2	3/8	5/16	3/16	3/16	1/8
3/4	3/4	9/16	7/16	5/16	1/4	3/16	1/8
13/16	13/16	5/8	7/16	5/16	1/4	3/16	1/8
7/8	7/8	11/16	1/2	3/8	1/4	3/16	1/8
15/16	15/16	11/16	1/2	3/8	5/16	1/4	3/16
1	1	3/4	9/16	7/16	5/16	1/4	3/16
1 1/8	1 1/8	7/8	5/8	1/2	3/8	1/4	3/16
1 1/4	1 1/4	15/16	11/16	1/2	3/8	5/16	1/4
1 3/8	1 3/8	1 1/16	3/4	9/16	7/16	5/16	1/4
1 1/2	1 1/2	1 1/8	7/8	5/8	1/2	3/8	1/4
1 5/8	1 5/8	1 1/4	15/16	11/16	1/2	3/8	5/16
1 3/4	1 3/4	1 5/16	1	3/4	9/16	7/16	5/16
1 7/8	1 7/8	1 7/16	1 1/16	13/16	9/16	7/16	5/16
2	1	1 1/2	1 1/8	7/8	5/8	1/2	3/8
2 1/8	2 1/8	1 5/8	1 3/16	7/8	11/16	1/2	3/8
2 1/4	2 1/4	1 11/16	1 1/4	15/16	11/16	9/16	3/8
2 3/8	2 3/8	1 13/16	1 5/16	1	3/4	9/16	7/16
2 1/2	2 1/2	1 7/8	1 7/16	1 1/16	13/16	9/16	7/16
2 5/8	2 5/8	2	1 1/2	1 1/8	13/16	5/8	7/16
2 3/4	2 3/4	2 1/16	1 9/16	1 1/8	7/8	5/8	1/2
2 7/8	2 7/8	2 3/16	1 5/8	1 3/16	15/16	11/16	1/2
3	3	2 1/4	1 11/16	1 1/4	15/16	11/16	9/16
3 1/8	3 1/8	2 3/8	1 3/4	1 5/16	1	3/4	9/16

TABLE 17 Permissible Variations in Cross Section for Standard Beams, Standard Mill H-Beams and Channels (Not Applicable to Alloy Steel).



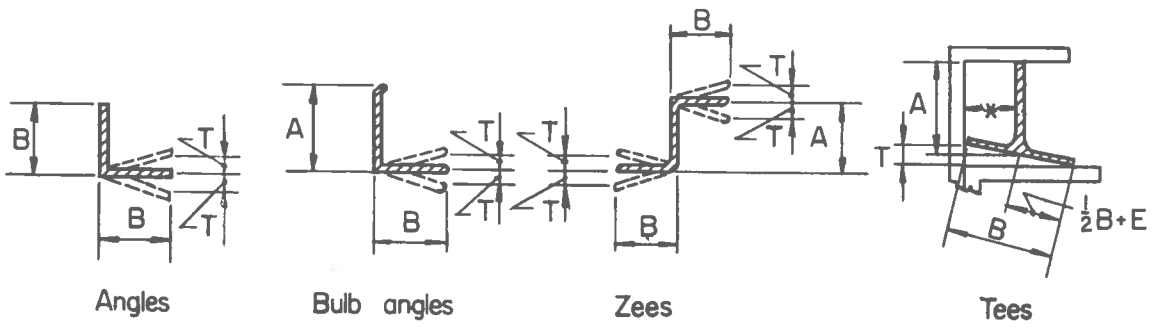
*Back of square and center line of web to be parallel when measuring "out-of-square."

$T \times T'$ applies when flanges of channels are toed in or out.

Section	Nominal Size, in.	*A*, Depth, in.[a]		*B*, Flange Width, in.		$T + T'$, Out of Square per Inch of *B*, in.
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical	
Standard beams	3 to 7, incl	3/32	1/16	1/8	1/8	1/32
	Over 7 to 14, incl	1/8	3/32	5/32	5/32	1/32
	Over 14 ro 24, incl	3/16	1/8	3/16	3/16	1/32
Standard mill H-beams	4	3/32	1/16	1/8	1/8	1/32
	5	3/32	1/16	5/32	5/32	1/32
	6 and 8	1/8	3/32	3/16	3/16	1/32
Channels	3 to 7, incl	3/32	1/16	1/8	1/8	1/32
	Over 7 to 14, incl	1/8	3/32	1/8	5/32	1/32
	Over 14	3/16	1/8	1/8	3/16	1/32

[a] *A* is measured at center line of web for beams; and at back of web for channels.

TABLE 18 Permissible Variations in Cross Section for Angles, Bulb Angles, Rolled Tees, and Zees (Not Applicable to Alloy Steel).



* Back of square and center line of stem to be parallel when measuring "out-of-square."

Section	Nomjnal Size, in.	*A*, Depth, in.		*B*, Flange Width or Length of Leg, in.		*T*, Out of Square per Inch of *B*, in.	*E*, Web off Center, max, in.
		Over Theo-retical	Under Theo-retical	Over Theo-retical	Under Theo-retical		
Angles[a]	3 to 4, incl	...	...	1/8	3/32	3/128[b]	...
	Over 4 to 6, incl	...	...	1/8	1/8	3/128[b]	...
	Over 6	...	...	3/16	1/8	3/128[b]	...
Bulb angles	(Depth) 3 to 4, incl	1/8	1/16	1/8	3/32	3/128[b]	...
	Over 4 to 6, incl	1/8	1/16	1/8	1/8	3/128[b]	...
	Over 6	1/8	1/16	3/16	1/8	3/128[b]	...
Rolled tees	(Stem or Flange) 5 and under	3/32	1/16	1/8	1/8	1/32	3/32
	(Stem or Flange) over 5 to 7, incl	3/32	1/16	1/8	1/8	1/32	1/8
Zees	3 to 4, incl	1/8	1/16	1/8	3/32	3/128[b]	...
	Over 4 to 6, incl	1/8	1/16	1/8	1/8	3/128[b]	...

[a] For unequal leg angles, longer leg determines classification.
[b] 3/128 in./in. = 1½ deg.

TABLE 19 Permissible Variations in Length for Standard Shapes (Not Applicable to Alloy Steel).

	Variations from Specified Length for Lengths Given, in.									
	To 30 ft, incl		Over 30 to 40 ft, incl		Over 40 to 50 ft, incl		Over 50 to 65 ft, incl		Over 65 ft	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
All standard shapes	½	¼	¾	¼	1	¼	1⅛	¼	1¼	¼

TABLE 20 Permissible Variations in Ends Out-Of-Square for Standard Shapes (Not Applicable to Alloy Steel).

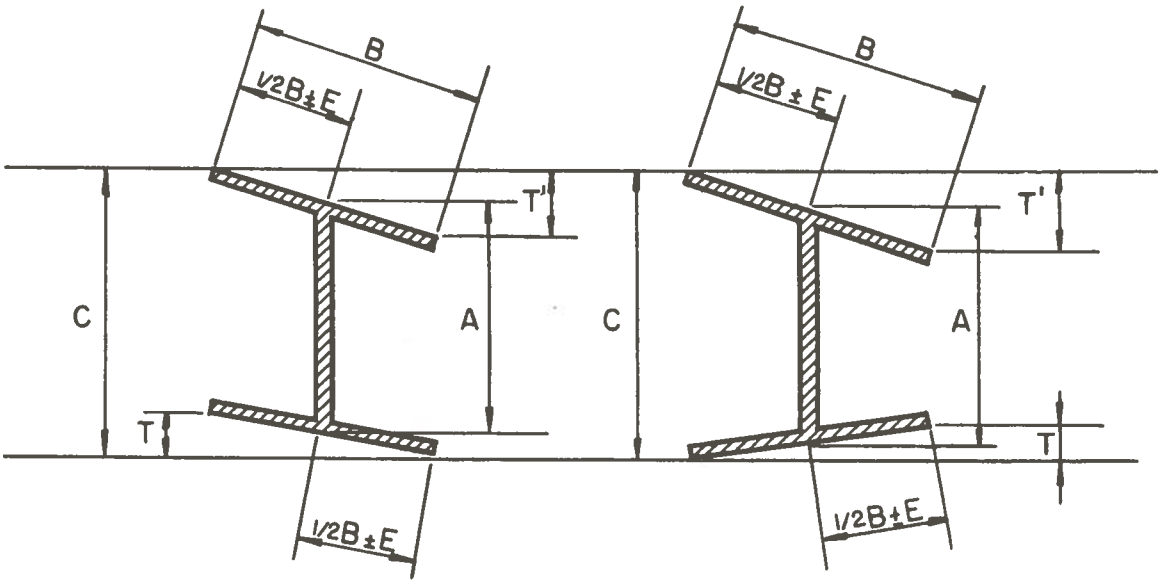
Shapes	Permissible Variations
Standard beams, channels Standard mill H-beams	1/64 in./in. of depth
Angles[a]	3/128 in./in. of leg length or 1½ deg
Bulb angles	3/128 in./in. of depth or 1½ deg
Rolled tees[a]	1/64 in./in. of flange or stem
Zees	3/128 in./in. of sum of both flange lengths

[a] Permissible variations for ends out-of-square are determined on the longer members of the shape.

TABLE 21 Permissible Variations in Straightness for Standard Shapes (Not Applicable to Alloy Steel).

	Permissible Variations
Camber	1/8 in. × (number of feet of total length/5)
Sweep	Due to the extreme variations in flexibility of standard beams and channels, straightness tolerances for sweep are subject to negotiations between the manufacturer and the purchaser for the individual sections involved.

TABLE 22 Permissible Variations in Cross Section for Wide Flange Shapes (Not Applicable to Alloy Steel).



Section Nominal Size, in.	*A*, Depth, in.		*B*, Flange Width, in.		*T* + *T'*, Flanges Out-of-Square, max, in.	*E*, Web off Center, max, in.[a]	*C*, Maximum Depth at any Cross-Section over Theoretical Depth, in.
	Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical			
Up to 12, incl	1/8	1/8	1/4	3/16	1/4	3/16	1/4
Over 12	1/8	1/8	1/4	3/16	5/16	3/16	1/4

A is measured at center line of web.
B is measured parallel to flange.
C is measured parallel to web.

[a] Variation of 5/16 in., max, for sections over 426 lb/ft.

TABLE 23 Permissible Variations in Length for Wide Flange Shapes[a, b] (Not Applicable to Alloy Steel).

Wide Flange Shapes	Variations from Specified Length for Lengths Given, in.			
	30 ft and under		Over 30 ft.	
	Over	Under	Over	Under
Beams 24 in. and under in nominal depth	3/8	3/8	3/8 plus 1/16 for each additional 5 ft or fraction thereof	3/8
Beams over 24 in. in nominal depth and all columns	1/2	1/2	1/2 plus 1/16 for each additional 5 ft or fraction thereof	1/2

[a] When wide flange shapes are used as bearing piles, the length tolerance is plus 5 in. and minus 0 in.
[b] The ends out-of-square tolerance for wide flange shapes shall be 1/64 in./in. of depth, or of flange width if it is greater than the depth.

TABLE 24 Permissible Variations for Length and Ends Out-of-Square, Milled Structural Sections (Not Applicable to Alloy Steel).

Nominal, Depth, in.	Length, ft[a,c]	Milled Both Ends[b]			Milled One End[b]		
		Length, in.		Maximum End Out-of-Square, in.	Length, in.		Maximum End Out-of-Square, in., for Milled End
		Over	Under		Over	Under	
6 to 36	6 to 70	1/32	1/32	1/32	1/4	1/4	1/32

[a] Length is measured along center line of web. Measurements are made with the steel and tape at the same temperature.
[b] Ends out-of-square are measured by (*a*) squaring from the center line of the web and (*b*) squaring from the center line of the flange. The measured variation from true squareness in either plane may not exceed the total tabular amount.
[c] Length variation and out-of-square variation are additive.

TABLE 25 Permissible Variations in Straightness for Wide Flange Shapes (Not Applicable to Alloy Steel).

Wide Flange Shapes	Permissible Variation
Camber and sweep	1/8 in. × (number of feet of total length[a]/10)
When certain sections[b] with a flange width approximately equal to depth are specified on order as columns:	
Lengths of 45 ft and under	1/8 in. × (number of feet of total length/10) but not over 3/8 in.
Lengths over 45 ft	3/8 in. + [1/8 in. × (number of feet of total length − 45/10)]

[a] Sections with a flange width less than 6 in., tolerance for sweep = 1/8 in. × (number of feet of total length/5).
[b] Applies only to:
8-in. deep sections 31 lb/ft and heavier,
10-in. deep sections 49 lb/ft and heavier,
12-in. deep sections 65 lb/ft and heavier, and
14-in. deep sections 78 lb/ft and heavier.
If other sections are specified on the order as columns, the tolerance will be subject to negotiation with the manufacturer.

TABLE 26 Permissible Variations in Dimensions for Split Tees and Angles[a] (Not Applicable to Alloy Steel).

Specified Depth, in.	Variations from Depth,[b] Over and Under, in.
To 6, excl (beams and channels)	1/8
6 to 16, excl (beams and channels)	3/16
16 to 20, excl (beams and channels)	1/4
20 to 24, excl (beams)	5/16
24 and over (beams)	3/8

[a] The length tolerance for split tees or angles are the same as those applicable to the section from which the tees or angles are split.

[b] The above tolerances for depth of tees or angles include the allowable tolerances in depth for the beams or channels before splitting. Tolerances both for dimensions and straightness, as set up for the beams or channels from which these tees or angles are cut, will apply, except

straightness = 1/8 in. × (length in feet/5)

TABLE 27 Permissible Variations in Sectional Dimensions for Standard Bar Size Angles (Not Applicable to Alloy Steel).

NOTE 1—The longer leg of an unequal angle determines the size for permissible variations.

NOTE 2—Permissible out-of-square in either direction, 1½ deg.

Specified Length of Leg, in.	Variations from Thickness for Thicknesses Given, Over and Under, in.			Variations from Length of Leg, Over and Under, in.
	3/16 and under	Over 3/16 to 3/8, incl	Over 3/8	
1 and under	0.008	0.010	...	1/32
Over 1 to 2, incl	0.010	0.010	0.012	1/64
Over 2 to 3, excl	0.012	0.015	0.015	1/16

TABLE 28 Permissible Variations in Sectional Dimensions for Standard Bar Size Channels (Not Applicable to Alloy Steel).

NOTE—Measurements for depth of shape and width of flanges are overall.

Specified Size of Channel, in.	Variations from Size, Over and Under, in.				Permissible Out-of-Square[a] of Either Flange per Inch of Flange Width, in.
	Depth of Section	Width of Flanges	Thickness of Web for Thicknesses Given		
			3/16 and under	Over 3/16	
1½ and under	1/32	1/32	0.010	0.015	1/32
Over 1½ to 3, excl	1/16	1/16	0.015	0.020	1/32

[a] For channels 5/8 in. and under in depth, the permissible out-of-square is 1/64 in./in. of depth.

TABLE 29 Permissible Variations in Sectional Dimensions for Standard Bar Size Tees (Not Applicable to Alloy Steel).

Specified Size of Tee, in.[a]	Width or Depth, in.[b]		Thickness of Flange, in.		Thickness of Stem, in.		Stem Out-of-Square, in.
	Over	Under	Over	Under	Over	Under	
1¼ and under	1/64	1/64	0.010	0.010	0.005	0.020	1/32
Over 1¼ to 2, incl	1/16	1/16	0.012	0.012	0.010	0.020	1/16
Over 2 to 3, excl	1/32	1/32	0.015	0.015	0.015	0.020	1/32

[a] The longer member of an unequal tee determines the size for permissible variations.

[b] Measurements for both width and depth are overall.

[c] Stem out-of-square is the variation from its true position of the center line of stem, measured at the point.

TABLE 30 Permissible Variations in Sectional Dimensions for Square Edge and Round Edge Flat Bars (Not Applicable to Alloy Steel).

Specified Widths, in.	Variations from Thickness, for Thicknesses Given, Over and Under, in.							Variations from Width, in.	
	0.203 to 0.230, excl	0.230 to ¼, excl	¼ to ½, incl	Over ½ to 1, incl	Over 1 to 2, incl	Over 2 to 3, incl	Over 3	Over	Under
To 1, incl	0.007	0.007	0.008	0.010	...	...	...	1/64	1/64
Over 1 to 2, incl	0.007	0.007	0.012	0.015	1/32	...	...	1/32	1/32
Over 2 to 4, incl	0.008	0.008	0.015	0.020	1/32	3/64	3/64	1/16	1/32
Over 4 to 6, incl	0.009	0.009	0.015	0.020	1/32	1/16	1/16	3/32	1/16
Over 6 to 8, incl	[a]	0.015	0.016	0.025	1/32	1/16	[b]	1/8[b]	3/32[b]

[a] Flats over 6 to 8 in., incl, in width are not available as hot-rolled carbon steel bars in thickness under 0.230.
[b] For flats over 6 to 8 in., in width, and over 3 in. in thickness, consult the producer for thickness and width tolerances.

TABLE 31 Permissible Variations in Sectional Dimensions for Round and Square Bars and Round-Cornered Squares (Not Applicable to Alloy Steel).

Specified Size, in.	Variations from Size, in.		Out-of-Round or Out-of-Square, in.[a]
	Over	Under	
To 5/16, incl	0.005	0.005	0.008
Over 5/16 to 7/16, incl	0.006	0.006	0.009
Over 7/16 to 5/8, incl	0.007	0.007	0.010
Over 5/8 to 7/8, incl	0.008	0.008	0.012
Over 7/8 to 1, incl	0.009	0.009	0.013
Over 1 to 1⅛, incl	0.010	0.010	0.015
Over 1⅛ to 1¼, incl	0.011	0.011	0.016
Over 1¼ to 1⅜, incl	0.012	0.012	0.018
Over 1⅜ to 1½, incl	0.014	0.014	0.021
Over 1½ to 2, incl	1/64	1/64	0.023
Over 2 to 2½, incl	1/32	0	0.023
Over 2½ to 3½, incl	3/64	0	0.035
Over 3½ to 4½, incl	1/16	0	0.046
Over 4½ to 5½, incl	5/64	0	0.058
Over 5½ to 6½, incl	1/8	0	0.070
Over 6½ to 8¼, incl	5/32	0	0.085
Over 8¼ to 9½, incl	3/16	0	0.100
Over 9½ to 10, incl	¼	0	0.120

[a] Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross section. Out-of-square is the difference in the two dimensions at the same cross section of a square bar between opposite faces.

TABLE 32 Permissible Variations in Sectional Dimensions for Hexagons (Not Applicable to Alloy Steel).

Specified Sizes Between Opposite Sides, in.	Variation from Size, in.		Maximum Difference, Three Measurements, in.[a]
	Over	Under	
½ and under	0.007	0.007	0.011
Over ½ to 1, incl	0.010	0.010	0.015
Over 1 to 1½, incl	0.021	0.013	0.025
Over 1½ to 2, incl	1/32	1/64	1/32
Over 2 to 2½, incl	3/64	1/64	3/64
Over 2½ to 3½, incl	1/16	1/64	1/16

[a] Greatest difference between any two of the three possible measurements.

TABLE 33 Permissible Variations in Sectional Dimensions for Half-Rounds, Ovals, and other Special Bar Size Shapes (Not Applicable to Alloy Steel).

Permissible variations in half-rounds, ovals, and other special bar size shapes not included in the foregoing tables are subject to individual negotiation.

TABLE 34 Permissible Variations in Straightness for Bars and Bar Size Shapes (Not Applicable to Alloy Steel).

	Maximum Permissible Variation in Straightness, in.
Bars and bar-size shapes[a]	¼ in any 5 ft or ¼ × (number of feet of total length/5)

[a] Permissible variations in straightness do not apply to hot-rolled bars if any subsequent heating operation has been performed.

TABLE 35 Permissible Variations in Length for Hot-Cut Carbon Steel Bars (Not Applicable to Alloy Steel)[a]

Specified Sizes of Rounds, Squares, and Hexagons, in.	Specified Sizes of Flats, in.		Permissible Variations over Specified Length Given in Feet, in. (No Variation Under)				
	Thickness	Width	5 to 10 ft, excl	10 to 20 ft, excl	20 to 30 ft, excl	30 to 40 ft, excl	40 to 60 ft, incl
To 1, incl	To 1, incl	To 3, incl	½	¾	1¼	1¾	2¼
Over 1 to 2, incl	Over 1	to 3, incl	⅝	1	1½	2	2½
Over 1 to 2, incl	To 1, incl	Over 3 to 6, incl	⅝	1	1½	2	2½
Over 2 to 5, incl	Over 1	Over 3 to 6, incl	1	1½	1¾	2¼	2¾
Over 5 to 10, incl	...	...	2	2½	2¾	3	3¼
	0.230 to 1, incl	Over 6 to 8, incl	¾	1¼	1¾	3½	4
	Over 1 to 3, incl	Over 6 to 8, incl	1¼	1¾	2	3½	4
Bar size sections	...	...	⅝	1	1½	2	2½
		Hot Sawing					
2 to 5, incl[b]	1 and over	3 and over	[b]	1½	1¾	2¼	2¾
Over 5 to 10, incl	...	...	[b]	2½	2¾	3	3¼

[a] For flats over 6 to 8 in., incl, in width and over 3 in. in thickness, consult the producer for length tolerances.
[b] Smaller sizes and shorter lengths are not commonly hot sawed.

TABLE 36 Permissible Variations in Length for Recutting After Straightening (Not Applicable to Alloy Steel)[a, b]

Sizes of Rounds, Squares, Hexagons, Width of Flats and Maximum Dimension of Other Section, in.	Permissible Variations for Specified Length, in.			
	To 12 ft, incl		Over 12 ft	
	Over	Under	Over	Under
To 3, incl	3/16	1/16	¼	1/16
Over 3 to 6, incl	¼	1/16	3/8	1/16
Over 6 to 8, incl	3/8	1/16	½	1/16
Rounds over 8 to 10, incl	½	1/16	⅝	1/16

[a] For flats over 6 to 8 in., incl, in width, and over 3 in. in thickness, consult the producer for length tolerances.
[b] Variations are sometimes required all over or all under the specified length, in which case the sum of the two tolerances applies.

APPENDIX

A1. METRIC EQUIVALENTS

A1.1 Table A1 contains the metric equivalents of the U.S. customary units used in the body of the standard.

TABLE A1 Metric Equivalents

Inches to Millimetres								
In.	½ in.	¼ in.	⅛ in.	1/16 in.	1/32 in.	1/64 in.	mm	Decimals of an In.[a]
							0.127	0.005
							0.254	0.010
							0.381	0.015
						1	0.397	0.015625
					1	2	0.794	0.03125
						3	1.191	0.046875
				1	2	4	1.588	0.0625
						5	1.984	0.078125
					3	6	2.381	0.09375
						7	2.778	0.109375
			1	2	4	8	3.175[a]	0.1250
						9	3.572	0.140625
					5	10	3.969	0.15625
						11	4.366	0.171875
				3	6	12	4.762	0.1875
						13	5.159	0.203125
					7	14	5.556	0.21875
						15	5.953	0.234375
		1	2	4	8	16	6.350[a]	0.2500
						17	6.747	0.265625
					9	18	7.144	0.28125
						19	7.541	0.296875
				5	10	20	7.938	0.3125
						21	8.334	0.328125
					11	22	8.731	0.34375
						23	9.128	0.359375
			3	6	12	24	9.525[a]	0.3750
						25	9.922	0.390625
					13	26	10.319	0.40625
						27	10.716	0.421875
				7	14	28	11.112	0.4375
						29	11.509	0.453125
					15	30	11.906	0.46875
						31	12.303	0.484375
	1	2	4	8	16	32	12.700[a]	0.5000
			5	10	20	40	15.875[a]	0.6250
		3	6	12	24	48	19.050[a]	0.7500
			7	14	28	56	22.225[a]	0.8750
1	2	4	8	16	32	64	25.400[a]	1.0000

[a] Exact.

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.

Designation: A 27 – 73

American National Standard G50.1
American National Standards Institute
Endorsed by American Foundrymen's Society

AMERICAN SOCIETY FOR TESTING AND MATERIALS

1916 Race St., Philadelphia, Pa., 19103

Standard Specification for MILD- TO MEDIUM-STRENGTH CARBON-STEEL CASTINGS FOR GENERAL APPLICATION[1]

This Standard is issued under the fixed designation A 27; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

This specification has been approved by the Department of Defense for listing in the DoD Index of Specifications and Standards. Proposed revisions should be coordinated with the Federal Government through the Army Materials and Mechanics Research Center, Watertown, Mass. 02172

1. Scope

1.1 This specification covers mild-strength to medium-strength carbon steel castings for general application as distinguished from carbon-steel and alloy-steel castings requiring a tensile strength in excess of 70,000 psi (483 MPa).

NOTE 1—The grades covered by this specification represent materials that are recognized as readily weldable by procedure as established under the accepted welding rules of such bodies as the ASME Boiler Code Committee, but these limitations do not imply that material of composition differing from those specified is not weldable with the use of proper technique.

NOTE 2—The term "weldable" as related to steel castings does not imply that no special precautions need be taken in welding any or all shapes of steel castings. Regardless of composition, the welding of any steel casting or other steel part of intricate shape or of greatly varying cross sections may necessitate special welding technique not generally considered necessary for the welding of parts of reasonably symmetrical form.

1.2 Seven grades of steel castings are covered, as indicated below. The grade desired shall be specified by the purchaser.

1.2.1 *Grade N-1*—Not required to be mechanically tested nor heat treated, except as conditionally provided in 15.2.

1.2.2 *Grade N-2*—Not required to be mechanically tested but required to be heat treated as provided in 3.1.

1.2.3 *Grade U-60-30*—Required to be mechanically tested but not required to be heat treated, except as conditionally provided in 15.2.

1.2.4 *Grades 60-30, 65-35, 70-36, and 70-40*—Required to be heat treated as provided in 3.1 and to be mechanically tested.

NOTE 3—The five grades required to be mechanically tested are distinguished in their grade designations by numerals corresponding to the significant numbers of the specified tensile strength and yield point. For example, grade 60-30 calls for a minimum tensile strength and yield point of 60,000 and 30,000 psi (414 and 207 MPa), respectively.

NOTE 4—The values stated in U.S. customary units are to be regarded as the standard.

2. Process

2.1 The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, converter, or crucible.

3. Heat Treatment

3.1 All castings of Grades N-2, 60-30, 65-35, 70-36, and 70-40 shall be heat treated, either by full annealing, normalizing, normalizing and tempering, or quenching and tempering in accordance with the following 3.2 through 3.8 and ASTM Definitions E 44, Terms Relating to Heat Treatment of Metals,[2] as indicated. Unless otherwise specified in the inquiry, contract, or order, the castings may be heat treated by any of these heat treatments or combination of these heat treatments at the option of the manufacturer.

3.2 *Full Annealing*—The procedure for full annealing shall be as described in Definitions E 44 which states that castings are to be heated to a temperature above the transformation range and, after being held for a proper time at this temperature they are cooled slowly to a temperature below 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 A01.18 on Castings.

Current edition approved Dec. 27, 1973. Published March 1974. Originally published as A 27 – 01. Last previous edition A 27 – 71.

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

transformation range. The castings are ordinarily allowed to cool slowly in the furnace, although they may be removed from the furnace and cooled in some medium which assures a slow rate of cooling. Castings may be removed from the furnace when the entire furnace charge has fallen to a temperature of 850 F (455 C), or lower.

3.3 *Normalizing*—The procedure for normalizing shall be as described in Definitions E 44 which states that castings are to be heated to a temperature above the transformation range and subsequently cooled in still air at room temperature.

3.4 *Quenching*—The procedure for quenching shall be as described in Definitions E 44 which states that castings are to receive a rapid cooling from an elevated temperature by contact with liquids, gases, or solids.

NOTE 5—The term "elevated temperature" as used in this paragraph means a temperature above the critical range.

3.5 *Tempering*—The procedure for tempering (drawing) shall be as defined in Definitions E 44 which describes the reheating of hardened or normalized steel to a temperature below the transformation temperature range, followed by any desired rate of cooling.

3.6 *Stress Relieving*—The procedure for stress relieving shall be as defined in Definitions E 44 which covers the reduction of internal stresses in a metal object by heating the object to a suitable temperature and holding for a proper time at that temperature. This treatment may be applied to relieve stresses induced by casting, quenching, normalizing, machining, cold working, or welding.

4. Temperature Regulation

4.1 Furnace temperatures for heat treating shall be effectively regulated by the use of pyrometers.

5. Chemical Requirements

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

6. Ladle Analysis

6.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The chemical analysis shall be made from a test ingot taken during the pouring of the heat. If drillings are used they shall be taken not less than ¼ in. (6.4 mm) beneath the surface. The chemical composition thus determined shall conform to the requirements prescribed in Table 1 and when specified in the inquiry, contract, or order shall be reported to the purchaser or his representative.

7. Product Analysis

7.1 An analysis may be made by the purchaser from a broken tension test specimen or from a casting representing each heat. If drillings are used, they shall be taken not less than ¼ in. (6.4 mm) beneath the surface, and in such manner as not to impair the usefulness of any casting selected for such check analysis. The chemical composition thus determined shall conform to the requirements specified in Table 1.

7.2 As unspecified alloying elements are unavoidable in steel, the following restrictions shall be placed on their concentration in the welding grades, the determination of which shall be a matter of agreement between the manufacturer and the purchaser, and must have been specified in the inquiry, contract, or order:

Copper, max, percent	0.30
Nickel, max, percent	0.50
Molybdenum, max, percent	0.20
Chromium, max, percent	0.40

8. Tensile Requirements

8.1 Steel used for castings of the grades that are required to be mechanically tested shall conform to the requirements as to tensile properties (Note 6) prescribed in Table 2. When specified in the inquiry, contract, or order, the properties obtained shall be reported to the purchaser or his representative.

NOTE 6—Because it has come to the attention of Committee A-1 on Steel that the intent of tension test requirements in some specifications has at times been misinterpreted, the committee wishes to make it clear that it is not intended that a maximum limit shall be placed on any tensile property required in this specification.

8.2 Tension tests shall be performed in accordance with ASTM Methods and Definitions A 370, for Mechanical Testing of Steel Products.[3] The yield point shall be determined

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

by use of one of the following methods at a rate of separation of the crossheads under load not to exceed 1/16 in./in. (0.06 mm/mm) of gage length per min:

8.2.1 Drop of the beam or halt in the gage,

8.2.2 Autographic diagram,

8.2.3 Dividers, or

8.2.4 Total extension under load using an extensometer.

8.3 The tensile strength shall be determined at a rate of separation of the crossheads under load not to exceed 1/2 in./in. (0.5 mm/mm) of gage length per min.

9. Test Coupons

9.1 Test coupons from which tension test specimens are prepared shall be attached to the castings where practicable. If, in the opinion of the manufacturer, the design of the casting is such that test coupons should not be attached thereon, test coupons shall be cast attached to separate cast blocks. The test coupons from which test specimens are to be prepared shall remain attached to the castings or blocks they represent until submitted for inspection, and shall be heat treated with the castings. Test coupons shall be provided in sufficient number to furnish the specimens required in Section 10.

10. Number of Tests

10.1 One tension test shall be made from each heat in each lot.

NOTE 7—The term "lot" shall be considered as all castings in a heat subjected to the same heat-treating procedure.

10.2 If any test specimen shows defective machining or develops flaws, it may be discarded, and another specimen substituted from the same lot (Note 7).

10.3 If the percentage of elongation of any tension test specimen is less than that specified in Table 2 and any part of the fracture is more than 3/4 in. (19.0 mm) from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

10.4 If mutually agreed upon by the manufacturer and the purchaser and after acceptance (for one or more orders) of ten consecutive heats used for making castings of any one grade, the manufacturer may assemble the castings from succeeding melts in groups of five heats each. The castings in each such group shall be accepted on the basis of one test specimen taken from every fifth heat, provided that the chemical analysis of all the heats in the group fall within the range established by the first ten consecutive acceptable heats and all subsequent heats that are physically tested and found acceptable. If this test fails, a rehearing shall be granted for the heat represented by the failed specimen, and the four other heats in the group shall be tested individually. The same heat-treating procedure used for the first ten consecutive heats shall be used for all subsequent heats. This procedure shall be established for each grade separately.

11. Retests

11.1 If the results of the mechanical test for any lot (Note 7) do not conform to the requirements specified, the manufacturer may reheat treat such lot. Retests of an additional specimen from the same lot shall be made and shall conform to the requirements specified in Sections 8 and 10.

12. Radiographic Inspection

12.1 If specified in the inquiry, contract, or order, and when mutually agreed upon by the manufacturer and the purchaser, castings made in accordance with this specification may be subject to radiographic inspection.

12.2 Areas to be radiographed, number of pieces made from the same pattern which shall be radiographed, and standards of acceptability shall be agreed upon by the manufacturer and the purchaser.

NOTE 8—Reference can be made to ASTM Reference Radiographs E 446, for Steel Castings Up to 2 in. in Thickness,[4] for X-ray and gamma-ray inspection. These standards are available in the form of plates in ring binders from ASTM Headquarters, 1916 Race St., Philadelphia, Pa. 19103. Request Adjunct No. 12-500710-09.

13. Magnetic Particle Inspection

13.1 When so specified in the inquiry, contract, or order, and when mutually agreed upon by the manufacturer and the purchaser, castings made in accordance with this specification may be subject to magnetic particle inspection.

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[4] *1973 Annual Book of ASTM Standards*, Part 31.

13.2 Areas to be magnetic particle inspected, number of pieces made from the same pattern which shall be magnetic particle inspected, and standards of acceptability shall be agreed upon by the manufacturer and the purchaser.

13.3 When dry magnetic particle inspection is used it shall be in accordance with ASTM Method E 109, Dry Powder Magnetic Particle Inspection,[4] or ASTM Method E 138, Wet Magnetic Particle Inspection.[4] Castings showing injurious defects, as judged by ASTM Reference Photographs E 125, for Magnetic Particle Testing of Ferrous Castings,[4] shall be rejected or repaired with the approval of the purchaser. The circular or coil method of over-all magnetization or the wet method of magnetic particle inspection, or both, may be used if such methods are more practical.

14. Workmanship

14.1 All castings shall be made in a workmanlike manner and shall conform substantially to the dimensions on drawings furnished by the purchaser before manufacture is started, or to the dimensions predicated by the pattern supplied by the purchaser, if no drawing has been provided.

15. Quality

15.1 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 MSS SP-55[5] 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.

16. Repair by Welding

16.1 Repairs shall be made using a welding procedure and welding operators 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] Welds exceeding 20 % of the wall thickness or 1 in. (25.4 mm), whichever is smaller, shall be given a suitable stress relief or heat treatment. All welds shall be inspected to the same quality standards as are used to inspect the castings. When magnetic particle inspection is required for the castings, all welds shall be inspected by the magnetic particle method. When radiographic inspection is required for the castings, all welds shall be inspected by the magnetic particle method, except that radiographic inspection shall be required of those welds whose depth exceeds 20 % of the wall thickness of whose area exceeds 10 in.^{2}/in. of wall thickness.

17. Marking

17.1 When specified by the purchaser, the manufacturer's name or identification mark and the pattern number shall be cast on all castings, except those of such small size as to make such marking impracticable. In addition, suitable marking of the numbers of the heats used for pouring the castings, or some mark that will identify the heats, shall be made on all castings individually weighing 500 lb (230 kg) or more.

NOTE 9—The resistance of a sand mold to the erosive effect of inflowing metal is aided by smooth mold surfaces. Cast identification marks are formed by making indentations on the face of the mold. For the prevention of small defects caused by dislodged particles of molding sand, there should be provided the minimum feasible number of cast identification marks.

18. Inspection

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

18.2 If, in the case of important castings

[5] Available from the Manufacturers' Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Dr., Arlington, Va. 22209.

[6] *1974 Annual Book of ASTM Standards*, Part 2.

for special purposes, surface inspection in the green state is required, this shall be so specified in the inquiry, contract, or order.

19. Rejection

19.1 Unless otherwise specified, any rejection based on tests made in accordance with this specification shall be reported to the manufacturer within five working days from the receipt of samples by the purchaser.

19.2 Material that shows injurious defects subsequent to its original inspection and acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

20. Rehearing

20.1 Tested samples representing rejected material shall be held for two weeks from the date 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.

SUPPLEMENTARY REQUIREMENTS

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

S1. Permissible Variations in Dimensional Tolerances for Castings Made from Mounted Patterns

S1.1 Tolerances for commercial steel castings (Note 10) made from mounted patterns and the surfaces of which are not to be machined shall be in accordance with Table 3. Metal match plate patterns and precise molding methods can produce closer tolerances than the values shown in Table 3. Complex casting designs may require different permissible variations than those listed in Table 3.

NOTE 10—The term "commercial castings" does not cover castings requiring special fixtures for gaging, or finishing castings by grinding to special tolerance gages beyond the normal requirements as listed in Table 3.

S2. Gate and Riser Projections for Castings Made from Mounted Patterns

S2.1 Castings shall have gates and risers removed in such a manner that no riser or gate stub projects or a depression is made beyond or below the casting design contour in an amount that would exceed the values given in Table 4.

S3. Weight Deviation for Castings Made from Mounted Patterns

S3.1 The allowable deviations from the average casting weight is shown in Table 5.

TABLE 1 Chemical Requirements

Grade	Composition, percent				
	Carbon[a] max	Manganese,[a] max	Silicon, max	Sulfur, max	Phosphorus, max
Grade N-1	0.25	0.75	0.80	0.06	0.05
Grade N-2	0.35	0.60	0.80	0.06	0.05
Grade U-60-30	0.25	0.75	0.80	0.06	0.05
Grade 60-30	0.30	0.60	0.80	0.06	0.05
Grade 65-35	0.30	0.70	0.80	0.06	0.05
Grade 70-36	0.35	0.70	0.80	0.06	0.05
Grade 70-40	0.25	1.20	0.80	0.06	0.05

[a] For each reduction of 0.01 percent carbon below the maximum specified, an increase of 0.04 percent manganese above the maximum specified will be permitted to a maximum of 1.40 percent for grade 70-40 and 1.00 percent for the other grades.

TABLE 2 Tensile Requirements

Grade	Tensile Strength, min, ksi (MPa)	Yield Point, min, ksi (MPa)	Elongation, in 2 in. or 50 mm, min, percent	Reduction of Area, min, percent
Grade U-60-30	60 (414)	30 (207)	22	30
Grade 60-30	60 (414)	30 (207)	24	35
Grade 65-35	65 (448)	35 (241)	24	35
Grade 70-36	70 (483)	36 (248)	22	30
Grade 70-40[a]	70 (483)	40 (276)	22	30

[a] Grade 70-40 may be used to meet the requirement of Grade 70-36, when agreed upon by the manufacturer and the purchaser.

TABLE 3 Normally Expected Deviation of Linear Casting Dimensions from Design Dimensions

Blueprint Dimension, in. (mm)	Tolerances, in. (mm)	
Up to 3 (76.2), inc	+1/32 (3.2)	−1/32 (2.4)
Over 3 to 7 (76.2 to 177.8)	+1/32 (4.0)	−1/32 (3.2)
Over 7 to 20 (177.8 to 508)	+5/32 (4.8)	−5/32 (4.0)
Over 20 to 100 (508 to 2540)	+8/32 (6.4)	−6/32 (4.8)

TABLE 4 Gate and Riser Projection Tolerances

Riser or Gate Maximum Dimension, in. (mm)	Maximum Projection, in. (mm)	Maximum Depression, in. (mm)
Up to 4 (101.6)	1/8 (3.2)	1/8 (3.2)
Over 4 to 8 (101.6 to 203.2)	1/4 (6.4)	1/8 (3.2)
Over 8 to 20 (203.2 to 508)	3/8 (9.5)	1/8 (3.2)
Over 20 to 30 (508 to 762)	1/2 (12.7)	1/4 (6.4)
Over 30 (762)	3/4 (19.0)	1/4 (6.4)

TABLE 5 Allowable Deviation[a] from Average Casting Weight

Casting Weight lb (kg)	Positive Deviation, percent	Negative Deviation, percent
Up to 100 (45)	8.0	8.0
Over 100 to 500 (45 to 227)	6.5	5.0
Over 500 to 10,000 (227 to 4540)	5.0	3.0
Over 10,000 (4540)	3.0	2.5

[a] Deviations do not apply to mass as calculated from a design drawing.

Designation: A 36 – 74

American National Standard G41.5
American National Standards Institute

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Standard Specification for STRUCTURAL STEEL[1]

This Standard is issued under the fixed designation A 36; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

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

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

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

2. Appurtenant Materials

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

3. General Requirements for Delivery

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

4. Bearing Plates

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

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

5. Process

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

6. Chemical Requirements

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

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys, and is the direct responsibility of Subcommittee A01.02 on Structural Steel.

Current edition approved July 29, 1974. Published September 1974. Originally published as A 36 – 60 T. Last previous edition A 36 – 70a.

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

[3] *1974 Annual Book of ASTM Standards*, Part 4.

specified in 4.2.

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

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

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

7. Tensile Requirements

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

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

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

8. Bend Test Requirements

8.1 The bend test specimens 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 4.

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order.

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

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

TABLE 1 Material Specifications

Material	ASTM Designation[a]
Plate to be bent or formed cold	A 283, Grade C[b]
Steel rivets	A 502, Grade 1[b]
Bolts and nuts	A 307[b], A 325
Cast steel	A 27, Grade 65-35[b]
Forgings (carbon steel)	A 235, Class E
Hot-rolled sheets	A 570, Grade D
Hot-rolled strip	A 570, Grade D
Cold-formed tubing	A 500, Grade B
Hot-formed tubing	A 501

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

A 283, Low and Intermediate Tensile Strength Carbon Steel Plate of Structural Quality,[3]

A 502, Steel Structural Rivets,[3]

A 307, Low-Carbon Steel Externally and Internally Threaded Standard Fasteners,[3]

A 325, High Strength Bolts for Structural Steel Joints Including Suitable Nuts and Plain Hardened Washers,[3]

A 27, Mild- to Medium-Strength Carbon-Steel Castings for General Application,[4]

A 235, Carbon Steel Forgings for General Industrial Use,[3]

A 570, Hot-Rolled Carbon Steel Sheets and Strip, Structural Quality,[3]

A 500, Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes,[3] and

A 501, Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.[3]

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

[4] *1974 Annual Book of ASTM Standards*, Part 2.

TABLE 2 Chemical Requirements

Product	Shapes[a]	Plates					Bars			
Thickness, in. (mm)	All	To ¾ (19), incl.	Over ¾ to 1½ (19 to 38), incl.	Over 1½ to 2½ (38 to 64), incl.	Over 2½ to 4 (64 to 102), incl.	Over 4 (102)	To ¾ (19), incl.	Over ¾ to 1½ (19 to 38), incl.	Over 1½ to 4 (102), incl.	Over 4 (102)
Carbon, max, percent	0.26	0.25	0.25	0.26	0.27	0.29	0.26	0.27	0.28	0.29
Manganese, percent	...	...	0.80–1.20	0.80–1.20	0.85–1.20	0.85–1.20	...	0.60–0.90	0.60–0.90	0.60–0.90
Phosphorus, max, percent	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max, percent	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Silicon, percent	...	...	...	0.15–0.30	0.15–0.30	0.15–0.30	...	...	...	...
Copper, min, percent, when copper steel is specified	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

[a] Manganese content of 0.85–1.35% and silicon content of 0.15–0.30% is required for shapes over 426 lb/ft.

TABLE 3 Tensile Requirements

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

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

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

[c] See 7.3.

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

TABLE 4 Bend Test Requirements

Thickness of Material, in. (mm)	Ratio of Bend Diameter to Thickness of Specimen for Plates, Shapes, and Bars[a]
¼ (19) and under	½
Over ¼ to 1 (19 to 25), incl	1
Over 1 to 1½ (25 to 38), incl	1½
Over 1½ to 2 (38 to 51), incl	2½
Over 2 (51)	3

[a] These 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.

Designation: A 53 – 73

American National Standard B125.1
American National Standards Institute

AMERICAN SOCIETY FOR TESTING AND MATERIALS

1916 Race St., Philadelphia, Pa., 19103

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Standard Specification for WELDED AND SEAMLESS STEEL PIPE[1]

This Standard is issued under the fixed designation A 53; 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[2] covers seamless and welded black and hot-dipped galvanized steel pipe in nominal sizes 1/8 in. to 26 in., incl, with nominal (average) wall thickness as given in Tables 5 and 6. Pipe having other dimensions (Note 1) may be furnished provided such pipe complies with all other requirements of this specification.

NOTE 1—A comprehensive listing of standardized pipe dimensions is contained in American National Standard ANSI B 36. 10.

1.2 Pipe may be furnished in the following types and grades:

1.2.1 *Type F*—Furnace-butt welded, continuous welded,

1.2.2 *Type E*—Electric-resistance welded, Grades A and B, and

1.2.3 *Type S*—Seamless, Grades A and B.

NOTE 2—See the Appendix for definition of types of pipe.

1.3 Pipe ordered under this specification is suitable for welding, and suitable for forming operations involving coiling, bending and flanging, subject to the following qualifications:

1.3.1 Type F is not intended for flanging.

1.3.2 When Types S and E are required for close coiling or cold bending, Grade A should be specified. This provision is not intended to prohibit the cold bending of Grade B pipe.

1.3.3 When pipe is required for close coiling, this should be specified on the order.

1.3.4 Type E may be furnished either nonexpanded or cold expanded at the option of the manufacturer. When pipe is cold expanded, the amount of expansion shall not exceed 1½ percent of the outside diameter pipe size.

NOTE 3—The values stated in U.S. customary units are to be regarded as the standards. The metric equivalents of U.S. customary units given in the body of the standard and in the appendix may be approximate.

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 (steel pipe),

2.1.3 Method of manufacture (seamless, electric-resistance welded or furnace welded),

2.1.4 Type (see 1.2) and Table 2),

2.1.5 Grade (Table 2),

2.1.6 Finish (black or galvanized),

2.1.7 Size (either nominal and weight class or schedule number or both; or outside diameter, and nominal wall thickness, Tables A2 and A3),

2.1.8 Length (specific or random, Section 15),

2.1.9 End finish (plain or threaded, Section 16),

2.1.10 Close coiling, if required (see 1.3.3),

2.1.11 Skelp for tensile tests, if permitted (see 10.2),

2.1.12 Couplings, if threaded (see 16.3): No couplings, if not desired, or power-tight, if so desired,

2.1.13 ASTM designation,

2.1.14 End use of material, and

2.1.15 Special requirements.

3. Materials and Manufacture

3.1 The steel for both seamless and welded pipe shall be made by one or more of the following processes: open-hearth, electric-fur-

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.09 on Pipe.

Current edition approved Sept. 27, 1973. Published December 1973. Originally published as A 53 – 15. Last previous edition A 53 – 72a.

[2] For *ASME Boiler and Pressure Vessel Code* applications see related Specification SA-53 in Section II of that Code.

nace, or basic-oxygen.

3.2 The weld seam of electric-resistance-welded pipe in Grade B shall be heat treated after welding to a minimum temperature of 1000 F (540C) or processed in such a manner that no untempered martensite remains.

4. Chemical Composition

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

5. Check Analysis

5.1 An analysis of two pipes from each lot of 500 lengths, or fraction thereof, may be made by the purchaser. Samples for chemical analysis, except for spectrographic analysis, shall be taken in accordance with ASTM Method E 59, Sampling Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron for Determination of Chemical Composition.[3] The chemical composition thus determined shall conform to the requirements specified in Table 1.

5.2 If the analysis of either pipe does not conform to the requirements specified in Table 1, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified.

6. Tensile Properties

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

6.2 The yield strength corresponding to a permanent offset of 0.2 percent of the gage length of the specimen or to a total extension of 0.5 percent of the gage length under load shall be determined.

6.3 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be required for pipe under 8 in. (203.2 mm) in outside diameter.

6.4 Transverse tension test specimens for electric welded pipe $8^5/_8$ in. (219.1 mm) in outside diameter and larger shall be taken opposite the weld. All transverse test specimens shall be approximately $1^1/_2$ in. (38.1 mm) wide in the gage length, and shall represent the full wall thickness of the pipe from which the specimen was cut.

7. Bending Properties

7.1 For pipe 2 in. and under in nominal diameter, a sufficient length of pipe shall stand being bent cold through 90 deg around a cylindrical mandrel, the diameter of which is twelve times the nominal diameter of the pipe, without developing cracks at any portion and without opening the weld. When ordered for close coiling, the pipe shall stand being bent cold through 180 deg around a cylindrical mandrel, the diameter of which is eight times the nominal diameter of the pipe, without failure. Double-extra-strong pipe over $1^1/_4$ in. in diameter need not be subjected to the bend test.

8. Flattening Test

8.1 The flattening test shall be made on pipe over 2 in. in nominal diameter with wall thicknesses extra strong and lighter.

8.2 *Seamless Pipe:*

8.2.1 For seamless pipe a section not less than $2^1/_2$ in. (63.5 mm) in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside or outside or end surfaces shall occur until the distance between the plates (Table 3) is less than the value of H calculated as follows:

$$H = (1 + e)t/(e + t/D)$$

where:

H = distance between flattening plates, in. (Note 4),
e = deformation per unit length (constant for a given grade of steel, 0.09 for Grade A and 0.07 for Grade B),
t = specified wall thickness, in., and
D = specified outside diameter, in.

8.2.2 During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

NOTE 4—The H values have been calculated for standard and extra-heavy weight sizes from $2^1/_2$ in. to 24 in., inclusive, and are shown in Table A 1.

8.3 *Electric-Resistance-Welded Pipe*—A specimen at least 4 in. (101.6 mm) in length shall be flattened cold between parallel plates

[3] *1974 Annual Book of ASTM Standards*, Part 12.

in three steps with the weld located either 0 or 90 deg from the line of direction of force as required in 8.3.1. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than one third of the original outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

8.3.1 For pipe produced in single lengths, the flattening test specified in 8.3 shall be made on both crop ends cut from each length of pipe. The tests from each end shall be made alternately with the weld at 0 deg and at 90 deg from the line of direction of force. For pipe produced in multiple lengths, the flattening test shall be made on crop ends representing the front and back of each coil with the weld at 90 deg from the line of direction of force, and on two intermediate rings representing each coil with the weld 0 deg from the line of direction of force.

8.4 *Butt Welded Pipe*—For butt welded pipe a specimen not less than 4 in. in length shall be flattened cold between parallel plates in three steps. The weld shall be located 90 deg from the line of direction of force. During the first step, which is a test for quality of the weld, no cracks or breaks on the inside, outside, or end surfaces shall occur until the distance between the plates is less than three fourths of the original outside diameter for butt welded pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside, outside, or end surfaces shall occur until the distance between the plates is less than 60 percent of the original outside diameter for butt welded pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

8.5 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 18.

8.6 Superficial ruptures as a result of surface imperfections shall not be cause for rejection.

9. Hydrostatic Test

9.1 Each length of plain-end pipe shall be tested at the mill to the hydrostatic pressures prescribed in Table A 2, and each threaded-and-coupled length shall be hydrostatically tested to pressures prescribed in Table A 3. The hydrostatic test may be applied, at the discretion of the manufacturer, on pipe with plain ends, with threads only, or with threads and couplings and may be applied to pipe in single lengths or multiple lengths. Welded pipe 2 in. and larger shall be jarred near one end while under test pressure.

9.2 The maximum specified hydrostatic test pressure shall not exceed 2500 psi (1.77 kgf/mm^2) for nominal sizes 3 in. and under, or 2800 psi (1.98 kgf/mm^2) for all nominal sizes over 3 in. The hydrostatic pressure shall be maintained for not less than 5 s for all sizes of seamless and electric-welded pipe.

10. Methods of Test

10.1 The test specimens and the tests 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.[4]

10.2 The longitudinal tension test specimen shall be taken from the end of the pipe or, by agreement between the manufacturer and the purchaser, may be taken from the skelp, at a point approximately 90 deg from the weld, and shall not be flattened between gage marks. The sides of each specimen shall be parallel between gage marks. If desired, the tension test may be made on the full sec-

[4] *1974 Annual Book of ASTM Standards*, Part 1.

tion of pipe. When impracticable to pull a test specimen in full thickness, the standard 2-in. (50.8 mm) gage length tension test specimen shown in Fig. 6 of Methods A 370 may be used.

10.3 Transverse weld test specimens from electric-welded pipe shall be taken with the weld at the center of the specimen. All transverse test specimens shall be approximately $1^1/_2$ in. (38.1 mm) wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

10.4 Test specimens for the bend and flattening tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends taken with welded pipe.

10.5 All specimens shall be tested at room temperature.

11. Number of Tests

11.1 One of each of the tests specified in Sections 6, 7, and 8, except 8.3 shall be made on one length of pipe from each lot of 500 lengths, or fraction thereof, of each size. A length is defined as the length as ordered, except that in the case of orders for cut lengths shorter than single random, the term lot shall apply to the lengths as rolled, prior to cutting to the required short lengths.

11.2 The number of flattening tests for electric-resistance welded pipe shall be in accordance with 8.3.1.

11.3 Each length of pipe shall be subjected to the hydrostatic test specified in Section 9.

12. Retests

12.1 If the results of the mechanical tests of any lot do not conform to the requirements specified in Sections 6, 7 and 8, retests may be made on additional pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

12.2 If any section of the pipe fails to comply with the requirements of 8.3 for pipe produced in single lengths, other sections may be cut from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80 percent of its length after the original cropping; otherwise the length shall be rejected. For pipe produced in multiple lengths, retests may be cut from each end of each individual length in the multiple. Such tests shall be made with the weld alternately 0 deg and 90 deg from the line of direction of force.

13. Dimensions and Weights

13.1 The dimensions and weights of plain-end pipe included in this specification are listed in Table A 2. Dimensions and weights of threaded-and-coupled pipe are listed in Table A 3.

13.2 The dimensions and weights furnished under this specification are included in the American Nat onal Standard for Steel and Wrought-Iron Pipe (ANSI B36.10).

14. Permissible Variations in Weight and Dimensions

14.1 *Weight*—The weight of the pipe as specified in Tables A2 and A3 shall not vary by more than the following amounts:

Extra-strong and lighter wall thickness,	±5 percent
Heavier than extra-strong wall thickness,	±10 percent

NOTE 5—The weight tolerance of ±5 percent or ±10 percent, as the case may be, is determined from the weights of the customary lifts of pipe as produced for shipment by the mill, divided by the number of feet of pipe in the lift. On pipe sizes over 4 in. where individual lengths may be weighed, the weight tolerance is applicable to the individual length.

14.2 *Diameter*—For pipe $1^1/_2$ in. and under in nominal diameter, the outside diameter at any point shall not vary more than $^1/_{64}$ in. (0.397 mm) over nor more than $^1/_{32}$ in. (0.794 mm) under the standard specified. For pipe 2 in. and over in nominal diameter, the outside diameter shall not vary more than ±1 percent from the standard specified.

14.3 *Thickness*—The minimum wall thickness at any point shall be not more than 12.5 percent under the nominal wall thickness specified. The minimum wall thickness on inspection shall conform to the requirements in Table A4.

15. Lengths

15.1 Unless otherwise specified, pipe lengths shall be in accordance with the following regular practice:

15.1.1 Pipe of weights lighter than extra-strong shall be in single-random lengths of 16 to 22 ft (4.88 to 6.71 m), but not more than 5 percent of the total number of threaded

lengths may be jointers, which are two pieces coupled together. When ordered with plain ends, 5 percent may be in lengths of 12 to 16 ft (3.66 to 4.88 m).

15.1.2 Pipe of extra-strong and heavier weights shall be in random lengths of 12 to 22 ft. Five percent may be in lengths of 6 to 12 ft (1.83 to 3.66 m).

15.1.3 When extra-strong or lighter pipe is ordered in double-random lengths, the minimum lengths shall be not less than 22 ft, with a minimum average for the order of 35 ft (10.67 m).

15.1.4 When lengths longer than single random are required for wall thicknesses heavier than extra-strong, the length shall be subject to negotiation.

16. End Finish

16.1 *Plain End*—Pipe sizes and weights shown in Table A2 ordered with plain end shall be furnished to the following regular practices, unless otherwise specified:

16.1.1 Pipe of standard or extra-strong weights, or in wall thicknesses less than 0.500 in., (12.7 mm) other than double-extra-strong pipe, shall be plain end beveled.

16.1.2 Pipe with wall thicknesses over 0.500 in., and all double-extra-strong pipe, shall be plain end cut square.

16.2 *Threaded End*—The sizes and weights shown in Table A3 may be ordered with threads and couplings, and when so ordered, the ends shall be provided with threads in accordance with the gaging practice and tolerances of the American National Standard for Pipe Threads (ANSI B2.1). For standard-weight pipe in sizes 6 in. and smaller, refer to Table A5 for basic threading data, and Fig. A1 for an illustration of the joint. For standard-weight pipe in sizes 8 in. and larger and for all sizes of extra-strong-weight and double-extra-strong-weight pipe, refer to Table A6 for basic threading data and Fig. A2 for an illustration of the joint.

16.3 *Couplings*—Each length of threaded pipe shall be provided with one coupling, unless otherwise specified. The coupling threads shall be in accordance with the gaging practice of the American National Standard for Pipe Threads (ANSI B2.1). The coupling shall be applied handling-tight, unless power-tight is specified on the order. Couplings may be wrought-iron or steel. Taper-tapped couplings shall be furnished on all weights of threaded pipe $2^1/_2$ in. and larger. For sizes 2 in. and smaller, it is regular practice to furnish straight-tapped couplings for standard-weight pipe and taper-tapped couplings for extra-strong and double-extra-strong pipe, and standard-weight pipe 8 in. and larger. If taper-tapped couplings are required for sizes 2 in. and under on standard-weight pipe, line pipe in accordance with Specification 5L of the American Petroleum Institute should be ordered. The taper-tapped couplings provided on line pipe in these sizes may be used on mill-threaded standard-weight pipe of the same size.

17. Galvanized Pipe

17.1 Galvanized pipe ordered under this specification shall be coated with zinc inside and outside by the hot-dip process. The zinc used for the coating shall be any grade of zinc conforming to ASTM Specification B 6, for Zinc Metal (Slab Zinc).[5]

17.2 *Weight of Coating*—The weight of zinc coating shall be not less than 1.8 oz/ft^2 (0.55 kg/m^2) as determined from the average results of the two specimens taken for test in the manner prescribed in 17.5 and not less than 1.6 oz/ft^2 (0.49 kg/m^2) for either of these specimens. The weight of coating expressed in ounces per square foot shall be calculated by dividing the total weight of zinc, inside plus outside, by the total area, inside plus outside of the surface coated.

17.3 *Weight of Coating Test*—The weight of zinc coating shall be determined by a stripping test in accordance with ASTM Methods A 90, Test for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles.[6] The total zinc on each specimen shall be determined in a single stripping operation.

17.4 *Test Specimens*—Test specimens for determination of weight of coating shall be cut approximately 4 in. (101.6 mm) in length.

17.5 *Number of Tests*—Two test specimens for the determination of weight of coating shall be taken, one from each end of

[5] *1973 Annual Book of ASTM Standards*, Part 7.
[6] *1974 Annual Book of ASTM Standards*, Part 3.

one length of galvanized pipe selected at random from each lot of 500 lengths or fraction thereof, of each size.

17.6 *Retests*—If the weight of coating of any lot does not conform to the requirements specified in 17.2, retests of two additional pipes from the same lot shall be made, each of which shall conform to the requirements specified.

17.7 When pipe ordered under this specification is to be galvanized, the tension, flattening, and bend tests shall be made on the base material before galvanizing. When specified, results of the mechanical tests on the base material shall be reported to the purchaser. If impracticable to make the mechanical tests on the base material before galvanizing, such tests may be made on galvanized samples, and any flaking or cracking of the zinc coating shall not be considered cause for rejection. When galvanized pipe is bent or otherwise fabricated to a degree which causes the zinc coating to stretch or compress beyond the limit of elasticity, some flaking of the coating may occur.

18. Finish

18.1 The finished pipe shall be reasonably straight and free from injurious defects. All burrs at the ends of the pipe shall be removed.

19. Marking

19.1 Each length of pipe shall be legibly marked by rolling, stamping or stenciling to show: the name or brand of the manufacturer; the kind of pipe, that is, furnace-butt-welded, electric-resistance-welded A, electric-resistance-welded B, seamless A, or seamless B; the use of electric-furnace, or basic oxygen, XS for extra strong, XXS for double extra strong; ASTM A 53; and the length. Length shall be marked in feet and tenths of a foot, unless otherwise specified on the purchase order.

19.2 For pipe sizes $1^1/_2$ in. and smaller which is bundled, this information may be marked on a tag securely attached to each bundle.

20. Packaging, Marking, and Loading

20.1 When specified on the purchase order, packaging, marking, and loading or shipment shall be in accordance with those procedures recommended by the United States Department of Commerce in its *Simplified Practice Recommendation R 247-62* (Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment).[7]

21. Inspection

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

22. Rejection

22.1 Each length of pipe 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 pipe shall be a matter of agreement between the manufacturer and the purchaser.

22.2 Pipe 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 pipe 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.

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[7] *Simplified Practice Recommendation R 247-62* may be obtained from the National Bureau of Standards, Office of Engineering Standards Service, Washington, D.C. 20234.

TABLE 1 Chemical Requirements

	Composition, max, percent			
	Carbon	Manganese	Phosphorus	Sulfur
Type S (seamless pipe)				
Open-hearth, electric-furnace or basic-oxygen:				
Grade A	0.25	0.95	0.05	0.06
Grade B	0.30	1.20	0.05	0.06
Type E (electric-resistance-welded)				
Open-hearth, electric-furnace or basic-oxygen:				
Grade A	0.25	0.95	0.05	0.06
Grade B	0.30	1.20	0.05	0.06
Type F (furnace-welded pipe)				
Open-hearth, electric-furnace, or basic oxygen	...	...	0.08	0.06

TABLE 3 Flattening Requirements

Kind of Pipe	Distance Between Plates, "*H*"
Butt-welded	60 percent of outside diameter
Electric-resistance-welded, Grades A and B	one-third of outside diameter
Seamless, Grades A and B	to the distance *H*

TABLE 2 Tensile Requirements

	Type F	Types E and S	
	Open-Hearth, Basic Oxygen, or Electric-Furnace	Grade A	Grade B
Tensile strength, min, psi (kgf/mm²)	45 000 (31.6)	48 000 (33.7)	60 000 (42.2)
Yield strength, min, psi (kgf/mm²)	25 000 (17.6) [a,b]	30 000 (21.1) [a,b]	35 000 (24.6) [a,b]
Elongation in 2 in.			

[a] The minimum elongation in 2 in. (50.8 mm) shall be that determined by the following equation:

$$e = 625{,}000\ A^{0.2}/U^{0.9}$$

where:

e = minimum elongation in 2 in. (50.8 mm) in percent rounded to the nearest 0.5 percent.

A = cross-sectional area of the tension test specimen in square inches, based on specified outside diameter or nominal specimen width and specified wall thickness rounded to the nearest 0.01 in.². If the area thus calculated is greater than 0.75 in.², then the value 0.75 shall be used.

U = specified tensile strength, psi.

[b] See Table A 7 for minimum elongation values for various size tension specimens and grades.

APPENDIXES

A1. Definitions of Types of Pipe

A1.1 *Type F, Furnace-Butt-Welded Pipe, Continuous-Welded*—Pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.

A1.2 *Type E, Electric-Resistance-Welded Pipe*—Pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure.

A1.3 *Type S, Wrought Steel Seamless Pipe*—Wrought steel seamless pipe is a tubular product made without a welded seam. It is manufactured by hot working steel and, if necessary, by subsequently cold finishing the hot-worked tubular product to produce the desired shape, dimensions, and properties.

A2. Tables for Dimensional and Certain Mechanical Requirements

TABLE A1 Calculated *H* Values for Seamless Pipe

Size: Nominal, in.	Outside Diameter, in.[a]	Wall Thickness, in.[a]	Distance, in Inches,[a] Between Plates "*H*" by Formula: $H = (1 + e)T/e + t/D$	
			Grade A	Grade B
2½	2.875	0.203	1.378	1.545
		0.276	1.618	1.779
3	3.500	0.216	1.552	1.755
		0.300	1..861	2.062
3½	4.000	0.226	1.862	1.912
		0.318	2.045	2.276
4	4.500	0.237	1.811	2.067
		0.337	2.228	2.489
5	5.563	0.258	2.062	2.372
		0.375	2.597	2.920
6	6.625	0.280	2.308	2.669
		0.432	3.034	3.419
8	8.625	0.277	2.473	2.902
		0.322	2.757	3.210
		0.500	3.683	4.181
10	10.750	0.279[b]	2.623	3.111
		0.307	2.823	3.333
		0.365	3.210	3.757
		0.500	3.993	4.592
12	12.750	0.330	3.105	3.683
		0.375	3.423	4.037
		0.500	4.218	4.899
14	14.000	0.375	3.500	4.146
		0.500	4.336	5.061
16	16.000	0.375	3.603	4.294
		0.500	4.494	5.284
18	18.000	0.375	3.688	4.417
		0.500	4.628	5.472
20	20.000	0.375	3.758	4.521
		0.500	4.740	5.632
24	24.000	0.375	3.869	4.686
		0.500	4.918	5.890

[a] 1 in. = 25.4 mm.
[b] Special order only.

TABLE A2 Dimensions, Weights, and Test Pressures for Plain End Pipe

Nominal Size, in.	Outside Diameter in.[a]	Wall Thickness, in.[a]	Nominal Weight per ft, Plain End, lb[b]	Weight Class	Schedule No.	Test Pressure[c, d] psi		
						Butt-Welded	Grade A	Grade B
1/8	0.405	0.068	0.24	STD	40	700	700	700
		0.095	0.31	XS	80	850	850	850
1/4	0.540	0.088	0.42	STD	40	700	700	700
		0.119	0.54	XS	80	850	850	850
3/8	0.675	0.091	0.57	STD	40	700	700	700
		0.126	0.74	XS	80	850	850	850
1/2	0.840	0.109	0.85	STD	40	700	700	700
		0.147	1.09	XS	80	850	850	850
		0.188	1.31	...	160	900	900	900
		0.294	1.71	XXS	...	1000	1000	1000
3/4	1.050	0.113	1.13	STD	40	700	700	700
		0.154	1.47	XS	80	850	850	850
		0.219	1.94	...	160	950	950	950
		0.308	2.44	XXS	...	1000	1000	1000
1	1.315	0.133	1.68	STD	40	700	700	700
		0.179	2.17	XS	80	850	850	850
		0.250	2.84	...	160	950	950	950
		0.358	3.66	XXS	...	1000	1000	1000
1 1/4	1.660	0.140	2.27	STD	40	1000	1200	1300
		0.191	3.00	XS	80	1300	1800	1900
		0.250	3.76	...	160	1350	1900	2000
		0.382	5.21	XXS	...	1400	2200	2300
1 1/2	1.900	0.145	2.72	STD	40	1000	1200	1300
		0.200	3.63	XS	80	1300	1800	1900
		0.281	4.86	...	160	1350	1950	2050
		0.400	6.41	XXS	...	1400	2200	2300
2	2.375	0.154	3.65	STD	40	1000	2300	2500
		0.218	5.02	XS	80	1300	2500	2500
		0.344	7.46	...	160	1400	2500	2500
		0.436	9.03	XXS	...	1400	2500	2500
2 1/2	2.875	0.203	5.79	STD	40	1000	2500	2500
		0.276	7.66	XS	80	1300	2500	2500
		0.375	10.01	...	160	1400	2500	2500
		0.552	13.70	XXS	...	1400	2500	2500
3	3.500	0.125	4.51	...	...	800	1290	1500
		0.156	5.57	...	...	1000	1600	1870
		0.188	6.65	...	...	1000	1930	2260
		0.216	7.58	STD	40	1000	2220	2500
		0.250	8.68	...	...	1300	2500	2500
		0.281	9.66	...	...	1300	2500	2500
		0.300	10.25	XS	80	1300	2500	2500
		0.438	14.32	...	160	...	2500	2500
		0.600	18.58	XXS	...	...	2500	2500
3 1/2	4.000	0.125	5.17	...	...	800	1120	1310
		0.156	6.40	...	...	1000	1400	1640
		0.188	7.65	...	...	1200	1690	1970
		0.226	9.11	STD	40	1200	2030	2370
		0.250	10.01	...	...	1300	2250	2500
		0.281	11.16	...	...	1500	2500	2500
		0.318	12.51	XS	80	1700	2800	2800
4	4.500	0.125	5.84	...	...	800	1000	1170
		0.156	7.24	...	...	1000	1250	1460
		0.188	8.66	...	...	1200	1500	1750
		0.219	10.01	...	...	1200	1750	2040
		0.237	10.79	STD	40	1200	1900	2210
		0.250	11.35	...	...	1300	2000	2330
		0.281	12.66	...	...	1400	2250	2620
		0.312	13.98	...	...	1600	2500	2800

TABLE A2 *Continued*

Nominal Size, in.	Outside Diameter in.[a]	Wall Thickness, in.[a]	Nominal Weight per ft, Plain End, lb[b]	Weight Class	Schedule No.	Test Pressure[c, d], psi		
						Butt-Welded	Grade A	Grade B
		0.337	14.98	XS	80	1700	2700	2800
		0.438	19.00	...	120	...	2800	2800
		0.531	22.51	...	160	...	2800	2800
		0.674	27.54	XXS	...	...	2800	2800
5	5.563	0.156	9.01	...	...	...	1010	1180
		0.188	10.79	...	...	...	1220	1420
		0.219	12.50	...	...	...	1420	1650
		0.258	14.62	STD	40	...	1670	1950
		0.281	15.85	...	...	...	1820	2120
		0.312	17.50	...	...	...	2020	2360
		0.344	19.17	...	...	...	2230	2600
		0.375	20.78	XS	80	...	2430	2800
		0.500	27.04	...	120	...	2800	2800
		0.625	32.96	...	160	...	2800	2800
		0.750	38.55	XXS	...	...	2800	2800
6	6.625	0.188	12.92	...	...	...	1020	1190
		0.219	14.98	...	...	...	1190	1390
		0.250	17.02	...	...	...	1360	1580
		0.280	18.97	STD	40	...	1520	1780
		0.312	21.04	...	...	...	1700	1980
		0.344	23.08	...	...	...	1870	2180
		0.375	25.03	...	...	...	2040	2380
		0.432	28.57	XS	80	...	2350	2740
		0.562	36.39	...	120	...	2800	2800
		0.719	45.35	...	160	...	2800	2800
		0.864	53.16	XXS	...	...	2800	2800
8	8.625	0.188	16.94	...	...	...	780	920
		0.203	18.26	...	...	...	850	1000
		0.219	19.66	...	...	...	910	1070
		0.250	22.36	...	20	...	1040	1220
		0.277	24.70	...	30	...	1160	1350
		0.312	27.70	...	...	...	1300	1520
		0.322	28.55	STD	40	...	1340	1570
		0.344	30.42	...	...	...	1440	1680
		0.375	33.04	...	...	...	1570	1830
		0.406	35.64	...	60	...	1700	2000
		0.438	38.30	...	...	...	1830	2130
		0.500	43.39	XS	80	...	2090	2430
		0.594	50.95	...	100	...	2500	2800
		0.719	60.71	...	120	...	2800	2800
		0.812	67.76	...	140	...	2800	2800
		0.875	72.42	XXS	...	...	2800	2800
		0.906	74.69	...	160	...	2800	2800
10	10.750	0.188	21.21	...	...	...	630	730
		0.203	22.87	...	...	...	680	800
		0.219	24.63	...	...	...	730	860
		0.250	28.04	...	20	...	840	980
		0.279	31.20	...	...	...	930	1090
		0.307	34.24	...	30	...	1030	1200
		0.344	38.23	...	...	...	1150	1340
		0.365	40.48	STD	40	...	1220	1430
		0.438	48.19	...	...	...	1470	1710
		0.500	54.74	XS	60	...	1670	1950
		0.594	64.43	...	80	...	1990	2320
		0.719	77.03	...	100	...	2410	2800
		0.844	89.29	...	120	...	2800	2800
		1.000	104.13	XXS	140	...	2800	2800
		1.125	115.65	...	160	...	2800	2800
12	12.750	0.203	27.20	...	...	...	570	670
		0.219	29.31	...	...	...	620	720
		0.250	33.38	...	20	...	710	820
		0.281	37.42	...	...	...	790	930
		0.312	41.45	...	...	...	880	1030

TABLE A2 *Continued*

Nominal Size, in.	Outside Diameter in.[a]	Wall Thickness, in.[a]	Nominal Weight per ft, Plain End, lb[b]	Weight Class	Schedule No.	Test Pressure[c, d], psi		
						Butt-Welded	Grade A	Grade B
		0.330	43.77	...	30	...	930	1090
		0.344	45.58	...	...	...	970	1130
		0.375	49.56	STD	...	...	1060	1240
		0.406	53.52	...	40	...	1150	1340
		0.438	57.59	...	...	...	1240	1440
		0.500	65.42	XS	...	...	1410	1650
		0.562	73.15	...	60	...	1590	1850
		0.688	88.63	...	80	...	1940	2270
		0.844	107.32	...	100	...	2390	2780
		1.000	125.49	XXS	120	...	2800	2800
		1.125	139.68	...	140	...	2800	2800
		1.312	160.27	...	160	...	2800	2800
14	14.000	0.210	30.93	...	...	...	540	630
		0.219	32.23	...	...	...	560	660
		0.250	36.71	...	10	...	640	750
		0.281	41.17	...	...	...	720	840
		0.312	45.61	...	20	...	800	940
		0.344	50.17	...	...	...	880	1030
		0.375	54.57	STD	30	...	960	1120
		0.438	63.44	...	40	...	1130	1310
		0.469	67.78	...	...	...	1210	1410
		0.500	72.09	XS	...	...	1290	1500
		0.594	85.05	...	60	...	1530	1790
		0.750	106.13	...	80	...	1930	2250
		0.938	130.85	...	100	...	2410	2800
		1.094	150.79	...	120	...	2800	2800
		1.250	170.22	...	140	...	2800	2800
		1.406	189.11	...	160	...	2800	2800
		2.000	256.32	...	...	...	2800	2800
		2.125	269.51	...	...	...	2800	2800
		2.200	277.26	...	...	...	2800	2800
		2.500	307.05	...	...	...	2800	2800
16	16.000	0.219	36.91	...	...	...	490	570
		0.250	42.05	...	10	...	560	660
		0.281	47.17	...	...	...	630	740
		0.312	52.27	...	20	...	700	820
		0.344	57.52	...	...	...	770	900
		0.375	62.58	STD	30	...	840	980
		0.438	72.80	...	...	...	990	1150
		0.469	77.79	...	...	...	1060	1230
		0.500	82.77	XS	40	...	1120	1310
		0.656	107.50	...	60	...	1480	1720
		0.844	136.62	...	80	...	1900	2220
		1.031	164.82	...	100	...	2320	2710
		1.219	192.43	...	120	...	2740	2800
		1.438	223.64	...	140	...	2800	2800
		1.594	245.25	...	160	...	2800	2800
18	18.000	0.250	47.39	...	10	...	500	580
		0.281	53.18	...	...	...	560	660
		0.312	58.94	...	20	...	620	730
		0.344	64.87	...	...	...	690	800
		0.375	70.59	STD	...	...	750	880
		0.406	76.29	...	...	...	810	950
		0.438	82.15	...	30	...	880	1020
		0.469	87.81	...	...	...	940	1090
		0.500	93.45	XS	...	...	1000	1170
		0.562	104.67	...	40	...	1120	1310
		0.750	138.17	...	60	...	1500	1750
		0.938	170.92	...	80	...	1880	2190
		1.156	207.96	...	100	...	2310	2700
		1.375	244.14	...	120	...	2750	2800
		1.562	274.22	...	140	...	2800	2800
		1.781	308.50	...	160	...	2800	2800

TABLE A2 *Continued*

Nominal Size, in.	Outside Diameter in.[a]	Wall Thickness, in.[a]	Nominal Weight per ft, Plain End, lb[b]	Weight Class	Schedule No.	Test Pressure[c, d], psi		
						Butt-Welded	Grade A	Grade B
20	20.000	0.250	52.73	...	10	...	450	520
		0.281	59.18	...	...	...	510	590
		0.312	65.60	...	...	...	560	660
		0.344	72.21	...	...	...	620	720
		0.375	78.60	STD	20	...	680	790
		0.406	84.96	...	...	...	730	850
		0.438	91.51	...	...	...	790	920
		0.469	97.83	...	...	...	850	950
		0.500	104.13	XS	30	...	900	1050
		0.594	123.11	...	40	...	1170	1250
		0.812	166.40	...	60	...	1460	1710
		1.031	208.87	...	80	...	1860	2170
		1.281	256.10	...	100	...	2310	2690
		1.500	296.37	...	120	...	2700	2800
		1.750	341.10	...	140	...	2800	2800
		1.969	379.17	...	160	...	2800	2800
24	24.000	0.250	63.41	...	10	...	380	440
		0.281	71.18	...	...	...	420	490
		0.312	78.93	...	...	...	470	550
		0.344	86.91	...	...	...	520	600
		0.375	94.62	STD	20	...	560	660
		0.406	102.31	...	...	...	610	710
		0.438	110.22	...	...	...	660	770
		0.469	117.86	...	...	...	700	820
		0.500	125.49	XS	...	...	750	880
		0.562	140.68	...	30	...	840	980
		0.688	171.29	...	40	...	1030	1200
		0.938	231.03	...	...	...	1410	1640
		0.969	238.85	...	60	...	1450	1700
		1.219	296.58	...	90	...	1830	2130
		1.531	367.39	...	100	...	2300	2680
		1.812	429.39	...	120	...	2720	2800
		2.062	483.12	...	140	...	2800	2800
		2.344	542.14	...	160	...	2800	2800
26	26.000	0.250	68.75	...	...	...	350	400
		0.281	77.18	...	...	...	390	450
		0.312	85.60	...	10	...	430	500
		0.344	94.26	...	...	...	480	560
		0.375	102.63	STD	...	...	520	610
		0.406	110.98	...	...	...	560	660
		0.438	119.57	...	...	...	610	710
		0.469	127.88	...	...	...	650	760
		0.500	136.17	XS	20	...	690	810
		0.562	152.68	...	...	...	780	910

[a] 1 in. = 25.4 mm.
[b] 1 lb/ft = 1.49 kg/m.
[c] 1 psi = 6.8948 kPa.
[d] For wall thicknesses of pipe not listed in Table A2, the following procedure shall be followed to determine the required test pressure:

(*1*) When the wall thickness for a given diameter is between the lightest and heaviest wall thickness listed:

(*a*) If the wall thickness is between two wall thicknesses on which the test pressures are identical, use that test pressure as the required test pressure.

(*b*) If the test pressure is different for the next lighter and heavier walls listed, interpolate to obtain the required test pressure, using the ratio of the nominal weight per foot ($W = 10.68\ (D - t)t$) of the desired thickness to the nominal weight per foot of the next heavier thickness (to the nearest 50 lb).

(*2*) When the wall thickness is greater than the heaviest wall thickness shown for a given diameter, the test pressure for the heaviest wall listed shall be the required test pressure.

(*3*) When the wall thickness is lighter than the lightest shown for a given diameter:

(*a*) For *Grades A and B in sizes 2 in. and larger*, determine the test pressure from the following equation:

$$P = 2St/D$$

where:
P = minimum hydrostatic test pressure, psi,
S = 0.60 times the minimum specified yield point, psi,
t = specified wall thickness, in., and
D = specified outside diameter, in.

(*b*) For *Grades A and B in sizes under 2 in. and for all sizes butt welded pipe*, use the test pressure given for the lightest wall thickness of the table for the diameter involved.

TABLE A3 Dimensions, Weights, and Test Pressures for Threaded and Coupled Pipe

Nominal Size, in.	Outside Diameter, in.[a]	Wall Thickness, in.[a]	Nominal Weight per ft, Threads and Couplings, lb[b]	Weight Class	Schedule No.	Test Pressure, psi[c]		
						Butt-Welded	Grade A	Grade B
1/8	0.405	0.068	0.24	STD	40	700	700	700
		0.095	0.32	XS	80	850	850	850
1/4	0.540	0.088	0.42	STD	40	700	700	700
		0.119	0.54	XS	80	850	850	850
3/8	0.675	0.091	0.57	STD	40	700	700	700
		0.126	0.74	XS	80	850	850	850
1/2	0.840	0.109	0.85	STD	40	700	700	700
		0.147	1.09	XS	80	850	850	850
		0.294	1.72	XXS	...	1000	1000	1000
3/4	1.050	0.113	1.13	STD	40	700	700	700
		0.154	1.48	XS	80	850	850	850
		0.308	2.44	XXS	...	1000	1000	1000
1	1.315	0.133	1.68	STD	40	700	700	700
		0.179	2.18	XS	80	850	850	850
		0.358	3.66	XXS	...	1000	1000	1000
1 1/4	1.660	0.140	2.28	STD	40	1000	1000	1100
		0.191	3.02	XS	80	1300	1500	1600
		0.382	5.22	XXS	...	1400	1800	1900
1 1/2	1.900	0.145	2.73	STD	40	1000	1000	1100
		0.200	3.66	XS	80	1300	1500	1600
		0.400	6.41	XXS	...	1400	1800	1900
2	2.375	0.154	3.68	STD	40	1000	2300	2500
		0.218	5.07	XS	80	1300	2500	2500
		0.436	9.03	XXS	...	1400	2500	2500
2 1/2	2.875	0.203	5.82	STD	40	1000	2500	2500
		0.276	7.73	XS	80	1300	2500	2500
		0.552	13.70	XXS	...	1400	2500	2500
3	3.500	0.216	7.62	STD	40	1000	2200	2500
		0.300	10.33	XS	80	1300	2500	2500
		0.600	18.57	XXS	...	...	2500	2500
3 1/2	4.000	0.226	9.20	STD	40	1200	2000	2400
		0.318	12.63	XS	80	1700	2800	2800
4	4.500	0.237	10.89	STD	40	1200	1900	2200
		0.337	15.17	XS	80	1700	2700	2800
		0.674	27.58	XXS	...	...	2800	2800
5	5.563	0.258	14.81	STD	40	...	1700	1900
		0.375	21.09	XS	80	...	2400	2800
		0.750	38.61	XXS	...	...	2800	2800
6	6.625	0.280	19.18	STD	40	...	1500	1800
		0.432	28.89	XS	80	...	2300	2700
		0.864	53.14	XXS	...	...	2800	2800
8	8.625	0.277	25.55	...	30	...	1200	1300
		0.322	29.35	STD	40	...	1300	1600
		0.500	43.90	XS	80	...	2100	2400
		0.875	72.44	XXS	...	...	2800	2800
10	10.750	0.279	32.75	...	...	...	950	1100
		0.307	35.75	...	30	...	1000	1200
		0.365	41.85	STD	40	...	1200	1400
		0.500	55.82	XS	60	...	1700	2000
12	12.750	0.330	45.45	...	30	...	950	1100
		0.375	51.15	STD	...	...	1100	1200
		0.500	66.71	XS	...	...	1400	1600

[a] 1 in. = 25.4 mm.
[b] 1 lb/ft = 1.49 kg/m.
[c] 1 psi = 6.8948 kPa.

TABLE A4 Table of Minimum Wall Thicknesses on Inspection for Nominal (Average) Pipe Wall Thicknesses

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in., and
t_m = minimum wall thickness, in.

The wall thickness is expressed to three decimal places the fourth decimal place being carried forward or dropped in accordance with ASTM Recommended Practice E 29, for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values.[8]

NOTE 2—This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Nominal (Average) Thickness (t_n), in.[a]	Minimum Thickness on Inspection (t_m), in.[a]	Nominal (Average) Thickness (t_n), in.[a]	Minimum Thickness on Inspection (t_m), in.[a]	Nominal (Average) Thickness (t_n), in.[a]	Minimum Thickness on Inspection (t_m), in.[a]
0.068	0.060	0.294	0.257	0.750	0.656
0.088	0.077	0.300	0.262	0.812	0.710
0.091	0.080	0.307	0.269	0.844	0.739
0.095	0.083	0.308	0.270	0.864	0.756
0.109	0.095	0.312	0.273	0.875	0.766
0.113	0.099	0.318	0.278	0.906	0.793
0.119	0.104	0.322	0.282	0.938	0.821
0.125	0.109	0.330	0.289	0.968	0.847
0.126	0.110	0.337	0.295	1.000	0.875
0.133	0.116	0.343	0.300	1.031	0.902
0.140	0.122	0.344	0.301	1.062	0.929
0.145	0.127	0.358	0.313	1.094	0.957
0.147	0.129	0.365	0.319	1.125	0.984
0.154	0.135	0.375	0.328	1.156	1.012
0.156	0.136	0.382	0.334	1.219	1.067
0.179	0.157	0.400	0.350	1.250	1.094
0.187	0.164	0.406	0.355	1.281	1.121
0.188	0.164	0.432	0.378	1.312	1.148
0.191	0.167	0.436	0.382	1.343	1.175
0.200	0.175	0.437	0.382	1.375	1.203
0.203	0.178	0.438	0.383	1.406	1.230
0.216	0.189	0.500	0.438	1.438	1.258
0.218	0.191	0.531	0.465	1.500	1.312
0.219	0.192	0.552	0.483	1.531	1.340
0.226	0.198	0.562	0.492	1.562	1.367
0.237	0.207	0.594	0.520	1.594	1.395
0.250	0.219	0.600	0.525	1.750	1.531
0.258	0.226	0.625	0.547	1.781	1.558
0.276	0.242	0.656	0.574	1.812	1.586
0.277	0.242	0.674	0.590	1.968	1.722
0.279	0.244	0.688	0.602	2.062	1.804
0.280	0.245	0.719	0.629	2.344	2.051
0.281	0.246				

[a] 1 in. = 25.4 mm.

[3] *1973 Annual Book of ASTM Standards*, Part 30.

A3. Basic Threading Data

TABLE A5 Basic Threading Data for Standard-Weight Pipe Sizes 6 in. and Under

NOTE 1—All dimensions in this table are nominal and subject to mill tolerances.
NOTE 2—The taper of threads is 3/4 in./ft (62.5 mm/m) on the diameter.

Pipe		Threads					Coupling		
Nominal Size, in.	Outside Diameter, in.	Number per Inch	End of Pipe to Hand Tight Plane, in.[a]	Effective Length, in.[a]	Total Length, in.[a]	Pitch Diameter at Hand Tight Plane, in.[a]	Outside Diameter, in.[a]	Length, in.[a]	Hand Tight Stand-Off (Number of Threads)
	D		L_1	L_2	L_4	E_1	W	N_L	A
1/8	0.405	27	0.1615	0.2638	0.3924	0.37360	0.563	1 3/16	4
1/4	0.540	18	0.2278	0.4018	0.5946	0.49163	0.719	1 3/16	5 1/2
3/8	0.675	18	0.240	0.4078	0.6006	0.62701	0.875	1 3/16	5
1/2	0.840	14	0.320	0.5337	0.7815	0.77843	1.063	1 9/16	5
3/4	1.050	14	0.339	0.5457	0.7935	0.98887	1.313	1 5/8	5
1	1.315	11 1/2	0.400	0.6828	0.9845	1.23863	1.576	2	5
1 1/4	1.660	11 1/2	0.420	0.7068	1.0085	1.58338	1.900	2 1/16	5
1 1/2	1.900	11 1/2	0.420	0.7235	1.0252	1.82234	2.200	2 1/16	5 1/2
2	2.375	11 1/2	0.436	0.7565	1.0582	2.29627	2.750	2 1/8	5 1/2
2 1/2	2.875	8	0.682	1.1375	1.5712	2.76216	3.250	3 1/8	5 1/2
3	3.500	8	0.766	1.2000	1.6337	3.38850	4.000	3 1/4	5 1/2
3 1/2	4.000	8	0.821	1.2500	1.6837	3.88881	4.625	3 3/8	5 1/2
4	4.500	8	0.844	1.3000	1.7337	4.38713	5.000	3 1/2	5
5	5.563	8	0.937	1.4063	1.8400	5.44929	6.296	3 3/4	5
6	6.625	8	0.958	1.5125	1.9462	6.50597	7.390	4	6

[a] 1 in. = 25.4 mm.

TABLE A6 Basic Threading Data for Standard-Weight Pipe in Sizes 8 in. and Larger, and all Sizes of Extra-Strong and Double-Extra-Strong Weight

NOTE—The taper of threads is 3/4 in./ft (62.5 mm/m) on the diameter.

Pipe		Threads					Coupling		
Nominal Size, in.	Outside Diameter, in.	Number per Inch	End of Pipe to Hand Tight Plane, in.[a]	Effective Length, in.[a]	Total Length, in.[a]	Pitch Diameter at Hand Tight Plane, in.[a]	Outside Diameter, in.[a]	Length, in.[a]	Hand Tight Stand-Off (Number of Threads)
			L_1	L_2	L_4	E_1	W	N_L	
1/8	0.405	27	0.1615	0.2638	0.3924	0.37360	0.563	1 1/16	3
1/4	0.540	18	0.2278	0.4018	0.5946	0.49163	0.719	1 5/8	3
3/8	0.675	18	0.240	0.4078	0.6006	0.62701	0.875	1 5/8	3
1/2	0.840	14	0.320	0.5337	0.7815	0.77843	1.063	2 1/8	3
3/4	1.050	14	0.339	0.5457	0.7935	0.98887	1.313	2 1/8	3
	1.315	11 1/2	0.400	0.6828	0.9845	1.23863	1.576	2 5/8	3
1 1/4	1.660	11 1/2	0.420	0.7068	1.0085	1.58338	2.054	2 3/4	3
1 1/2	1.900	11 1/2	0.420	0.7235	1.0252	1.82234	2.200	2 3/4	3
2	2.375	11 1/2	0.436	0.7565	1.0582	2.29627	2.875	2 7/8	3
2 1/2	2.875	8	0.682	1.1375	1.5712	2.76216	3.375	4 1/8	2
3	3.500	8	0.766	1.2000	1.6337	3.38850	4.000	4 1/4	2
3 1/2	4.000	8	0.821	1.2500	1.6837	3.88881	4.625	4 3/8	2
4	4.500	8	0.844	1.3000	1.7337	4.38713	5.200	4 1/2	2
5	5.563	8	0.937	1.4063	1.8400	5.44929	6.296	4 5/8	2
6	6.625	8	0.958	1.5125	1.9462	6.50597	7.390	4 7/8	2
8	8.625	8	1.063	1.7125	2.1462	8.50003	9.625	5 1/4	2
10	10.750	8	1.210	1.9250	2.3587	10.62094	11.750	5 3/4	2
12	12.750	8	1.360	2.1250	2.5587	12.61781	14.000	6 1/8	2
14[b]	14.000	8	1.562	2.2500	2.6837	13.87263	15.000	6 3/8	2
16[b]	16.000	8	1.812	2.4500	2.8837	15.87575	17.000	6 3/4	2
18[b]	18.000	8	2.000	2.6500	3.0837	17.87500	19.000	7 1/8	2
20[c]	20.000	8	2.125	2.8500	3.2837	19.87031	21.000	7 5/8	2

[a] 1 in. = 25.4 mm.
[b] Nominal size is outside diameter.

TABLE A7 Elongation Values

A4.1 Tabulated in Table A7 are the minimum elongation values calculated by the equation given in Table 2.

Tension Test Specimen				Elongation in 2 in. min, percent			
Area, A, in.^{2a}	Specified Wall Thickness, in.[b]			Specified Tensile Strength, psi			
	3/4-in. Specimen	1-in. Specimen	1 1/2-in. Specimen	45 000	48 000	50 000	60 000
0.75 and greater	0.994 and greater	0.746 and greater	0.497 and greater	38.5	36.0	35.0	29.5
0.74	0.980–0.993	0.735–0.745	0.490–0.496	38.0	36.0	34.5	29.5
0.73	0.967–0.979	0.726–0.734	0.484–0.489	38.0	36.0	34.5	29.5
0.72	0.954–0.966	0.715–0.725	0.477–0.483	38.0	36.0	34.5	29.5
0.71	0.941–0.953	0.706–0.714	0.471–0.476	38.0	35.5	34.5	29.0
0.70	0.927–0.940	0.695–0.705	0.464–0.470	38.0	35.5	34.5	29.0
0.69	0.914–0.926	0.686–0.694	0.457–0.463	37.5	35.5	34.0	29.0
0.68	0.900–0.913	0.675–0.685	0.450–0.456	37.5	35.5	34.0	29.0
0.67	0.887–0.899	0.666–0.674	0.444–0.449	37.5	35.5	34.0	29.0
0.66	0.874–0.886	0.655–0.665	0.437–0.443	37.5	35.0	34.0	29.0
0.65	0.861–0.873	0.646–0.654	0.431–0.436	37.0	35.0	34.0	28.5
0.64	0.847–0.860	0.635–0.645	0.424–0.430	37.0	35.0	33.5	28.5
0.63	0.834–0.846	0.626–0.634	0.417–0.423	37.0	35.0	33.5	28.5
0.62	0.820–0.833	0.615–0.625	0.410–0.416	37.0	35.0	33.5	28.5
0.61	0.807–0.819	0.606–0.614	0.404–0.409	36.5	34.5	33.5	28.5
0.60	0.794–0.806	0.595–0.605	0.397–0.403	36.5	34.5	33.5	28.5

[a] 1 in.^{2} = 645.16 mm^2.
[b] 1 in. = 25.4 mm.

TABLE A7—*Continued*

Tension Test Specimen				Elongation in 2 in. min, percent			
Area, A, in.^{2}	Specified Wall Thickness, in.			Specified Tensile Strength, psi			
	$^3/_4$-in. Specimen	1-in. Specimen	$1^1/_2$-in. Specimen	45 000	48 000	50 000	60 000
0.59	0.781–0.793	0.586–0.594	0.391–0.396	36.5	34.5	33.0	28.0
0.58	0.767–0.780	0.575–0.585	0.384–0.390	36.5	34.5	33.0	28.0
0.57	0.754–0.766	0.566–0.574	0.377–0.383	36.0	34.0	33.0	28.0
0.56	0.740–0.753	0.555–0.565	0.370–0.376	36.0	34.0	33.0	28.0
0.55	0.727–0.739	0.546–0.554	0.364–0.369	36.0	34.0	32.5	28.0
0.54	0.714–0.726	0.535–0.545	0.357–0.363	36.0	34.0	32.5	27.5
0.53	0.701–0.713	0.526–0.534	0.351–0.356	35.5	33.5	32.5	27.5
0.52	0.687–0.700	0.515–0.525	0.344–0.350	35.5	33.5	32.5	27.5
0.51	0.674–0.686	0.506–0.514	0.337–0.343	35.5	33.5	32.0	27.5
0.50	0.660–0.673	0.495–0.505	0.330–0.336	35.5	33.5	32.0	27.0
0.49	0.647–0.659	0.486–0.494	0.324–0.329	35.0	33.0	32.0	27.0
0.48	0.634–0.646	0.475–0.485	0.317–0.323	35.0	33.0	32.0	27.0
0.47	0.621–0.633	0.466–0.474	0.311–0.316	35.0	33.0	31.5	27.0
0.46	0.607–0.620	0.455–0.465	0.304–0.310	34.5	33.0	31.5	27.0
0.45	0.594–0.606	0.446–0.454	0.297–0.303	34.5	32.5	31.5	26.5
0.44	0.580–0.593	0.435–0.445	0.290–0.296	34.5	32.5	31.5	26.5
0.43	0.567–0.579	0.426–0.434	0.284–0.289	34.5	32.5	31.0	26.5
0.42	0.554–0.566	0.415–0.425	0.277–0.283	34.0	32.0	31.0	26.5
0.41	0.541–0.553	0.406–0.414	0.271–0.276	34.0	32.0	31.0	26.0
0.40	0.527–0.540	0.395–0.405	0.264–0.270	34.0	32.0	30.5	26.0
0.39	0.514–0.526	0.386–0.394	0.257–0.263	33.5	31.5	30.5	26.0
0.38	0.500–0.513	0.375–0.385	0.250–0.256	33.5	31.5	30.5	26.0
0.37	0.487–0.499	0.366–0.374	0.244–0.249	33.0	31.5	30.0	25.5
0.36	0.474–0.486	0.355–0.365	0.237–0.243	33.0	31.0	30.0	25.5
0.35	0.461–0.473	0.346–0.354	0.231–0.236	33.0	31.0	30.0	25.5
0.34	0.447–0.460	0.335–0.345	0.224–0.230	32.5	31.0	29.5	25.0
0.33	0.434–0.446	0.326–0.334	0.217–0.223	32.5	30.5	29.5	25.0
0.32	0.420–0.433	0.315–0.325	0.210–0.216	32.5	30.5	29.5	25.0
0.31	0.407–0.419	0.306–0.314	0.204–0.209	32.0	30.5	29.0	25.0
0.30	0.394–0.406	0.295–0.305	0.197–0.203	32.0	30.0	29.0	24.5
0.29	0.381–0.393	0.286–0.294	0.191–0.196	31.5	30.0	29.0	24.5
0.28	0.367–0.380	0.275–0.285	0.184–0.190	31.5	29.5	28.5	24.5
0.27	0.354–0.366	0.266–0.274	0.177–0.183	31.0	29.5	28.5	24.0
0.26	0.340–0.353	0.255–0.265	0.170–0.176	31.0	29.0	28.0	24.0
0.25	0.327–0.339	0.246–0.254	0.164–0.169	30.5	29.0	28.0	23.5
0.24	0.314–0.326	0.235–0.245	0.157–0.163	30.5	29.0	27.5	23.5
0.23	0.301–0.313	0.226–0.234	0.151–0.156	30.0	28.5	27.5	23.5
0.22	0.287–0.300	0.215–0.225	0.144–0.150	30.0	28.5	27.0	23.0
0.21	0.274–0.286	0.206–0.214	0.137–0.143	29.5	28.0	27.0	23.0
0.20	0.260–0.273	0.195–0.205	0.130–0.136	29.5	27.5	26.5	22.5
0.19	0.247–0.259	0.186–0.194	0.124–0.129	29.0	27.5	26.5	22.5
0.18	0.234–0.246	0.175–0.185	0.117–0.123	29.0	27.0	26.0	22.0
0.17	0.221–0.233	0.166–0.174	0.111–0.116	28.5	27.0	26.0	22.0
0.16	0.207–0.220	0.155–0.165	0.104–0.110	28.0	26.5	25.5	21.5
0.15	0.194–0.206	0.146–0.154	0.097–0.103	27.5	26.0	25.0	21.5
0.14	0.180–0.193	0.135–0.145	0.091–0.096	27.5	26.0	25.0	21.0
0.13	0.167–0.179	0.126–0.134	0.084–0.090	27.0	25.5	24.5	21.0
0.12	0.154–0.166	0.115–0.125	0.077–0.083	26.5	25.0	24.0	20.5
0.11	0.141–0.153	0.106–0.114	0.071–0.076	26.0	24.5	23.5	20.0
0.10	0.127–0.140	0.095–0.105	0.064–0.070	25.5	24.0	23.5	19.5
0.09	0.114–0.126	0.086–0.094	0.057–0.063	25.0	23.5	23.0	19.5
0.08	0.100–0.113	0.075–0.085	0.050–0.056	24.5	23.0	22.5	19.0
0.07	0.087–0.099	0.066–0.074	0.044–0.049	24.0	22.5	21.5	18.5
0.06	0.074–0.086	0.055–0.065	0.037–0.043	23.0	22.0	21.0	18.0
0.05	0.061–0.073	0.046–0.054	0.031–0.036	22.5	21.0	20.5	17.0
0.04	0.047–0.060	0.035–0.045	0.024–0.030	21.5	20.0	19.5	16.5
0.03	0.034–0.046	0.026–0.034	0.017–0.023	20.0	19.0	18.5	15.5
0.02	0.020–0.033	0.015–0.025	0.010–0.016	18.5	17.5	17.0	14.5
0.01 and less	0.019 and less	0.014 and less	0.009 and less	16.0	15.0	14.5	12.5

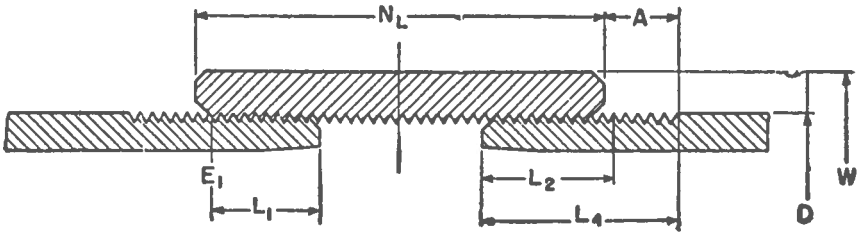

FIG. A1 Dimensions of Hand Tight Assembly for Use with Table A5.

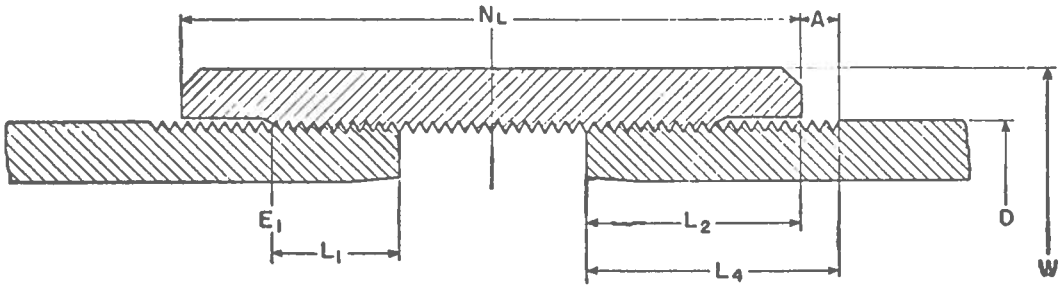

FIG. A2 Dimensions of Hand Tight Assembly for Use with Table A6.

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Designation: A 108 – 73

AMERICAN SOCIETY FOR TESTING AND MATERIALS

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Standard Specification for STEEL BARS, CARBON, COLD FINISHED, STANDARD QUALITY[1]

This Standard is issued under the fixed designation A 108; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

This specification has been approved by the Department of Defense for listing in the DoD Index of Specifications and Standards. Proposed revisions should be coordinated with the Federal Government through the Army Materials and Mechanics Research Center, Watertown, Mass. 02172.

1. Scope

1.1 This specification covers standard quality cold-finished carbon steel bars produced to chemical compositions. Standard quality cold-finished bars are suitable for heat treatment, for machining into components, or for use in the as-finished condition as shafting, or in constructional applications, or for other similar purposes (Note 1). Grades of steel are identified by grade numbers or by chemical composition.

NOTE 1—A guide for the selection of steel bars is contained in Recommended Practice A 400, for Selection of Steel Bar Compositions.[2]

1.2 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 29.

1.3 Some end uses may require material superior to standard quality involving one or more of the available designations shown under Supplementary Requirements. Supplementary requirements shall apply only when specified individually by the purchaser.

2. Applicable Documents

2.1 *ASTM Standards:*

A 29 Specification for General Requirements for Hot-Rolled and Cold-Finished Carbon and Alloy Steel Bars[2]

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

A 510 Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel[2]

A 576 Specification for Special Quality Hot-Rolled Carbon Steel Bars[2]

E 45 Recommended Practice for Determining the Inclusion Content of Steel[4]

E 112 Estimating the Average Grain Size of Metals[4]

2.2 *Other Documents:*

SAE Handbook[5]

Federal Standard 66 C Steel, Chemical Composition and Hardenability[6]

AISI Steel Product Manual for Cold Finished Bars[7]

3. Definitions

3.1 *standard quality*—cold-finished carbon steel bars produced from special quality hot-rolled carbon steel bars or rods of equivalent quality.

3.1.1 Bars of standard quality are commonly produced in standard chemical grade compositions or to mechanical property specifications and are subject to product analysis tolerances.

3.1.2 The available sections and sizes are covered by Specification A 29. The bars are

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.15 on Bar Steels.

Current edition approved July 27, 1973. Published October 1973. Originally published as A 108 – 26 T. Last previous edition A 108 – 69.

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

[3] *Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, 31.

[4] *Annual Book of ASTM Standards*, Part 31.

[5] Available from Society of Automotive Engineers, 2 Pennsylvania Plaza, New York, N.Y. 10001.

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

[7] Available from the American Iron and Steel Institute, 150 East 42nd St., New York, N.Y. 10017.

normally produced in cut lengths but some small sizes are supplied in coils. The producer should be consulted regarding sections and sizes available in coils.

4. Basis of Purchase

4.1 Orders for cold-finished bars to this specification shall include the following items to adequately describe the material:

4.1.1 Name of material,

4.1.2 ASTM specification number and date of issue,

4.1.3 Chemical composition grade designation or limits,

4.1.4 Silicon, if required,

4.1.5 Condition,

4.1.6 Quantity,

4.1.7 Shape (round, hex, square, etc.), size, and length,

4.1.8 Report of heat analysis, if required,

4.1.9 End use,

4.1.10 Additions to the specification and special or supplementary requirements, if required, and

4.1.11 For coiled product, the coil weights, ID and OD limitations, when required.

NOTE 2—A typical ordering description is as follows: Steel Bar, ASTM A 108; SAE 1117; Coarse Grain; Cold Drawn; 6000 lb of 1.500 in. diameter by 10.0 to 12.0 ft long; Heat Analysis Required; Screw Machine Parts.

5. Materials and Manufacture

5.1 *Melting Practice*—The steel shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

5.2 *Deoxidation:*

5.2.1 Unless otherwise specified, the steel may be rimmed, capped, semi-killed, or killed at the manufacturer's option.

5.2.2 When required, the deoxidation practice, including killed steel, may be specified.

5.3 *Discard*—Sufficient discard shall be made to ensure freedom from pipe and undue segregation.

5.4 *Redraw Stock*—The bars shall be produced from special quality hot-rolled carbon steel bars (Specification A 576) or from hot-rolled rods designated for cold finished bars (Specification A 510).

5.5 *Condition*—The bars shall be furnished in one of the following conditions as specified by the purchaser:

5.5.1 *Rounds:*

5.5.1.1 Cold drawn,

5.5.1.2 Cold drawn, turned, and polished,

5.5.1.3 Cold drawn, ground, and polished,

5.5.1.4 Hot rolled, turned, and polished, or

5.5.1.5 Hot rolled, turned, ground, and polished.

5.5.2 *Squares, Hexagons*—Cold drawn.

5.5.3 *Flats:*

5.5.3.1 Cold drawn or

5.5.3.2 Cold rolled.

5.6 *Heat Treatment:*

5.6.1 Unless otherwise specified, the bars shall be furnished as cold finished except that when the maximum of the carbon range is over 0.55 % they shall be annealed for cold finishing.

5.6.2 When property characteristics are required that are not available for the specified grade as developed in the as-rolled cold-finished condition, the following thermal treatments can be ordered:

5.6.2.1 Annealed and cold finished,

5.6.2.2 Normalized and cold finished,

5.6.2.3 Cold drawn and stress relieved, or

5.6.2.4 Carbon restoration anneal to overcome surface decarburization on cold-drawn bars. (For round bars produced by turning, surface decarburization is removed during the manufacturing process.)

6. Chemical Requirements

6.1 *Chemical Composition:*

6.1.1 The steel shall conform to the chemical composition limits specified in Table 1 for the grade specified by the purchaser.

6.1.2 Carbon steels not listed in Table 1 can be specified. Steels may be selected from Specifications A 576 and A 510; Federal Standard 66 C; the SAE Handbook; or the AISI Steel Products Manual for Carbon Steel Bars.

6.1.3 When a steel cannot be identified by a standard grade number in accordance with 6.1.1 and 6.1.2, the limits for each required element may be specified using the chemical ranges shown in Table 3 of Specification A 29.

6.2 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified. The analysis shall be made from a test sample preferably taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or his

representative when required by the purchase order, and shall conform to the specified requirements.

6.3 *Product Analysis*—A product analysis may be made by the purchaser. The chemical composition thus determined, as to elements required or restricted, shall conform to the ordered chemical composition subject to the permissible variations on product analysis of Table 5 in Specification A 29.

7. Workmanship, Finish, and Appearance

7.1 *Workmanship*—The bars shall be free of pipe, cracks, and flakes. Within the limits of good manufacturing and inspection practices, the bars shall be free of injurious seams, laps, segregation, or other imperfections which, due to their nature, degree, or extent, will interfere with the use of the material in machining or fabrication of suitable parts.

7.2 *Finish:*

7.2.1 Unless otherwise specified, the bars shall have a commercial bright smooth surface finish obtained by conventional cold-finishing operations such as cold drawing, cold rolling, or turning and polishing.

7.2.2 When required, bars may be specified to be ground and polished, turned and polished, or turned, ground, and polished.

7.2.3 Bars that are thermal treated after cold finishing may have a discolored or oxidized surface.

7.3 *Oiling*—The bars shall be given a surface coating of oil or other rust inhibitor to protect against rust during shipment.

8. Certification

8.1 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 test results shall be furnished at the time of shipment.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Cold-Heading and Cold-Forging Quality

S1.1 Bars for cold-heading and cold-forging applications are subject to severe cold plastic deformation by upsetting, heading, or forging. Such processing requires sound steel and freedom from harmful surface imperfections.

S1.2 If the type of steel or chemical composition does not have adequate cold-heading or cold-forging characteristics in the cold-finished condition, appropriate thermal treatment should be specified.

S1.3 When Supplementary Requirement S1 is specified, the bars shall be produced by manufacturing practices and subjected to mill tests and inspection procedures to assure internal soundness, uniformity of chemical composition, and freedom from injurious surface defects to the extent that the bars shall be suitable for the manufacture of identified parts.

S2. Cold Extrusion Quality

S2.1 Cold-finished bars of this quality are used in the production of solid or hollow shapes

by means of severe cold plastic deformation involving forward or backward extrusion, or both, with or without expansion.

S2.2 The quality requirements of individual applications vary.

S2.3 When ultimate plasticity is required for the desired grade and cold-finished condition, annealing or spheroidize annealing should be specified.

S2.4 When Supplementary Requirement S2 is specified, the bars shall be produced by manufacturing practices and subjected to mill tests and inspection procedures to assure internal soundness, uniformity of chemical composition, and freedom from injurious surface defects to the extent that the bars shall be suitable for the manufacture of identified parts.

S3. Special Surface Quality

S3.1 Special surface steels are produced with exacting control and appropriate inspection and surface preparation to minimize the frequency and degree of seams and other surface imperfections.

S4. Special Internal Soundness Requirement

S4.1 Special internal soundness is relative freedom from segregation and porosity, as evaluated by means of a macroetch test which is performed on representative billet or bar samples. The test consists of deep etching a cross section in a hot acid solution and examination to evaluate soundness. An alternative method consists of fracturing a billet section and examination of the fracture to evaluate soundness.

S5. Nonmetallic Inclusion Requirements

S5.1 The nonmetallic inclusion requirement comprises a metallographic examination of longitudinal sections to determine the nature and frequency of the nonmetallic inclusions. Experience indicates that samples taken midway between the center and surface of the bloom, billet, slab, or bar are most representative of the average inclusion content of the lot involved. The test specimen is generally heated and quenched to harden it before being polished to avoid polishing pits. The specimen is examined at 100 diameters. Methods for determining the nonmetallic inclusion content of steel are described in Recommended Practice E 45.

S5.2 For resulfurized steels, much of the sulfur is present as sulfide inclusions. For this reason, those steels are not generally produced to inclusion rating.

S6. Special Heat-Treating Requirements

S6.1 *Special heat treating* (*hardenability*) is a term used when the purchaser specifies as a requirement the ability of a steel to heat treat to specified mechanical property values that the purchaser must meet after his heat treatment. Care should be taken so that the desired mechanical property values are compatible with the chemical composition, size, and cross section of the steel.

S6.2 Hardenability band limits have been established for 1038H, 1045H, and 1041H and are published in the SAE handbook.

S7. Grain Size

S7.1 When required, austenitic grain size may be specified in killed steels as either coarse (grain size 1 to 5, inclusive) or fine (grain size 5 to 8, inclusive); to be determined in accordance with Method E 112. The grain structure shall be considered satisfactory if 70 % is within the specified limits.

S7.2 Certain elements, or combinations of elements, such as manganese, sulfur, and lead tend to produce grain refinement and it is technically inappropriate to assure coarse grain size as measured by the McQuaid-Ehn test on high manganese, high sulfur, and leaded steels such as 1144, 1151 and 11L41.

S8. Restricted Incidental Elements

S8.1 The purchaser may specify maximum requirements for copper, nickel, chromium, molybdenum, or other elements.

S9. Thermal Treatment

S9.1 When required, the purchaser may specify that the material be stress relieved, annealed to specified structure, annealed to no specified structure, or normalized.

S10. Mechanical Properties

S10.1 When required, cold-finished bars can be supplied to mechanical properties. Mechanical properties shall be determined in accordance with Methods and Definitions A 370.

TABLE 1 Composition of Cold-Finished Carbon Steel Bars

NOTE—Grade designations and compositions correspond to the respective AISI designations and compositions.

Grade Designation	Carbon, %	Manganese, %	Phosphorus, %	Sulfur, %
Open-Hearth, Basic-Oxygen, and Electric-Furnace Grades[a, b]				
1008	0.10 max	0.30–0.50	0.040 max	0.050 max
1010	0.08–0.13	0.30–0.60	0.040 max	0.050 max
1015	0.13–0.18	0.30–0.60	0.040 max	0.050 max
1016	0.13–0.18	0.60–0.90	0.040 max	0.050 max
1018	0.15–0.20	0.60–0.90	0.040 max	0.050 max
1020	0.18–0.23	0.30–0.60	0.040 max	0.050 max
1022	0.18–0.23	0.70–1.00	0.040 max	0.050 max
1025	0.22–0.28	0.30–0.60	0.040 max	0.050 max
1030	0.28–0.34	0.60–0.90	0.040 max	0.050 max
1035	0.32–0.38	0.60–0.90	0.040 max	0.050 max
1040	0.37–0.44	0.60–0.90	0.040 max	0.050 max
1045	0.43–0.50	0.60–0.90	0.040 max	0.050 max
1050	0.48–0.55	0.60–0.90	0.040 max	0.050 max
1095	0.90–1.03	0.30–0.50	0.040 max	0.050 max
1117	0.14–0.20	1.00–1.30	0.040 max	0.08–0.13
1118	0.14–0.20	1.30–1.60	0.040 max	0.08–0.13
1137	0.32–0.39	1.35–1.65	0.040 max	0.08–0.13
1141	0.37–0.45	1.35–1.65	0.040 max	0.08–0.13
1144	0.40–0.48	1.35–1.65	0.040 max	0.24–0.33
1151	0.48–0.55	0.70–1.00	0.040 max	0.08–0.13
1211	0.13 max	0.60–0.90	0.07–0.12	0.10–0.15
1212	0.13 max	0.70–1.00	0.07–0.12	0.16–0.23
1213	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33
12L14[d]	0.15 max	0.85–1.15	0.04–0.09	0.26–0.35
1215	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35

[a] When silicon is required, the following ranges and limits are commonly specified: 0.10% max, 0.10%–0.20%, 0.15%–0.30%, or 0.20%–0.40%.

[b] When required, lead is specified as an added element to a standard steel. A range from 0.15 to 0.35%, inclusive, is commonly specified. Such a steel is identified by inserting the letter "L" between the second and third numeral of the grade number, for example, 11L17. Heat analysis for lead is not determinable since lead is added to the ladle stream while each ingot is poured.

[c] Grades 1211, 1212, 1213, 12L14 and 1215 are not supplied with a specified silicon content.

[d] Lead content shall be 0.15–0.35%.

Designation: A 242 – 74

American National Standard G41.2
American National Standards Institute

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Specification for HIGH-STRENGTH LOW-ALLOY STRUCTURAL STEEL[1]

This Standard is issued under the fixed designation A 242; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

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

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

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

2. General Requirements for Delivery

2.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of ASTM Specification A 6, General Requirements for 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 or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4. Chemical Requirements

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

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

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

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

5. Tensile Requirements

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

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

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys, and is the direct responsibility of Subcommittee A01.02 on Structural Steel.

Current edition approved July 29, 1974. Published September 1974. Originally published as A 242 – 41 T. Last previous edition A 242 – 70a.

[2] *1974 Annual Book of ASTM Standards*, Part 4.

the specified thickness or diameter below 5/16 in.

6. Bend Test Requirements

6.1 The bend test specimens 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 as Table 3.

TABLE 1 Chemical Requirements (Heat Analysis)

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

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

TABLE 2 Tensile Requirements

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

[a] See 5.2
[b] For wide flange shapes over 426 lb/ft elongation in 2 in. or 50 mm of 18% minimum applies.
[c] Elongation not required to be determined for floor plate.

TABLE 3 Bend Test Requirements

Thickness of Material, in. (mm)	Ratio of Bend Diameter to Thickness of Specimen
To 3/4 (19.1), incl	1
Over 3/4 to 1 (19.1 to 25.4), incl	1 1/2
Over 1 to 1 1/2 (25.4 to 38.1), incl	2
Over 1 1/2 to 2 (38.1 to 50.8), incl	2 1/2
Over 2 to 4 (50.8 to 101.6), incl	3

Designation: A 252 – 74

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Standard Specification for
WELDED AND SEAMLESS STEEL PIPE PILES[1]

This Standard is issued under the fixed designation A 252; 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 approval.

1. Scope

1.1 This specification covers nominal (average) wall steel pipe piles of cylindrical shape and applies to pipe piles in which the steel cylinder acts as a permanent load-carrying member, or as a shell to form cast-in-place concrete piles.

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 (steel pipe piles),

2.1.3 Method of manufacture (seamless or welded),

2.1.4 Grade (Table 1),

2.1.5 Size (outside diameter and nominal wall size),

2.1.6 Length (Section 14),

2.1.7 End finish (Section 15), and

2.1.8 ASTM designation.

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 pipe piles may be made by any of the following processes: seamless, electric resistance welded, flash welded, fusion welded. For welded pipe piles, the seams may be straight, spiral-butt or spiral-lap construction and shall be welded in such a manner that the full driving column and containment properties designed into the pile are assured.

5. Chemical Requirements

5.1 The steel shall conform to the following requirements as to chemical composition:

	Phosphorus, Max, percent
Seamless and welded pipe:	
Open-hearth, electric-furnace, or basic oxygen	0.050

6. Heat Analysis

6.1 An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified. When requested by the purchaser, the chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified.

7. Product Analysis

7.1 Samples for chemical analysis, except for spectrographic analysis, shall be taken in accordance with ASTM Method E 59, Sampling Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron for Determination of Chemical Composition.[2]

7.2 An analysis may be made by the purchaser on samples from lots of pipe piles as follows:

Pipe Size Outside Diameter, in.	Number of Samples and Size of Lot
Under 14	2 from 200 pipe or fraction thereof
14 to 36, incl	2 from 100 pipe or fraction thereof
Over 36	2 from 3000 ft or fraction thereof

The chemical composition thus determined shall conform to the requirements specified in Section 5.

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys, and is the direct responsibility of Subcommittee A01.09 on Pipe.

Current edition approved July 29, 1974. Published September 1974. Originally published as A 252 – 44 T. Last previous edition A 252 – 73.

[2] *1974 Annual Book of ASTM Standards*, Part 12.

7.3 If the analysis of either pipe does not conform to the requirements specified in Section 5, analysis shall be made on additional pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1.

8.2 The yield point shall be determined by the drop of the beam, by the halt in the gage of the testing machine, by the use of dividers, or by other approved methods. When a definite yield point is not exhibited, the yield strength corresponding to a permanent offset of 0.2 percent of the gage length of the specimen, or to a total extension of 0.5 percent of the gage length under load shall be determined.

9. Test Specimens and Methods of Test

9.1 The specimens and the mechanical tests required shall be in accordance with ASTM Methods and Definitions A 370, Mechanical Testing of Steel Products,[3] especially Supplement II thereof.

9.2 Specimens for the tension test may be cut either longitudinally or transversely at the option of the manufacturer. Longitudinal specimens shall not be flattened between gage marks. Unless otherwise specified, the tension test specimen may be taken from the skelp. The width of the specimens within the gage length shall be 1½ in. At the option of the manufacturer, the specimens shall have either the 2 or 8-in. gage lengths indicated in Table 1. The sides of the specimens shall be parallel between gage marks.

9.3 For welded pipe piles the tension test specimens shall be taken as follows:

9.3.1 For straight-seam pipe piles, the longitudinal specimen shall be taken 90 deg from the weld and the transverse specimen opposite the weld.

9.3.2 For spiral-seam pipe piles, the longitudinal specimen shall be parallel to the axis of the pipe and at such a location that the center of the specimen is located at least one quarter of the sheet or plate width between weld convolutions. The transverse specimen shall be 90 deg to the axis of the pipe with the center of the specimen located approximately half the distance between adjacent weld convolutions.

9.4 Specimens shall be tested at room temperature.

10. Number of Tests

10.1 One tension test shall be made on one length of pile from each lot of 200 lengths or fraction thereof of each size.

10.2 If the percentage of elongation of any tension test specimen is less than that prescribed in Table 1, and any part of the fracture is more than ¾ in. from the center of the gage length of a 2-in. specimen, or is outside of the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

10.3 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

11. Retests

11.1 If the results of the mechanical tests of any lot do not conform to the requirements prescribed in Table 1, retests shall be made on additional lengths of double the original number from the same lot, each of which shall conform to the requirements specified.

12. Standard Weights

12.1 The standard weights with the corresponding wall thicknesses for steel pipe piles of various outside diameters are prescribed in Table 2.

12.2 The calculated weight per foot, based upon a specified average wall thickness, for sizes not listed in Table 2 shall be determined as follows:

$$W = 10.68(D - t)t$$

where:

W = weight, lb/ft,
D = specified outside diameter, in., and
t = specified average wall thickness, in.

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

13. Permissible Variations in Weights and Dimensions

13.1 *Weight*—The weight of any length of pile shall not vary more than 15 percent over or 5 percent under that prescribed in Table 2. Each length shall be weighed separately.

13.2 *Diameter*—The outside diameter of steel pipe piles shall not vary more than ±1 percent from the diameter specified.

13.3 *Thickness*—The minimum wall thickness at any point shall not be more than 12.5 percent under the nominal wall thickness specified.

NOTE—The minimum wall thickness on inspection is shown in Table A1 (Appendix).

14. Lengths

14.1 Pipe piles shall be ordered either in single or double random lengths, or in uniform lengths, and shall be furnished in accordance with the following practice:

Single random lengths	16 to 25 ft, incl
Double random lengths	over 25 ft with a minimum average of 35 ft
Uniform lengths	length as specified with a tolerance of ±1 in.

14.2 Lengths that have been spliced at the mill by welding shall be acceptable as the equivalent of unspliced lengths provided tension test specimens cut from sample splices conform to the tensile strength requirements prescribed in Table 1. The welding bead shall not be removed for this test. Such specimens shall be made in accordance with the provisions specified in Sections 9, 10, and 11.

15. Ends

15.1 Unless otherwise specified, material shall be furnished with either flame or machine cut plain ends. When ends are specified to be beveled, they shall be beveled to an angle of 30 +5, −0 deg. All burrs at the ends shall be removed.

16. Finish

16.1 The finished pipe piles shall be reasonably straight and shall not contain imperfections in such number or of such character as to render the pipe unsuitable for pipe piles.

16.2 Surface defects, the depth of which does not exceed 25 percent of the nominal wall thickness, shall be permitted. These may be explored by grinding or filing to establish the depth.

16.3 Surface defects, the depth of which exceeds 25 percent of the nominal wall thickness, may be considered as injurious defects. Welding of injurious defects will be permitted when the depth of the defect does not exceed 33⅓ percent of the nominal wall thickness. Before welding, the defect shall be completely removed.

17. Marking

17.1 Each length of pipe pile shall be legibly marked by stenciling, stamping, or rolling to show: the name or brand of the manufacturer; heat number; the kind of pipe, that is seamless, flash welded, fusion welded, electric resistance welded, spiral lap welded or spiral butt welded seams; the size, weight, length, and wall thickness; and ASTM A 252 and the grade.

18. Inspection

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

19. Certification

19.1 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.

20. Rejection

20.1 Each length of pipe 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 re-

jected pipe shall be a matter of agreement between the manufacturer and the purchaser.

20.2 Pipe 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 pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

TABLE 1 Tensile Requirements

	Grade 1	Grade 2	Grade 3
Tensile strength, min, psi	50 000	60 000	66 000
Yield point, min, psi	30 000	35 000	45 000
Basic minimum elongation for walls 5/16 in. and over in thickness:			
Elongation in 8 in., min, percent	18	14	...
Elongation in 2 in., min, percent	30	25	20
For walls less than 5/16 in. in thickness a deduction for each 1/32-in. decrease in wall thickness below 5/16 in. from the basic minimum elongation of the following percentage points	1.50[a]	1.25[a]	1.0[a]

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

Wall Thickness, in.	Elongation in 2 in., min, percent		
	Grade 1	Grade 2	Grade 3
5/16 (0.312)	30.00	25.00	20.00
9/32 (0.281)	28.50	23.75	19.00
1/4 (0.250)	27.00	22.50	18.00
7/32 (0.219)	25.50	21.25	17.00
3/16 (0.188)	24.00	20.00	16.00
11/64 (0.172)	23.25	19.50	15.50
5/32 (0.156)	22.50	18.75	15.00
9/64 (0.141)	21.75	18.25	14.50
1/8 (0.125)	21.00	17.50	14.00
7/64 (0.109)	20.25	16.75	13.50

NOTE—The above table gives the calculated minimum elongation values for each 1/32-in. decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined as follows:

Grade	
1	$E = 48t + 15.00$
2	$E = 40t + 12.50$
3	$E = 32t + 10.00$

where:
E = elongation in 2 in., percent, and
t = actual thickness of specimen, in.

TABLE 2 Common Sizes and Weight Per Foot of Welded and Seamless Steel Pipe Piles[a]

Outside Diameter, in.	Nominal Thickness, in.	Weight per Linear Foot (Plain Ends), lb	Outside Diameter, in.	Nominal Thickness, in.	Weight per Linear Foot (Plain Ends), lb
6	0.134	8.40	12	0.134	17.04
	0.141	8.80		0.141	17.81
	0.156	9.74		0.150	18.92
	0.164	10.28		0.164	20.78
	0.172	10.70		0.172	21.71
				0.179	22.60
8	0.141	11.80		0.188	23.72
	0.172	14.36		0.203	25.57
				0.219	27.56
8⅝	0.109	9.95		0.230	28.98
	0.141	12.74		0.250	31.87
	0.172	15.20		0.281	35.17
	0.188	16.90		0.312	38.95
	0.203	18.26			
	0.219	19.64	12¾	0.109	14.77
	0.250	22.36		0.134	18.12
	0.277	24.70		0.141	18.94
	0.312	27.74		0.150	20.12
	0.322	28.55		0.164	22.10
	0.344	30.40		0.172	23.09
	0.375	33.04		0.179	24.07
	0.438	38.26		0.188	25.16
	0.500	43.39		0.203	27.20
				0.219	29.28
10	0.109	11.51		0.230	30.75
	0.120	12.62		0.250	33.38
	0.134	14.17		0.281	37.45
	0.141	14.81		0.312	41.51
	0.150	15.73		0.330	43.77
	0.164	17.27		0.344	45.55
	0.172	18.04		0.375	49.56
	0.179	18.81		0.438	57.53
	0.188	19.65		0.500	65.44
	0.203	21.25			
	0.219	22.85	14	0.134	19.92
	0.230	24.00		0.141	20.82
	0.250	26.03		0.150	22.11
				0.164	24.29
10¾	0.109	12.43		0.172	25.38
	0.120	13.58		0.179	26.47
	0.134	15.25		0.188	27.66
	0.141	15.93		0.203	29.93
	0.150	16.93		0.219	32.20
	0.164	18.59		0.230	33.82
	0.172	19.42		0.250	36.71
	0.179	20.24		0.281	41.21
	0.188	21.15		0.312	45.68
	0.203	22.88		0.344	50.14
	0.219	24.60		0.375	54.57
	0.230	25.84		0.438	63.37
	0.250	28.04		0.469	67.78
	0.279	31.20		0.500	72.00
	0.307	34.24			
	0.344	38.20	16	0.134	22.79
	0.365	40.48		0.141	23.82
	0.438	48.19		0.150	25.31
	0.500	54.74		0.164	27.80

TABLE 2 *Continued*

Outside Diameter, in.	Nominal Thickness, in.	Weight per Linear Foot (Plain Ends), lb	Outside Diameter, in.	Nominal Thickness, in.	Weight per Linear Foot (Plain Ends), lb
16	0.172	29.06	20	0.188	39.67
	0.179	30.30		0.219	46.21
				0.250	52.73
	0.188	31.66		0.281	59.23
	0.203	34.27		0.312	65.71
	0.219	36.87		0.344	72.16
	0.230	38.74		0.375	78.60
	0.250	42.05		0.438	91.41
	0.281	47.22		0.469	97.78
	0.312	52.36		0.500	104.13
	0.344	57.48			
	0.375	62.58	22	0.172	40.07
	0.438	72.72		0.188	43.68
	0.469	77.75		0.219	50.88
	0.500	82.77		0.250	58.07
				0.281	65.24
18	0.141	26.82		0.312	72.38
	0.172	32.73		0.375	86.61
	0.188	35.67		0.438	100.75
	0.219	41.54		0.469	107.79
	0.230	43.65		0.500	114.81
	0.250	47.39			
	0.281	53.22	24	0.172	43.74
	0.312	59.03		0.188	47.68
	0.344	64.82		0.219	55.56
	0.375	70.59		0.250	63.41
	0.438	82.06		0.281	71.25
	0.469	87.77		0.312	79.06
	0.500	93.45		0.375	94.62
				0.438	110.10
20	0.141	29.83		0.469	117.81
	0.172	36.40		0.500	125.49

[a] Sizes and weights smaller or greater than those listed may be furnished by special agreement between the manufacturer and the purchaser.

APPENDIX

TABLE A1 Table of Minimum Wall Thicknesses on Inspection for Nominal (Average) Pipe Wall Thicknesses

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:

t_n = nominal (average) wall thickness, in., and

t_m = minimum wall thickness, in.

The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with ASTM Recommended Practice E 29, Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values.[2]

NOTE 2—This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Nominal (Average) Thickness (t_n), in.	Minimum Thickness on Inspection (t_m), in.	Nominal (Average) Thickness (t_n), in.	Minimum Thickness on Inspection (t_m), in.	Nominal (Average) Thickness (t_n), in.	Minimum Thickness on Inspection (t_m), in.
0.068	0.060	0.276	0.242	0.674	0.590
0.088	0.077	0.277	0.242	0.687	0.601
0.091	0.080	0.279	0.244	0.719	0.629
0.095	0.083	0.280	0.245	0.750	0.656
0.109	0.095	0.281	0.246	0.812	0.710
0.113	0.099	0.294	0.257	0.843	0.738
0.119	0.104	0.300	0.262	0.864	0.756
0.120	0.105	0.307	0.269	0.875	0.766
0.125	0.109	0.308	0.270	0.906	0.793
0.126	0.110	0.312	0.273	0.937	0.820
0.133	0.116	0.318	0.278	0.968	0.847
0.134	0.117	0.322	0.282	1.000	0.875
0.140	0.122	0.330	0.289	1.031	0.902
0.141	0.123	0.337	0.295	1.062	0.929
0.145	0.127	0.343	0.300	1.093	0.956
0.147	0.129	0.344	0.301	1.125	0.984
0.150	0.131	0.358	0.313	1.156	1.012
0.154	0.135	0.365	0.319	1.218	1.066
0.156	0.136	0.375	0.328	1.250	1.094
0.164	0.143	0.382	0.334	1.281	1.121
0.172	0.150	0.400	0.350	1.312	1.148
0.179	0.157	0.406	0.355	1.343	1.175
0.187	0.164	0.432	0.378	1.375	1.203
0.188	0.164	0.436	0.382	1.406	1.230
0.191	0.167	0.437	0.382	1.438	1.258
0.200	0.175	0.438	0.383	1.500	1.312
0.203	0.178	0.469	0.410	1.531	1.340
0.216	0.189	0.500	0.438	1.562	1.367
0.218	0.191	0.531	0.465	1.593	1.394
0.219	0.192	0.552	0.483	1.750	1.531
0.226	0.198	0.562	0.492	1.781	1.558
0.230	0.201	0.593	0.519	1.812	1.586
0.237	0.207	0.600	0.525	1.968	1.722
0.250	0.219	0.625	0.547	2.062	1.804
0.258	0.226	0.656	0.574	2.343	2.050

Designation: A 296–74

American National Standard G81.10
American National Standards Institute

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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If not listed in the current combined Index, will appear in the next edition.

Standard Specification for

CORROSION-RESISTANT IRON-CHROMIUM, IRON-CHROMIUM-NICKEL, AND NICKEL BASE ALLOY CASTINGS FOR GENERAL APPLICATION[1]

This Standard is issued under the fixed designation A 296; 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 approval.

1. Scope

1.1 This specification covers iron-chromium, iron-chromium-nickel, nickel-molybdenum, nickel, and nickel-copper alloy castings for corrosion-resistant service. The grades covered by this specification represent types of alloy castings suitable for broad ranges of application which are intended for a wide variety of corrosion-resistant applications.

NOTE 1—For general heat-resistant alloy castings, reference should be made to ASTM Specification A 297, for Heat-Resistant Iron-Chromium and Iron-Chromium-Nickel Alloy Castings for General Application.[2]

NOTE 2—The intergranular corrosion test is not required unless it is specified in the purchase order. If so specified, the test shall be performed by the manufacturer in accordance with the appropriate ASTM recommended practice for the particular grade involved, as listed in ASTM Recommended Practices A 262, for Detecting Susceptibility to Intergranular Attack in Stainless Steels,[3] or as agreed upon with the purchaser. Intergranular corrosion tests on stabilized or 0.03 percent carbon maximum grades (CF-3, CF-3M and CF-8C) shall be made on sensitized specimens. On all other grades of chromium-nickel steels, intergranular corrosion tests shall be made on specimens representative of the as-shipped condition. In cutting a sample of the material to convenient testing size, bear in mind that the specimen should represent as nearly as practical the surface of the material as it will be used in service. Only such surface finishing should be performed as is necessary to remove foreign material and obtain a uniform standard finish as called for in the appropriate Recommended Practice A 262.

NOTE 3—The values stated in U.S. customary units are to be regarded as the standard.

2. Basis of Purchase

2.1 Purchase orders under this specification shall specify grade of alloy desired, including standards of acceptance where necessary. Where weldability of Grade M-35 is desired this shall be stipulated on the purchase order and the casting shall be marked M-35W.

3. Process

3.1 Alloys shall be made by the following processes: electric arc, electric induction, or other approved processes.

4. Heat Treatment

4.1 All corrosion-resistant castings shall be heat treated according to the requirements shown in Table 1, unless otherwise agreed upon by the manufacturer and the purchaser.

5. Chemical Requirements

5.1 Alloys shall conform to the requirements as to chemical composition prescribed in Table 2.

6. Ladle Analysis

6.1 An analysis of each melt shall be made by the manufacturer to determine the percentages of the elements specified in Table 2. The analysis shall be made from drillings taken

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

Current edition approved June 28, 1974. Published August 1974. Originally published as A 296 – 46 T. Last previous edition A 296 – 72.

[2] *1974 Annual Book of ASTM Standards*, Part 2.

[3] *1974 Annual Book of ASTM Standards*, Part 3.

not less than ¼ in. (6.4 mm) beneath the surface of the test ingot made during the pouring of the heat. Chemical composition shall conform to the requirements prescribed in Table 2 and when specified in the inquiry, contract, or order shall be reported to the purchaser or his representative.

7. Check Analysis

7.1 An analysis may be made by the purchaser from a broken tension test specimen or from a casting representing each melt. Drillings for analysis shall be taken not less than ¼ in. (6.4 mm) beneath the surface, and in such manner as not to impair the usefulness of any casting selected. The chemical composition thus determined shall conform to the requirements specified in Table 2.

8. Tensile Properties

8.1 Tension tests shall be required only when specified in the inquiry, contract, or order. When so specified, the properties obtained shall be reported to the purchaser or his representative and shall conform to the requirements prescribed in Table 3.

8.2 Tension tests shall be performed in accordance with ASTM Methods and Definitions A 370, for Mechanical Testing of Steel Products.[4]

9. Hardness Tests

9.1 Unless otherwise specified in the inquiry, contract, or order, Grades CA-15, CA-15M, CB-30, and CC-50 shall have a Brinell hardness of 241 maximum.

NOTE 4—Hardness tests are not considered a satisfactory index of quality for the other grades.

9.2 Hardness tests may be made on the ends of tension specimens or when so stated in the inquiry, contract, or order, on the castings, preferably on a rectangular boss of approximately ¾ by 1½ in. (19.0 by 25.4 mm), so located on the castings as to permit proper mounting in the Brinell machine. The location where the hardness reading is to be taken shall be properly prepared to eliminate the effect of surface variables.

9.3 The frequency of such Brinell hardness inspection on the castings shall be established by agreement between the manufacturer and the purchaser and shall be indicated in the inquiry, contract, or order.

10. Test Specimens

10.1 Test coupons, if required, from which tension test specimens are prepared, shall be attached to the castings where practicable. If in the opinion of the manufacturer the design of the casting is such that test coupons should not be attached thereon, test coupons shall be cast attached to separately cast blocks. The test coupons from which test specimens are to be prepared shall remain attached to the castings or blocks they represent until submitted for inspection, and shall be heat treated with the castings. Test coupons shall be provided in sufficient number to furnish specimens required in Section 11.

10.2 Tension test specimens shall be machined by the manufacturer and shall conform to the form and dimensions of the standard round 2-in. or 50-mm, gage length specimen shown in Fig. 5 of Methods A 370.

11. Number of Tests

11.1 One tension test, if required, shall be made from each melt in each lot (Note 5).

11.2 If any test specimen shows defective machining or develops flaws, it may be discarded, and another specimen substituted from the same lot (Note 5).

11.3 If the percentage of elongation of any tension test specimen is less than that specified in Table 3 and any part of the fracture is more than ¾ in. (19.0 mm) from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

NOTE 5—The term "lot" shall be considered as all castings in a melt subjected to the same heat-treating procedure.

12. Retests

12.1 If the results of the physical tests for any lot do not conform to the requirements specified, the manufacturer may reheat treat such lot. Retests of an additional specimen from the same lot shall be made and shall conform to the requirements specified in Sections 7 to 10.

13. Nondestructive Inspection

13.1 If specified in the inquiry, contract, or

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

order and when mutually agreed upon by the manufacturer and the purchaser, castings made to these specifications may be subject to radiographic or other methods of nondestructive inspection.

13.2 Magnetic particle inspection may be used for the ferritic grades, CA-6NM, CA-15, CA-15M. CA-40, CB-30, CC-50.

13.3 Methods of procedure and number of pieces and areas to be inspected shall be agreed upon by the manufacturer and the purchaser.

NOTE 6—Reference can be made to ASTM Reference Radiographs E 446, for Steel Castings Up to 2 In. in Thickness,[5] for X-ray and gamma ray inspection.

14. Workmanship

14.1 All castings shall be made in a workmanlike manner and shall conform substantially to the dimensions on drawings furnished by the purchaser before manufacture is started, or if the pattern is supplied by the purchaser to the dimensions predicated by the pattern.

15. Quality

15.1 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 MSS SP-55[6] 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 temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 4.

15.2 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.

16. Repair by Welding

16.1 Make repairs by using a welding procedure and operators capable of producing sound welds of similar composition as the casting. The composition of the deposited weld metal shall approximate that of the casting itself, unless otherwise agreed upon by the manufacturer and the purchaser. Heat treat the austenitic grades in accordance with Table 1 after all repairs. Heat treat Grades CB-30 and CC-50 in accordance with Table 1 after welding of major defects, but heat treatment is not required after welding of minor defects except by agreement between the manufacturer and the purchaser.

16.2 Retemper castings of Grades CA-6NM, CA-15, CA-15M, and CA-40 after completion of weld repairing as provided in Section 3, except that local tempering will be permitted if, in the opinion of the manufacturer furnace heat treating will be damaging to the finished surface of a machined casting. Heat treatment of Grades CA-6NM, CA-15, CA-15M, and CA-40 after weld repair, other than tempering, is required only when agreed upon between manufacturer and the purchaser.

16.3 *Permissible Repairs:*

16.3.1 Weld repairs shall be considered major in the case of a casting which had leaked on hydrostatic test or when the depth of the cavity after preparation for repair exceeds 20 percent of the actual wall thickness, or 1 in. (25.4 mm), whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} (64.5 cm^2). When specified on the purchase order or inquiry, such weld repairs shall be subject to the prior approval of the purchaser. When mutually agreed upon by the purchaser and the manufacturer, major weld repairs may be examined at the manufacturer's expense by magnetic particle inspection for Grades CA-6NM, CA-15, CA-15M, CA-40, CB-30 and CC-50, by fluid penetrant or by radiography or a combination to check the adequacy of the repair.

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[5] *1973 Annual Book of ASTM Standards*, Part 31.

[6] Available from the Manufacturers Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Drive, Arlington, Va. 22209.

16.3.2 All other weld repairs shall be considered minor and may be made at the discretion of the manufacturer without prior approval of the purchaser. Minor weld repairs shall be subjected to the same inspection standard as the casting.

17. Marking

17.1 When specified by the purchaser, the manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings, except those of such small size as to make such marking impractical. For the prevention of small defects caused by dislodged particles of molding sand, there should be provided the minimum feasible number of cast identification marks. The marking of melt numbers on individual castings shall be subject to agreement by the manufacturer and the purchaser and so stated in the inquiry, contract, or order.

18. Inspection

18.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. 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.

18.2 If in the case of important castings for special purposes surface inspection in the green state is required, this shall be so specified in the inquiry, contract, or order.

19. Rejection

19.1 Unless otherwise specified, any rejection based on tests made in accordance with these specifications shall be reported to the manufacturer within 5 working days from the receipt of samples by the purchaser.

19.2 Material that shows injurious defects following original inspection and acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

20. Rehearing

20.1 Tested samples representing rejected material shall be held for 2 weeks from the date 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.

TABLE 1 Heat Treatment Requirements

Grade	Heat Treatment
CF-8, CG-8M, CG-12, CF-20, CF-8M, CF-8C, CF-16F, CF-16Fa	Heat to 1900 F (1038 C), min, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means so as to develop acceptable corrosion resistance.
CH-20, CE-30, CK-20	Heat to 2000 F (1093 C), min, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means so as to develop acceptable corrosion resistance.
CA-15, CA-15M, CA-40	(*1*) Heat to 1750 F (954 C), min, air cool and temper at 1100 F (593 C), min, or (*2*) Anneal at 1450 F (788 C), min.
CB-30, CC-50	(*1*) Heat to 1450 F (788 C), min, and air cool, or (*2*) Heat to 1450 F (788 C), min, and furnace cool.
CF-3, CF-3M	(*1*) Heat to 1900 F (1038 C), min, hold for sufficient time to heat casting to temperature, and cool rapidly so as to develop acceptable corrosion resistance, or (*2*) As cast if corrosion resistance is acceptable.
CN-7M, CN-7MS	Heat to 2050 F (1121 C), min, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means so as to develop acceptable corrosion resistance.
CY-40, M-35, CZ-100	As cast.
CW-12M, N-12M	As agreed upon by the manufacturer and the purchaser so as to develop acceptable corrosion resistance.
CA-6NM	Heat to 1750 F (954 C), min, air cool and temper at 1100 F (593 C), min.

TABLE 2 Chemical Requirements

Grade	Type	Composition, percent														
		Carbon, max	Manganese, max	Silicon, max	Phosphorus,[c] max	Sulfur,[c] max	Chromium	Nickel	Molybdenum	Columbium	Selenium	Copper	Tungsten, max	Vanadium, max	Cobalt, max	Iron, max
CF-8	19 Chromium, 9 Nickel	0.08	1.50	2.00	0.04	0.04	18.0–21.0	8.0–11.0	...	...	...	...	...	...	...	...
CG-12	22 Chromium, 12 Nickel	0.12	1.50	2.00	0.04	0.04	20.0–23.0	10.0–13.0	...	...	...	...	...	...	...	...
CF-20	19 Chromium, 9 Nickel	0.20	1.50	2.00	0.04	0.04	18.0–21.0	8.0–11.0	...	...	...	...	...	...	...	...
CF-8M	19 Chromium, 10 Nickel, with Molybdenum	0.08	1.50	2.00	0.04	0.04	18.0–21.0	9.0–12.0	2.0–3.0	...	...	...	...	...	...	...
CF-8C	19 Chromium, 10 Nickel, with Columbium	0.08	1.50	2.00	0.04	0.04	18.0–21.0	9.0–12.0	...	[d]	...	...	...	...	...	...
CF-16F[a]	19 Chromium, 9 Nickel, Free Machining	0.16	1.50	2.00	0.04[a]	0.04[a]	18.0–21.0	9.0–12.0	[a]	...	[a]	...	...	...	...	...
CH-20[b]	25 Chromium, 12 Nickel	0.20[b]	1.50	2.00	0.04	0.04	22.0–26.0	12.0–15.0	...	...	...	...	...	...	...	...
CK-20	25 Chromium, 20 Nickel	0.20	2.00	2.00	0.04	0.04	23.0–27.0	19.0–22.0	...	...	...	...	...	...	...	...
CE-30	29 Chromium, 9 Nickel	0.30	1.50	2.00	0.04	0.04	26.0–30.0	8.0–11.0	...	...	...	...	...	...	...	...
CA-15	12 Chromium	0.15	1.00	1.50	0.04	0.04	11.5–14.0	1.00 max	0.50 max	...	...	...	...	...	...	...
CA-15M	12 Chromium	0.15	1.00	0.65	0.040	0.040	11.5–14.0	1.0 max	0.15–1.0	...	...	...	...	...	...	...
CB-30	20 Chromium	0.30	1.00	1.50	0.04	0.04	18.0–21.0	2.00 max	...	...	...	[e]	...	...	...	...
CC-50	28 Chromium	0.50	1.00	1.50	0.04	0.04	26.0–30.0	4.00 max	...	...	...	...	...	...	...	...
CA-40	12 Chromium	0.20–0.40	1.00	1.50	0.04	0.04	11.5–14.0	1.0 max	0.5 max	...	...	...	...	...	...	...
CF-3	19 Chromium, 9 Nickel	0.03[f]	1.50	2.00	0.04	0.04	17.0–21.0	8.0–12.0	...	...	...	...	...	...	...	...
CF-3M	19 Chromium, 10 Nickel, with Molybdenum	0.03[f]	1.50	1.50	0.04	0.04	17.0–21.0	9.0–13.0	2.0–3.0	...	...	...	...	...	...	...
CG-8M	19 Chromium, 11 Nickel, with Molybdenum	0.08	1.50	1.50	0.04	0.04	18.0–21.0	9.0–13.0	3.0–4.0	...	...	...	...	...	...	...

TABLE 2 *Continued*

Grade	Type	Composition, percent														
		Carbon, max	Manganese, max	Silicon, max	Phosphorus,[c] max	Sulfur,[c] max	Chromium	Nickel	Molybdenum	Columbium	Selenium	Copper	Tungsten max	Vanadium, max	Cobalt, max	Iron, max
CN-7M	20 Chromium, 29 Nickel, with Copper and Molybdenum	0.07	1.50	1.50	0.04	0.04	19.0–22.0	27.5–30.5	2.0–3.0	...	...	3.0–4.0	...	...	...	...
CN-7MS	19 Chromium, 24 Nickel, with Copper and Molybdenum	0.07	1.00	2.50–3.50	0.04	0.03	18.0–20.0	22.0–25.0	2.5–3.0	...	...	1.5–2.0	...	...	...	...
CW-12M	Nickel, Molybdenum, Chromium	0.12	1.00	1.50	0.040	0.030	15.50–20.00	remainder	16.00–20.00	...	...	...	5.25	0.40	2.50	7.50
CY-40	Nickel, Chromium, Iron	0.40	1.50	3.00	0.030	0.030	14.00–17.00	remainder	...	...	...	...	...	...	...	11.00
CZ-100	Nickel Alloy	1.00	1.50	2.00	0.030	0.030	...	remainder	...			1.25 max		...	...	3.00
M-35	Nickel-Copper Alloy	0.35	1.50	2.00	0.030	0.030	...	remainder	...			26.0–33.0		...	...	3.50
N-12M	Nickel-Molybdenum Alloy	0.12	1.00	1.00	0.040	0.030	1.00 max	remainder	26.0–33.0			...		0.60	2.50	6.00
CA-6NM	...	0.06	1.00	1.00	0.04	0.04	11.5–14.0	3.5–4.5	0.40–1.0	...	...	...	...	...	...	...

[a] For free machining properties the composition of Grade CF-16F may contain suitable combinations of selenium, phosphorus and molybdenum (Grade CF-16F) or of sulfur and molybdenum (Grade CF-16Fa) as follows:

Selenium, phosphorus and molybdenum:	
Selenium, percent	0.20–0.35
Phosphorus, max, percent	0.17
Molybdenum, max, percent	1.50
Sulfur and molybdenum:	
Sulfur, percent	0.20–0.40
Molybdenum, percent	0.40–0.80

Other combinations of elements for free-machining properties may be agreed upon by the manufacturer and the purchaser.

[b] For the more severe general corrosive conditions, and when so specified, the carbon content shall not exceed 0.10 percent. This low-carbon grade shall be designated as Grade CH-10.

[c] Chemical analysis is not normally required for the elements phosphorus, sulfur and molybdenum, but if they are present in amounts over those stated they may be cause for rejection.

[d] Grade CF-8C shall have a columbium content of not less than 8 times the carbon content and not more than 1.0 percent. If a columbium-plus-tantalum alloy in the approxi-

TABLE 2 *Continued*

mate Cb:Ta ratio of 3:1 is used for stabilizing this grade, the total columbium-plus-tantalum content shall not be less than nine times the carbon content and shall not exceed 1.1 percent.

[e] For Grade CB-30 a copper content of 0.90 to 1.20 percent is optional.

[f] For purposes of determining conformance with these specifications, the observed or calculated value for carbon content shall be rounded to the nearest 0.01 percent in accordance with the rounding method of ASTM Recommended Practice E 29, for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values (*1973 Annual Book of ASTM Standards*, Parts 27, 29, 30, 31, and 32).

TABLE 3 Tensile Requirements

Grade	Type	Tensile Strength, min		Yield Point, min		Elongation in 2 in. or 50 mm, min, percent	Reduction of Area, min, percent
		ksi	MPa	ksi	MPa		
CF-8	19 Chromium, 9 Nickel	65	448	28	193	35	...
CG-12	22 Chromium, 12 Nickel	70	483	28	193	35	...
CF-20	19 Chromium, 9 Nickel	70	483	30	207	30	...
CF-8M	19 Chromium, 10 Nickel, with Molybdenum	70	483	30	207	30	...
CF-8C	19 Chromium, 10 Nickel, with Columbium	70	483	30	207	30	...
CF-16 F and CF-16Fa	19 Chromium, 9 Nickel, Free Machining	70	483	30	207	25	...
CH-20 and CH-10	25 Chromium, 12 Nickel	70[a]	483[a]	30	207	30	...
CK-20	25 Chromium, 20 Nickel	65	448	28	193	30	...
CE-30	29 Chromium, 9 Nickel	80	552	40	276	10	...
CA-15 and Ca-15M	12 Chromium	90	621	65	448	18	30
CB-30	20 Chromium	65	448	30	207	...	...
CC-50	28 Chromium	55	379	...	...	...	...
CA-40	12 Chromium	100	689	70	483	15	25
CF-3	19 Chromium, 9 Nickel	65	448	28	193	35	...
CF-3M	19 Chromium, 10 Nickel, with Molybdenum	70	483	30	207	30	...
CG-8M	19 Chromium, 11 Nickel, with Molybdenum	75	517	35	241	25	...
CN-7M	20 Chromium, 29 Nickel, with Copper and Molybdenum	62.5	430	25	172	35	...
CN-7MS	19 Chromium, 24 Nickel, with Copper and Molybdenum	70	483	30	207	35	...
CW-12M	Nickel, Molybdenum, Chromium	72	496	46	317	4.0	...
CY-40	Nickel, Chromium, Iron	70	483	28	193	30	...
CZ-100	Nickel Alloy	50	345	18	124	10	...
M-35	Nickel-Copper Alloy	65	448	30[a]	207[a]	25	...
N-12M	Nickel-Molybdenum Alloy	72	496	46	317	6	...
CA-6NM	...	110	758	80	552	15	35

[a] When adequate weldability is stipulated the silicon content may have to be lowered, in which case the minimum required yield strength shall be 26 ksi (179 MPa).

TABLE 4 Minimum Preheat Temperatures

Grade	Minimum Preheat Temperature	
	deg F	deg C
CA-15	400	204
CA-15M	400	204
CA-40	400	204
Others	50	10

Designation: A 307 – 74

American National Standard G38.5-1969
American National Standards Institute

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Specification for CARBON STEEL EXTERNALLY AND INTERNALLY THREADED STANDARD FASTENERS[1]

This Standard is issued under the fixed designation A 307; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This specification[2] covers the chemical and mechanical requirements of two grades of carbon steel externally and internally threaded standard fasteners, in sizes ¼ in. (6.35 mm) through 4 in. (104 mm). This specification does not cover requirements for externally threaded fasteners having heads with slotted or recessed drives. The fasteners covered by this specification are frequently used for the following applications:

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

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

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

1.3 Nonheaded anchor bolts, either straight or bent, to be used for structural anchorage purposes, shall conform to the requirements of ASTM Specification A 36, for Structural Steel,[3] with tension tests to be made on the bolt body or on the bar stock used for making the anchor bolts.

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

2. Materials and Manufacture

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

2.2 Steel for nuts shall be made by the open-hearth, basic-oxygen, electric-furnace, or bessemer process.

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

2.4 Bolt threads may be rolled or cut.

2.5 Nuts may be produced by hot pressing, cold punching, cold forging, or machining from bar stock.

3. Chemical Requirements

3.1 Steel for bolts and nuts shall conform to the following chemical requirements:

	Grade A		Grade B	
	Bolts	Nuts	Bolts	Nuts
Phosphorus, max, percent	0.06	0.13	0.04	0.12
Sulfur, max, percent	0.15	0.23	0.05	0.15

3.2 Resulfurized material is not subject to rejection based on check analysis for sulfur.

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

4. Mechanical Requirements

4.1 Bolts shall meet the hardness requirements specified in Table 1. This shall be the only requirement for bolts which are too short or which have insufficient threads for tension testing or which have drilled or undersize heads that are weaker than the threaded section of the bolt. The hardness of Grade A bolts, except those tested by the wedge tension test, shall not exceed 241 Brinell (100 Rockwell B).

4.2 Bolts, other than those excepted in 4.1, shall be subject to a tension test as specified

[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 approved July 29, 1974. Published September 1974. Originally published as A 307 – 47 T. Last previous edition A 307 – 68.

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

[3] *1974 Annual Book of ASTM Standards*, Part 4.

in Section 6. Where both hardness and tension tests are performed, acceptance on the basis of the tensile requirements shall take precedence where the minimum requirements are the subject of controversy.

4.3 Bolts 1⅛ in. and under in diameter when tested in full size shall meet the requirements for tensile strength specified in Table 2.

4.4 Bolts 1¼ to 3 in. in diameter, inclusive, shall be tested preferably in full size and shall meet the requirements for tensile strength specified in Table 2. But when equipment of sufficient capacity for such tests is not available, they shall meet the following requirements on machined specimen tension tests:

	Tensile Strength, ksi (MPa)	Elongation in 2 in. or 50 mm, percent
Grade A and Grade B bolts	60 (414) min	18 min
Grade B bolts only	100 (689) max	...

4.5 Nuts shall meet the hardness requirement specified in Table 3. Hardness shall be the only requirement for jam, slotted, and castle nuts and for nuts larger than 1½ in. in size.

4.6 Nuts 1⅛ in. and under in size shall meet the proof loads specified in Table 3.

4.7 Nuts 1¼ to 1½ in., inclusive, in size shall preferably meet the requirements for proof load specified in Table 3, but when equipment of sufficient capacity for such tests is not available they shall meet the hardness requirements specified in Table 3.

5. Dimensions

5.1 Unless otherwise specified, threads shall be the Coarse Thread Series as specified in the latest issue of the American National Standard for Unified Screw Threads (ANSI B1.1), having a Class 2A tolerance for bolts and Class 2B tolerance for nuts.

5.2 Unless otherwise specified, Grade A bolts shall be hex bolts with dimensions as given in the latest issue of the American National Standard for Square and Hex Bolts and Screws (ANSI B18.2.1). Unless otherwise specified, Grade B bolts shall be heavy hex bolts with dimensions as given in the latest issue of American National Standard B18.2.1.

5.3 Unless otherwise specified, nuts for Grade A bolts shall be hex nuts, and nuts for Grade B bolts shall be heavy hex nuts with dimensions as given in the latest issue of American National Standard for Square and Hex Nuts (ANSI B18.2.2).

6. Methods of Test

6.1 The material shall be tested in accordance with Supplement III of ASTM Methods and Definitions A 370, for Mechanical Testing of Steel Products.[4]

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

6.3 Nuts shall be tested by the axial proof load method.

6.4 Speed of testing as determined with a free running crosshead shall be a maximum of 1 in. (25.4 mm)/min for the tensile strength tests of bolts and the proof load determination on nuts.

7. Number of Tests and Retests

7.1 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.

7.2 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.

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

7.3.1 One type of item, that is, bolts or nuts,

7.3.2 One nominal size, and

7.3.3 One nominal length of bolts.

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

7.4 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

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

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

8. Marking

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

9. Inspection

9.1 If the inspection described in 9.2 is required by the purchaser it shall be specified in the inquiry, order, or contract.

9.2 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 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.

10. Rejection

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

TABLE 1 Hardness Requirements for Bolts

Bolt Size, in.	Grade	Hardness			
		Brinell		Rockwell B	
		min	max	min	max
All	A	121	...	69	...
	B	121	207	69	95

TABLE 2 Tensile Requirements for Full-Size Bolts

Bolt Size, in.	Threads per inch	Stress Area[a], in.²	Tensile Strength, lbf[b]	
			Grades A and B, min[c]	Grade B only, max[d]
¼	20	0.0318	1 900	3 180
5/16	18	0.0524	3 100	5 240
⅜	16	0.0775	4 650	7 750
7/16	14	0.1063	6 350	10 630
½	13	0.1419	8 500	14 190
9/16	12	0.182	11 000	18 200
⅝	11	0.226	13 550	22 600
¾	10	0.334	20 050	33 400
⅞	9	0.462	27 700	46 200
1	8	0.606	36 350	60 600
1⅛	7	0.763	45 800	76 300
1¼	7	0.969	58 150	96 900
1⅜	6	1.155	69 300	115 500
1½	6	1.405	84 300	140 500
1¾	5	1.90	114 000	190 000
2	4½	2.50	150 000	250 000
2¼	4½	3.25	195 000	325 000
2½	4	4.00	240 000	400 000
2¾	4	4.93	295 800	493 000
3	4	5.97	358 200	597 000
3¼	4	7.10	426 000	710 000
3½	4	8.33	499 800	833 000
3¾	4	9.66	579 600	966 000
4	4	11.08	664 800	1 108 000

[a] Area calculated from the formula:

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

where:

A_s = stress area,
D = nominal diameter of bolt, and
n = threads per inch.

[b] 1 lbf = 4.448 N.
[c] Based on 60 ksi (414 MPa).
[d] Based on 100 ksi (689 MPa).

TABLE 3 Hardness and Proof Load Requirements for Nuts

Nut Size, in.	Threads per Inch	Proof Load, lbf[a,b]	Brinell Hardness, min
¼	20	2 850	...
5/16	18	4 700	...
⅜	16	7 000	...
7/16	14	9 550	...
½	13	12 750	...
9/16	12	16 400	...
⅝	11	20 350	...
¾	10	30 050	...
⅞	9	41 600	...
1	8	54 550	...
1⅛	7	68 650	...
1¼	7	87 200	104
1⅜	6	103 950	104
1½	6	126 450	104
1¾ to 4, incl.	...	...	104

[a] Based on 90 ksi (621 MPa) mandrel stress for nut sizes ¼ to 2¾ in., inclusive; 77 ksi (531 MPa) for 3 in.; and 67 ksi (462 MPa) for 3¼ to 4 in., inclusive.
[b] 1 lbf = 4.448 N.

Designation: A 325 – 74

American National Standard G38.6
American National Standards Institute

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Standard Specification for HIGH-STRENGTH BOLTS FOR STRUCTURAL STEEL JOINTS, INCLUDING SUITABLE NUTS AND PLAIN HARDENED WASHERS[1]

This Standard is issued under the fixed designation A 325; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

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

1.1.1 *Type 1*—Bolts made of medium-carbon steel, supplied in sizes ½ to 1 ½ in., inclusive, in diameter.

1.1.2 *Type 2*—Bolts made from what is generally described as low-carbon martensite steel, supplied in sizes ½ to 1 ½ in., inclusive, in diameter.

1.1.3 *Type 3*—Bolts, ½ to 1 ½ in., inclusive, in diameter having atmospheric corrosion resistance and weathering characteristics comparable to that of the steels covered in ASTM Specification A 588, for High-Strength Low-Alloy Structural Steel with 50,000 psi Minimum Yield Point to 4 in. Thick,[4] and ASTM Specification A 242, for High-Strength Low-Alloy Structural Steel[4] (these steels have atmospheric corrosion resistance approximately two times that of carbon structural steel with copper). Nuts and washers used in assemblies with these bolts shall also have comparable atmospheric corrosion resistance and weathering characteristics.

NOTE 1—Bolts for general applications, including anchor bolts, are covered by ASTM Specification A 449, for Quenched and Tempered Steel Bolts and Studs.[4]

1.2 When the type of bolts is not specified, Type 1 bolts shall be supplied. Type 2 and Type 3 bolts may be supplied by the manufacturers if agreed upon by the purchaser.

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

1.4 Suitable nuts and plain hardened washers are also covered by this specification.

1.5 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 in the Specification for Structural Joints Using ASTM A 325 or A 490 bolts cited in 1.1.

1.6 When galvanized high-strength structural bolts are specified, the bolts shall be Type 1 unless otherwise approved by the purchaser, the nuts shall be Grade DH of ASTM Specification A 563, for Carbon Steel Nuts,[4, 5] or Grade 2H of ASTM Specification A 194, for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Tem-

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys, and is the direct responsibility of Subcommittee A01.26 on Bolting.

Current edition approved July 29, 1974. Published September 1974. Originally published as A 325 – 49 T. Last previous edition A 325 – 71a.

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

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

[4] *1974 Annual Book of ASTM Standards*, Part 4.

perature Service,[5] and washers shall be quenched and tempered. Galvanized bolts and nuts shall be shipped in the same container.

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

2. Materials and Manufacture

2.1 Steel for bolts, nuts, and washers shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

2.2 Bolts shall be heat treated by quenching in a liquid medium from above the austenitizing temperature and then tempering by reheating to a temperature of at least 800°F (427°C).

2.3 Threads of bolts may be cut or rolled.

2.4 Washers shall preferably be through quenched and tempered. Alternatively, carburized, quenched, and tempered washers may be furnished for use with Type 1 and Type 2 bolts.

2.5 Galvanized bolts, nuts, and washers shall be hot-dip galvanized in accordance with the requirements of ASTM Specification A 153, Class C, for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.[6] Nuts shall be tapped oversize, after galvanizing, by the minimum diametral amounts specified in Specification A 563. Nuts shall be provided with an additional lubricant which shall be clean and dry to the touch.

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

3. Chemical Requirements

3.1 Type 1 and 2 bolts, nuts, and washers shall conform to the requirements as to chemical composition prescribed in Table 1.

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

3.3 Product analyses may be made by the purchaser from finished material representing each lot of bolts, nuts, or washers. The chemical composition thus determined shall conform to the requirements prescribed in 2.1 or 2.2, except that resulfurized material is not subject to rejection based on product analysis for sulfur.

4. Mechanical Requirements

4.1 Bolts shall not exceed the maximum hardness specified in Table 3. Bolts that are too short for tension testing shall meet or exceed the minimum hardness specified in Table 3.

4.2 Bolts other than those too short for tension testing shall be subject to tension tests specified in 4.3 and 4.4 and in Section 6.

4.3 Bolts 1 1/8 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 4.

4.4 Bolts 1 1/4, 1 3/8, and 1 1/2 in. in diameter, shall preferably be tested in full size and when so tested shall meet the requirements for tensile strength and proof load or alternate proof load specified in Table 4, but when equipment of sufficient capacity for such tests is not available, the bolts shall meet the requirements for machined specimens specified in Table 5.

4.5 Nuts 1 1/8 in. and under in size shall meet the proof load and hardness requirements specified in Table 6.

4.6 Nuts 1 1/4, 1 3/8, and 1 1/2 in. in size shall meet the requirements for proof load and maximum hardness specified in Table 6, except when equipment of sufficient capacity for such tests is not available, they shall meet the hardness requirements specified in Table 6.

4.7 Quenched and tempered washers shall have a Rockwell hardness of C38 to C45. Carburized, quenched, and tempered washers shall have the equivalent Rockwell A hardness of A69 to A73 or R15N hardness of 15N79 to 15N83, and shall be carburized to a minimum depth of 0.015 in. (0.38 mm). Washers, if hot-dip galvanized, shall have a Rockwell hardness of C26 to C45.

4.8 In addition, galvanized bolts and nuts shall be tested full size in an assembled joint as specified in 6.5. After initial tightening the nut shall be capable of being turned 360 deg with respect to the bolt without producing failure.

[5] *1974 Annual Book of ASTM Standards*, Part 1.
[6] *1974 Annual Book of ASTM Standards*, Part 3.

5. Dimensions

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

5.2 Unless otherwise specified, heavy hex 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).

5.3 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 may be used on bolts over 1 in. in diameter.

5.4 Dimensions of washers shall conform to those shown in the latest issue of the Specifications for Structural Joints Using ASTM A 325 Bolts issued by the Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation. Unless otherwise specified, circular washers shall be furnished.

6. Methods of Test

6.1 Tests shall be conducted in accordance with Supplement III of ASTM Methods and Definitions A 370, for Mechanical Testing of Steel Products.[7]

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

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

6.4 The speed of testing as determined with a free-running cross head shall be a maximum of ⅛ in. (3.18 mm)/min for the bolt proof-load determination, and a maximum of 1 in. (25.4 mm)/min for the bolt tensile-strength determination and nut proof-load determination.

6.5 The galvanized bolt shall be placed in a steel joint and assembled with a galvanized washer and a galvanized nut. The joint shall be one or more flat structural steel plates with a total thickness, including the washer, such that 3 to 5 full threads of the bolt are located between the bearing surfaces of the bolt head and nut. The hole in the joint shall have the same nominal diameter as the hole in the washer. The initial tightening of the nut shall produce a load in the bolt not less than 10 % of the specified proof load.[8] After this initial tightening, the nut position shall be marked, and this marking shall serve as the base from which the rotation requirements of 4.8 shall be measured. During nut rotation the bolt head shall be restrained from turning.

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 material 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

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[7] *1974 Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, and 5, and *1973 Annual Book of ASTM Standards*, Part 31.

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

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 4.4, 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 4.4 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. Marking

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

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

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

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

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

8.6 Heavy hex nuts for Type 1, Type 2, and Type 3 bolts shall be marked on one face with three equally spaced circumferential lines. In addition heavy hex nuts for Type 3 bolts shall be marked on one face with the numeral 3, and the manufacturer may add other distinguishing marks indicating that the nut is atmospheric corrosion resistant and of a weathering type. Markings may be raised or depressed at the option of the manufacturer. However, if markings are applied to the bearing surface, they shall be depressed.

8.7 Washers for use with the Type 3 bolts shall be marked on one face near the outer edge with the numeral 3. In addition, at the manufacturers' option, other distinguishing marks may be added, indicating that the washer is atmospheric corrosion resistant and of a weathering type. Markings on top or bottom surfaces shall be depressed.

NOTE 3—Heavy hex nuts conforming to requirements for Grade 2 or 2H of ASTM Specifications A 194 for Carbon and Alloy Steel Nuts for High-Pressure and High-Temperature Service,[5] may be supplied as an alternative for use with Type 1 and Type 2 bolts. Grade C, D, or DH of ASTM Specification A 563, for Carbon Steel Nuts,[4, 5] are also an acceptable alternative. Such nuts are marked C, D, or DH in the case of nuts of Specification A 563 and are marked 2 or 2H and the manufacturers' symbol for nuts of Specification A 194.

9. Inspection

9.1 If the inspection described in 9.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

9.2 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 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.

10. Rejection

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

11. Certification

11.1 *Nuts and Washers:*

11.1.1 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.

11.2.1 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.

TABLE 1 Chemical Requirements for Types 1 and 2 Bolts, Nuts, and Washers

Element	Composition, %				
				Washers	
	Type 1 Bolts	Type 2 Bolts[a]	Nuts	Quenched and Tempered	Carburized
Carbon:					
Heat analysis	0.30 min	0.15–0.23	...	...	[b]
Product analysis	0.27 min	0.13–0.25	...	...	...
Manganese, min:					
Heat analysis	0.50	0.70	...	...	1.00 max
Product analysis	0.47	0.67	...	...	1.00 max
Phosphorus, max:					
Heat analysis	0.040	0.040	0.120	0.040	0.040
Product analysis	0.048	0.048	0.128	0.050	0.050
Sulfur, max:					
Heat analysis	0.050	0.050	0.23	0.050	0.050
Product analysis	0.058	0.058	...	0.060	0.060
Boron, min:					
Heat analysis	...	0.0005	...	...	...
Product analysis	...	0.0005	...	...	...

[a] Type 2 bolts shall be fully killed, fine grain steel.
[b] The stock used for manufacture of carburized washers shall not contain over 0.25 % carbon.

TABLE 2 Chemical Requirements for Type 3 Bolts, Nuts, and Washers

Element	Composition, percent							
	Type 3 Bolts[a]						Type 3 Nuts[b]	Type 3 Washers[b]
	A	B	C	D	E	F		
Carbon:								
Heat analysis	0.33–0.40	0.38–0.48	0.15–0.25	0.15–0.25	0.20–0.25	0.20–0.25	...	...
Product analysis	0.31–0.42	0.36–0.50	0.14–0.26	0.14–0.26	0.18–0.27	0.19–0.26	...	...
Manganese:								
Heat analysis	0.90–1.20	0.70–0.90	0.80–1.35	0.40–1.20	0.60–1.00	0.90–1.20	...	...
Product analysis	0.86–1.24	0.67–0.93	0.76–1.39	0.36–1.24	0.56–1.04	0.86–1.24	...	...
Phosphorus:								
Heat analysis	0.040 max	0.06–0.12	0.035 max	0.040 max	0.040 max	0.040 max	0.07–0.15	0.040 max
Product analysis	0.045 max	0.06–0.125	0.040 max	0.045 max	0.045 max	0.045 max	0.07–0.155	0.045 max
Sulfur:								
Heat analysis	0.050 max	0.050 max	0.040 max	0.050 max	0.040 max	0.040 max	0.050 max	0.050 max
Product analysis	0.055 max	0.055 max	0.045 max	0.055 max	0.045 max	0.045 max	0.055 max	0.055 max
Silicon:								
Heat analysis	0.15–0.30	0.30–0.50	0.15–0.30	0.25–0.50	0.15–0.30	0.15–0.30	0.20–0.90	0.15–0.30
Product analysis	0.13–0.32	0.25–0.55	0.13–0.32	0.20–0.55	0.13–0.32	0.13–0.32	0.15–0.95	0.13–0.32
Copper:								
Heat analysis	0.25–0.45	0.20–0.40	0.20–0.50	0.30–0.50	0.30–0.60	0.20–0.40	0.25–0.55	0.25–0.45
Product analysis	0.22–0.48	0.17–0.43	0.17–0.53	0.27–0.53	0.27–0.63	0.17–0.43	0.22–0.58	0.22–0.48
Nickel:								
Heat analysis	0.25–0.45	0.50–0.80	0.25–0.50	0.50–0.80	0.30–0.60	0.20–0.40	1.00 max	0.25–0.45
Product analysis	0.22–0.48	0.47–0.83	0.22–0.53	0.47–0.83	0.27–0.63	0.17–0.43	1.03 max	0.22–0.48
Chromium:								
Heat analysis	0.45–0.65	0.50–0.75	0.30–0.50	0.50–1.00	0.60–0.90	0.45–0.65	0.30–1.25	0.45–0.65
Product analysis	0.42–0.68	0.47–0.83	0.27–0.53	0.45–1.05	0.55–0.95	0.42–0.68	0.25–1.30	0.42–0.68
Vanadium:								
Heat analysis	...	...	0.020 min	...	...	...	...	...
Product analysis	...	...	0.010 min	...	...	...	...	...
Molybdenum:								
Heat analysis	...	0.06 max	...	0.10 max	...	...	...	...
Product analysis	...	0.07 max	...	0.11 max	...	...	...	...
Titanium:								
Heat analysis	...	...	...	0.05 max	...	...	...	...
Product analysis	...	...	...	...	...	...	...	...

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

[b] Nuts or washers may also be made of any of the above listed bolt material classes. Selection of the class shall be at the option of the manufacturer.

TABLE 3 Hardness Requirements for Bolts

Bolt Size, in.	Hardness Number			
	Brinell		Rockwell C	
	Min	Max	Min	Max
½ to 1, incl	241	331	23	35
1 1/8 to 1 1/2, incl	223	293	19	31

TABLE 4 Tensile Requirements for Full-Size Bolts

Bolt Size, Threads per Inch and Series Designation	Stress Area,[a] in.² (cm²)	Tensile Strength[b] min, lbf (kN)	Proof Load,[b] Length Measurement Method, lbf (kN)	Alternate Proof Load,[b] Yield Strength Method, min, lbf (kN)
Column 1	Column 2	Column 3	Column 4	Column 5
1/2 - 13 UNC	0.142 (0.92)	17 050 (76)	12 050 (54)	13 050 (58)
5/8 - 11 UNC	0.226 (1.46)	27 100 (121)	19 200 (85)	20 800 (93)
3/4 - 10 UNC	0.334 (2.15)	40 100 (178)	28 400 (126)	30 700 (137)
7/8 - 9 UNC	0.462 (2.98)	55 450 (247)	39 250 (175)	42 500 (189)
1 - 8 UNC	0.606 (3.91)	72 700 (323)	51 500 (229)	55 750 (248)
1 1/8 - 7 UNC	0.763 (4.92)	80 100 (356)	56 450 (251)	61 800 (275)
1 1/8 - 8 UN	0.790 (5.10)	82 950 (369)	58 450 (260)	64 000 (285)
1 1/4 - 7 UNC	0.969 (6.25)	101 700 (452)	71 700 (319)	78 500 (349)
1 1/4 - 8 UN	1.000 (6.45)	105 000 (467)	74 000 (329)	81 000 (360)
1 3/8 - 6 UNC	1.155 (7.45)	121 300 (540)	85 450 (380)	93 550 (416)
1 3/8 - 8 UN	1.233 (7.95)	129 500 (576)	91 250 (406)	99 870 (444)
1 1/2 - 6 UNC	1.405 (9.06)	147 500 (656)	104 000 (463)	113 800 (506)
1 1/2 - 8 UN	1.492 (9.63)	156 700 (697)	110 400 (491)	120 850 (538)

[a] The stress area is calculated as follows:

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

where:

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

[b] Loads tabulated are based on the following:

Bolt Size	Column 3	Column 4	Column 5
1/2, to 1 incl	120 000 psi (825 MPa)	85 000 psi (585 MPa)	92 000 psi (635 MPa)
1 1/8 to 1 1/2, incl	105 000 psi (725 MPa)	74 000 psi (510 MPa)	81 000 psi (560 MPa)

TABLE 5 Tensile Requirements for Specimens Machined from Bolts

Bolt Size, in.	Tensile Strength, min, psi (MPa)	Yield Strength (0.2 % Offset) min, psi (MPa)	Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
1 1/4, 1 3/8 and 1 1/2	105 000 (725)	81 000 (560)	14	35

TABLE 6 Proof Load and Hardness Requirements for Nuts

Nut Size, Threads per Inch, and Series Designation	Proof Load min, lbf (kN)[a]	Brinell Hardness	
		min	max
1/2 - 13 UNC	20 450 (91)	...	352
5/8 - 11 UNC	32 550 (145)	...	352
3/4 - 10 UNC	48 100 (214)	...	352
7/8 - 9 UNC	66 550 (296)	...	352
1 - 8 UNC	87 250 (388)	...	352
1 1/8 - 7 UNC	109 900 (489)	...	352
1 1/8 - 8 UN	113 800 (506)	...	352
1 1/4 - 7 UNC	139 500 (621)	143	352
1 1/4 - 8 UN	144 000 (641)	143	352
1 3/8 - 6 UNC	166 300 (740)	143	352
1 3/8 - 8 UN	177 600 (790)	143	352
1 1/2 - 6 UNC	202 300 (900)	143	352
1 1/2 - 8 UN	214 800 (955)	143	352

[a] Based on 144,000 psi (990 MPa) on stress area of test mandrel or test bolt.

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AMERICAN NATIONAL STANDARD G59.1-1971
APPROVED JULY 14, 1971
BY AMERICAN NATIONAL STANDARDS INSTITUTE

Standard Specification for

STEEL SHEET PILING[1]

ASTM Designation: A 328 – 70[e]

This Standard of the American Society for Testing and Materials is issued under the fixed designation A 328; 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.

[e] NOTE—Sections 7 and 8 were deleted editorially in October 1971 due to revision of ASTM Specification A 6.

1. Scope

1.1 This specification covers carbon steel[2] sheet piling of structural quality for use in the construction of dock walls, sea walls, cofferdams, excavations, and like applications.

1.2 When the steel is used in welded construction, it is presupposed that welding procedures will be suitable for the materials being welded. All welding shall be performed using a low-hydrogen process.

NOTE—The values stated in U. S. customary units are to be regarded as the standard. The metric equivalents of U. S. customary units given in the standard may be approximate.

2. General Requirements for Delivery

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

3. Appurtenant Materials

3.1 Unless otherwise provided in the order, the current edition of the specifications of the American Society for Testing and Materials listed in Table 1 shall govern delivery of otherwise unspecified appurtenant materials when included with material purchased under this specification.

4. Process

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

5. Chemical Composition

5.1 The heat analysis shall conform to the requirements prescribed in Table 2.

[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 A01.02 on Structural Steel.

Current edition effective Oct. 2, 1970. Originally issued 1950. Replaces A 328 – 69.

[2] See ASTM specification A 572, for High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality.[3]

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

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

6. Mechanical Properties

6.1 The material, as represented by the test specimens, shall conform to the requirements as to tensile properties prescribed in Table 3.

TABLE 1—APPURTENANT MATERIAL SPECIFICATIONS.

Commodity	ASTM Specification of Material[a] to be Furnished with Steel Sheet Piling
Plates, bars, structural shapes	A 36
Rivets	A 502, Grade 1[b]
Bolts	A 307, Grade A[c]

[a] These designations refer to the following Specifications[3] of the American Society for Testing and Materials:
A 36, Structural Steel,
A 307, Low-Carbon Steel Externally and Internally Threaded Standard Fasteners, and
A 502, Steel Structural Rivets.

[b] ASTM A 502, Grade 2, may be specified if desired.

[c] ASTM Specification A 325, for High-Strength Bolts for Structural Steel Joints Including Suitable Nuts and Plain Hardened Washers,[3] may be specified where required.

6.2 The bend test specimen shall stand being bent cold through 180 deg to an inside diameter of two times the thickness of the specimen without cracking on the outside of the bent portion.

NOTE—This ratio applies to the bending performance of a test specimen only. This specimen is always taken in the longitudinal direction and usually has some edge preparation. When sheet piles are to be bent in a fabricating operation, more liberal bend radii must be used.

6.3 A minimum tensile strength of 60,000 psi (42.0 kgf/mm^2) and a minimum yield point of 36,000 psi (25.5 kgf/mm^2) shall be permitted for piling sections used in the fabrication of cold-formed connections.

TABLE 2—CHEMICAL REQUIREMENTS.

Element	Composition, per cent
	Heat Analysis
Phosphorus, max	0.04
Sulfur, max	0.05
Copper (when specified), min	0.20

TABLE 3—TENSILE REQUIREMENTS.

Tensile strength, min, psi (kgf/mm^2)	70 000 (49.2)
Yield point, min, psi (kgf/mm^2)	38 500 (27.1)
Elongation in 8 in. (203.2 mm), min, per cent	17

SUPPLEMENTARY REQUIREMENT

The following supplementary requirement shall apply only when specified in in the purchase order.

S1. The minimum strength of the interlocked joint required for certain services may be specified for certain sheet piling sections subject to specific agreement between the material purchaser and the manufacturer.

Designation: A 354 – 74

American National Standard G38.10
American National Sandards Institute

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Standard Specification for QUENCHED AND TEMPERED ALLOY STEEL BOLTS, STUDS, AND OTHER EXTERNALLY THREADED FASTENERS[1]

This Standard is issued under the fixed designation A 354; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This specification covers the chemical and mechanical requirements of quenched and tempered alloy steel bolts, studs, and other externally threaded fasteners 4 in. and under in diameter for application at normal atmospheric temperatures, where high strength is required and for limited application at elevated temperatures (Note 1). Any alloy steel capable of meeting the minimum mechanical and chemical properties set forth in this specification may be used.

NOTE 1—For bolts, studs, or other externally threaded fasteners, to be used at elevated temperatures, reference should be made to Specification A 193.

1.2 Two levels of bolting strength are covered, designated Grades BC and BD. Selection will depend upon design and the stresses and service for which the product is to be used.

NOTE 2—Quenched and tempered alloy steel bolts for structural steel joints up through 1½-in. in diameter are covered in Specification A 490. Alloy steel bolts, studs, and other externally threaded fasteners (that is, heavy hex-structural bolts over 1½ in., hex bolts, anchor bolts, and countersunk bolts) exhibiting similar mechanical properties to bolts conforming to Specification A 490 shall be covered by Grade BD of this specification.

1.3 Suitable nuts are covered by reference to Specifications A 194, A 325, and A 563.

1.4 When nuts are used with bolts, studs, and other externally threaded fasteners described in this specification, they shall conform with Table 1.

NOTE 3—The values stated in U.S. customary units are to be regarded as the standard.

2. Applicable Documents

2.1 The following documents of the issue in effect on date of material procurement form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware[2]

A 193 Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service[3]

A 194 Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service[3]

A 325 Specification for High Strength Bolts for Structural Steel Joints Including Suitable Nuts and Plain Hardened Washers[4]

A 370 Methods and Definitions for Mechanical Testing of Steel Products[5]

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

A 563 Specification for Carbon Steel Nuts[3, 4]

2.1.2 *ANSI Standards:*[6]

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys, and is the direct responsibility of Subcommittee A01.26 on Bolting.

Current edition approved May 27, 1974. Published August 1974. Originally published as A 354 – 52 T. Last previous edition A 354 – 66.

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

[3] *1974 Annual Book of ASTM Standards*, Part 1.

[4] *1974 Annual Book of ASTM Standards*, Part 4.

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

[6] Available from American National Standards Institute, 1430 Broadway, New York, N. Y. 10018.

B1.1 Unified Screw Threads
B18.2.2 Square and Hex Nuts

3. Material and Manufacture

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

3.2 All fasteners shall be heat-treated by quenching in a liquid medium (except Grade BD must be quenched in oil) from above the transformation temperature and then tempering by reheating to a temperature of not less than 850°F (455°C) for Grade BC and 900°F (480°C) for Grade BD.

3.3 When used, suitable plain-hardened washers shall be quenched and tempered (noncarburized) as described in Specification A 325.

3.4 Galvanized fasteners (including nuts and washers if used) shall be hot-dip galvanized in accordance with the requirements for Class C Specification A 153. Nuts shall be tapped oversize after galvanizing by at least the minimum diametral amounts specified in Specification A 563. Nuts shall be provided with an additional lubricant which shall be clean and dry to the touch.

3.5 Galvanized bolts and nuts shall be shipped in the same container unless specifically requested otherwise by the purchaser.

4. Chemical Requirements

4.1 All fasteners shall be made from alloy steel conforming to the chemical composition requirements given in Table 2. The steel shall contain sufficient alloying elements to qualify it as an alloy steel.

NOTE 4—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, boron, and 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 analysis may be made by the purchaser from finished material representing each lot of fasteners. The chemical composition thus determined shall conform to the requirements given in Table 2. Choice of alloy steel composition necessary to assure meeting the specified mechanical requirements shall be made by the manufacturer and shall be reported to the purchaser for information purposes only.

5. Mechanical Requirements

5.1 All fasteners regardless of size or shape, shall meet the hardness requirements specified in Table 3. This shall be the only requirement for fasteners which are too short or are too long, or which have insufficient threads for tension testing or which have drilled or undersize heads that are weaker than the threaded section.

5.2 All fasteners 1¼ in. in diameter or less, shall be tested full size and shall conform to the tensile strength and proof load (or yield strength) in Table 4 (see 5.1).

5.3 All fasteners larger than 1¼ in. in diameter shall preferably be tested full size and shall conform to the tensile strength and proof load (or yield strength) in Table 4 (see 5.1). When equipment of sufficient capacity for such test is not available, machined test specimens may be used which shall conform to the requirements in Table 5.

5.4 For fasteners on which both hardness and tension tests are performed, acceptance shall be based on tension tests in the event a discrepancy between minimum hardness and tension tests exists.

5.5 When used, washers shall be in accordance with 4.7 of Specification A 325, which states in part that quenched and tempered washers shall have a Rockwell hardness of C 38 to 45. Hot-dip galvanized washers shall have a Rockwell hardness of 26 to 45 HRC.

6. Dimensions

6.1 *Threads* shall be the Unified Coarse Thread Series as specified in 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.

6.2 *Washers*—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, approved by the Research Council on Riveted and Bolted Structural Joints, of the Engineering Foundation.

6.3 *Nuts*—Unless otherwise specified, nuts for use with bolts and studs shall conform to the dimensions for heavy hex nuts specified in ANSI Standard B18.2.2.

7. Methods of Test

7.1 Methods of test shall be in accordance with Supplement III of Methods and Definitions A 370.

7.2 Proof load, rather than yield strength determination is preferred and shall be the arbitration method for fasteners 1¼ in. and under in diameter.

7.3 Hexagon bolts shall be tested by the wedge tension method. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body.

7.3.1 At the option of the manufacturer, the yield strength test (see S11.1.3.1 of Methods A 370) and the wedge tension test (S11.1.5) may be accomplished concurrently to satisfy 7.2 and 7.3.

7.4 Studs and bolts other than those in 7.4 shall be tested by the axial tension method.

7.4.1 At the option of the manufacturer, the yield strength test and the axial tension test may be accomplished concurrently to satisfy 7.2 and 7.4.

7.5 The speed of testing determined with a free running crosshead shall be a maximum of ⅛ in. (3.2 mm)/min for the bolt proof load (or yield strength) determination and a maximum of 1 in. (25.4 mm)/min for the tensile strength determination.

8. Number of Mechanical Tests

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

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

8.3.1 One type of item, bolts, studs, etc.,

8.3.2 One nominal diameter, and

8.3.3 One nominal length.

8.4 From each lot, the number of tests for each required property 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 machining it may be discarded and another specimen substituted.

9. Markings

9.1 All products shall be marked with the manufacturer's identification symbol. Marks may be raised or depressed at the manufacturer's option, on the top of the head for bolts and on one end for studs.

9.2 All products shall also be marked with the grade symbol except Grade BD bolts ¼ through 1½ in. in diameter, which shall be marked with six radial lines 60 deg apart on the top of the head.

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

TABLE 1 Bolt-Nut Suitability

Grade of Fastener	Specification, Grade, and Size of Nuts
BC	A 194 Grade 2 or 2H ¼ to 4 in. incl.
	A 563 Grade C ½ to 1½ in. incl.
	A 563 Grade D ¼ to 4 in. incl.
	A 563 Grade DH ¼ to 4 in. incl.
	A 325 ½ to 1½ in. incl.
BD	A 194 Grade 2H ¼ to 4 in. incl.
	A 563 Grade DH ¼ to 4 in. incl.
Hot-Dip Galvanized:	
BC and BD	A 194 Grade 2 H ¼ to 4 in. incl.
	A 563 Grade DH ¼ to 4 in. incl.

TABLE 2 Chemical Requirements

Element	Heat Analysis, %	Product Analysis, %
Carbon:		
For sizes through 1½ in.	0.30 to 0.53	0.28 to 0.55
For sizes larger than 1½ in.	0.35 to 0.53	0.33 to 0.55
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045

TABLE 3 Hardness Requirements for Full-Size Fasteners

Size, in.	Grade	Hardness			
		Brinell		Rockwell C	
		Min	Max	Min	Max
¼ to 2½	BC	255	331	25	36
Over 2½	BC	241	311	22	33
¼ to 2½	BD	311	352	32	38
Over 2½	BD	285	352	30	38

TABLE 4 Tensile Requirements for All Full-Size Fasteners— U.S. Customary Units

Bolt Size, in.	Threads per inch	Stress Area, in.²	Grade BC			Grade BD		
			Tensile Strength, min, lbf[a]	Proof Load min, lbf[b]	Yield Strength (0.2% offset), min, lbf[c]	Tensile Strength, min, lbf[d]	Proof Load min, lbf[e]	Yield Strength (0.2% offset), min, lbf[f]
1	2	3	4	5	6	7	8	9
¼	20	0.0318	4 000	3 350	3 450	4 750	3 800	4 100
5/16	18	0.0524	6 550	5 500	5 700	7 850	6 300	6 800
⅜	16	0.0775	9 700	8 150	8 450	11 650	9 300	10 075
7/16	14	0.1063	13 300	11 150	11 600	15 950	12 750	13 850
½	13	0.1419	17 750	14 900	15 450	21 300	17 050	18 500
9/16	12	0.182	22 750	19 100	19 850	27 300	21 850	23 600
⅝	11	0.226	28 250	23 750	24 650	33 900	27 100	29 400
¾	10	0.334	41 750	35 050	36 400	50 100	40 100	43 400
⅞	9	0.462	57 750	48 500	50 350	69 300	55 450	60 100
1	8	0.606	75 750	63 650	66 050	90 900	72 700	78 800
1⅛	7	0.763	95 400	80 100	83 150	114 450	91 550	99 200
1⅛	8	0.790	98 750	82 950	86 200	118 500	94 800	102 700
1¼	7	0.969	121 150	101 750	105 600	145 350	116 300	126 000
1¼	8	1.000	125 000	105 000	109 000	150 000	120 000	130 000
1⅜	6	1.155	144 400	121 300	125 900	173 250	138 600	150 200
1⅜	8	1.233	154 150	129 450	134 400	185 000	148 000	160 300
1½	6	1.405	175 650	147 550	153 150	210 750	168 600	182 500
1½	8	1.492	186 500	156 650	162 250	233 800	175 050	194 000
1¾	5	1.90	237 500	199 500	207 100	285 000	228 000	247 000
1¾	8	2.08	260 000	218 400	226 700	312 000	249 600	270 000
2	4½	2.50	312 500	262 500	272 500	375 000	300 000	325 000
2	8	2.77	346 250	290 850	301 950	415 500	332 400	360 000
2¼	4½	3.25	406 250	341 250	354 250	487 500	390 000	422 500
2¼	8	3.56	445 000	373 800	388 050	534 000	422 200	462 800
2½	4	4.00	500 000	420 000	436 000	600 000	480 000	520 000
2½	8	4.44	550 000	466 200	483 950	666 000	532 800	577 200
2¾	4	4.93	566 950	468 350	488 050	690 200	517 650	566 950
2¾	8	5.43	624 450	515 850	537 550	750 200	570 150	624 450
3	4	5.97	686 550	567 150	591 050	835 800	626 850	686 550
3	8	6.51	748 650	618 450	644 500	911 400	683 550	748 650
3¼	4	7.10	816 500	674 500	702 900	994 000	745 500	816 500
3¼	8	7.69	884 350	730 550	761 300	1 076 600	807 450	884 350
3½	4	8.33	957 950	791 350	824 650	1 166 200	874 650	957 950
3½	8	8.96	1 030 400	851 200	887 050	1 254 400	940 800	1 030 400
3¾	4	9.66	1 110 900	917 700	956 350	1 352 400	1 014 300	1 110 900
3¾	8	10.34	1 199 100	983 300	1 023 650	1 447 600	1 085 700	1 189 100
4	4	11.08	1 274 200	1 052 600	1 096 900	1 551 200	1 163 400	1 274 200
4	8	11.81	1 358 200	1 122 000	1 169 200	1 653 400	1 240 050	1 358 150

[a] Based on 125 000 psi for sizes ¼ to 2½ in., incl, and on 115 000 psi for sizes over 2½ to 4 in., incl.
[b] Based on 105 000 psi for sizes ¼ to 2½ in., incl, and on 95 000 psi for sizes over 2½ to 4 in., incl.
[c] Based on 109 000 psi for sizes ¼ to 2½ in., incl, and on 99 000 psi for sizes over 2½ to 4 in., incl.
[d] Based on 150 000 psi for sizes ¼ to 2½ in., incl, and on 140 000 psi for sizes over 2½ to 4 In. incl.
[e] Based on 120 000 psi for sizes ¼ to 2½ in., incl, and on 105 000 psi for sizes over 2½ to 4 in. incl.
[f] Based on 125 000 psi for sizes ¼ to 2½ in., incl, and on 115 000 psi for sizes over 2½ to 4 in. incl.

TABLE 4a Tensile Requirements for All Full-Size Fasteners—SI Units

Bolt Size, in.	Threads per Inch	Stress Area, in.[2]	Grade BC			Grade BD		
			Tensile Strength, min, N[a]	Proof Load min, N[b]	Yield Strength (0.2% offset), min, N[c]	Tensile Strength, min, N[d]	Proof Load min, N[e]	Yield Strength (0.2% offset), min, N[f]
1	2	3	4	5	6	7	8	9
¼	20	0.0318	28	23	24	33	26	28
5/16	18	0.0524	45	38	39	54	43	45
⅜	16	0.0775	67	56	58	80	64	67
7/16	14	0.1063	92	77	80	110	88	92
½	13	0.1419	122	103	107	147	118	122
9/16	12	0.182	157	132	137	188	151	157
⅝	11	0.226	195	164	170	234	187	195
¾	10	0.334	288	242	251	345	276	288
⅞	9	0.462	398	334	347	478	382	398
1	8	0.606	522	439	455	627	501	522
1⅛	7	0.763	658	552	573	789	631	658
1⅛	8	0.790	681	572	594	817	654	681
1¼	7	0.969	835	702	728	1002	802	835
1¼	8	1.000	862	724	752	1034	827	862
1⅜	6	1.155	996	836	868	1195	956	996
1⅜	8	1.233	1063	893	927	1276	1020	1063
1½	6	1.405	1211	1017	1056	1453	1162	1211
1½	8	1.492	1286	1080	1119	1543	1207	1286
1¾	5	1.90	1638	1376	1428	1964	1571	1702
1¾	8	2.08	1793	1506	1563	2150	1720	1863
2	4½	2.50	2155	1810	1879	2584	2067	2239
2	8	2.77	2387	2005	2082	2863	2290	2480
2¼	4½	3.25	2801	2353	2442	3359	2687	2911
2¼	8	3.56	3068	2577	2676	3679	2909	3189
2½	4	4.00	3447	2896	3006	4134	3307	3583
2½	8	4.44	3792	3214	3337	4589	3671	3977
2¾	4	4.93	3909	3229	3365	4755	3567	3906
2¾	8	5.43	4305	3557	3706	5169	3928	4302
3	4	5.97	4734	3909	4075	5759	4319	4730
3	8	6.51	5162	4264	4444	6280	4710	5158
3¼	4	7.10	5630	4651	4846	6849	5136	5626
3¼	8	7.69	6097	5037	5249	7418	5563	6093
3½	4	8.33	6605	5456	5685	8035	6026	6600
3½	8	8.96	7104	5869	6116	8643	6482	7099
3¾	4	9.66	7659	6327	6594	9318	6989	7654
3¾	8	10.34	8268	6780	7058	9974	7480	8193
4	4	11.08	8785	7257	7563	10 688	8016	8779
4	8	11.81	9365	7736	8061	11 392	8544	9358

[a] Based on 862 MPa for sizes ¼ to 2½ in., incl, and on 793 MPa for sizes over 2½ to 4 in., incl.
[b] Based on 724 MPa for sizes ¼ to 2½ in., incl, and on 655 MPa for sizes over 2½ to 4 in., incl.
[c] Based on 752 MPa for sizes ¼ to 2½ in., incl, and on 683 MPa for sizes over 2½ to 4 in., incl.
[d] Based on 1034 MPa for sizes ¼ to 2½ in., incl, and on 965 MPa for sizes over 2½ to 4 in. incl.
[e] Based on 827 MPa for sizes ¼ to 2½ in., incl, and on 724 MPa for sizes over 2½ to 4 in. incl.
[f] Based on 862 MPa for sizes ¼ to 2½ in., incl, and on 793 MPa for sizes over 2½ to 4 in. incl.

TABLE 5 Mechanical Requirements for Machined Specimens

Grade	Size, in.	Tensile Strength min, psi (kPa)	Yield Strength 0.2% offset), min, psi (kPa)	Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
BC	¼ to 2½ incl.	125 000 (862)	109 000 (752)	16	50
BC	Over 2½	115 000 (793)	99 000 (683)	16	45
BD	¼ to 2½ incl.	150 000 (1034)	130 000 (896)	14	40
BD	Over 2½	140 000 (965)	115 000 (793)	14	40

Designation: A 440 – 74

American National Standard G41.3
American National Standards Institute

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Standard Specification for HIGH-STRENGTH STRUCTURAL STEEL[1]

This Standard is issued under the fixed designation A 440; 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 steel shapes, plates, and bars of structural quality intended primarily for use in the construction of riveted or bolted bridges and buildings and for other special structural purposes, where saving in weight is important. The atmospheric corrosion resistance of this steel is approximately twice that of structural carbon steel. This specification is limited to material up to 4 in. (102 mm) inclusive in thickness.

NOTE 1—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 Specification A 6 for General Requirements for Delivery of Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use.[2]

2.2 Welding of defects shall be done with a welding electrode conforming to classification E7015 or E7016 of AWS Specifications A 5.1 for Mild Steel Covered Arc-Welding Electrodes.[3]

3. Process

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

4. Chemical Requirements

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

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

5. Tensile Properties

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

5.2 For material under $\frac{5}{16}$ in. (7.94 mm) in thickness or diameter, as represented by the test specimen, a deduction from the percentage elongation in 8 in. (200 mm), specified in Table 2, of 1.25% shall be made for each decrease of $\frac{1}{32}$ in. (0.79 mm) of the specified thickness or diameter below $\frac{5}{16}$ in.

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 which shall have a relation to the thickness of the specimen as prescribed in Table 3.

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

Current edition approved July 29, 1974. Published September 1974. Originally published as A 440 – 59 T. Last previous edition A 440 – 70a.

[2] *1974 Annual Book of ASTM Standards*, Part 4.

[3] Available from American Welding Society, 2501 North West 7th St., Miami, Fla. 33125.

TABLE 1 Chemical Requirements

	Heat Analysis, %
Carbon, max	0.28
Manganese	1.10–1.60
Phosphorus, max	0.04
Sulfur, max	0.05
Silicon, max	0.30
Copper, min	0.20

TABLE 2 Tensile Requirements

	Plates and Bars			Structural Shapes		
	For Thicknesses ¾ in. (19 mm) and under	For Thicknesses over ¾ to 1½ in. (19 to 38 mm), incl	For Thicknesses over 1½ to 4 in. (38 to 102 mm), incl	Groups 1 and 2[a]	Group 3[a]	Groups 4 and 5[a]
Tensile strength min, psi (MPa)	70 000 (485)	67 000 (460)	63 000 (435)	70 000 (485)	67 000 (460)	63 000 (435)
Yield point min, psi (MPa)	50 000 (345)	46 000 (315)	42 000 (290)	50 000 (345)	46 000 (315)	42 000 (290)
Elongation in 8 in. or 200 mm, min, %	18[b, d]	18[d]	18[d]	18[b]	18[c]	18
Elongation in 2 in. or 50 mm, min, %	...	21[d]	21[d]	...	...	21[c]

[a] See Specification A 6, Table A.
[b] See 5.2.
[c] For wide flange shapes over 426 lb/ft elongation in 2 in. (50 mm) of 19% minimum applies.
[d] Elongation not required to be determined for floor plate.

TABLE 3 Bend Test Requirements

Thickness of Material, in. (mm)	Ratio of Bend Diameter to Thickness of Specimen[a]
To ¾ (19), incl	1
Over ¾ to 1 (19 to 25), incl	1½
Over 1 to 1½ (25 to 38), incl	2
Over 1½ to 2 (38 to 51), incl	2½
Over 2 to 4 (51 to 102), incl	3

[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.

Designation: A 441 – 74

American National Standard G41.4
American National Standards Institute

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

This Standard is issued under the fixed designation A 441; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This specification covers high-strength low alloy structural steel shapes, plates, and bars for welded, riveted, or bolted construction but intended primarily for use in welded bridges and buildings where saving in weight or added durability are important. The atmospheric corrosion resistance of this steel is approximately twice that of structural carbon steel. This specification is limited to material up to 8 in. (203 mm) incl. in thickness.

NOTE 1—The values stated in 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 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 or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4. Chemical Requirements

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

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

5. Tensile Requirements

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

5.2 For material under 5/16 in. (7.94 mm) in thickness or diameter, as represented by the test specimen, a deduction of 1.25% from the percentage of elongation in 8 in. or 200 mm specified in Table 2 shall be made for each decrease of 1/32 in. (0.79 mm) of the specified thickness or diameter below 5/16 in.

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.

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

Current edition approved July 29, 1974. Published September 1974. Originally published as A 441 – 60 T. Last previous edition A 441 – 70a.

[2] *1974 Annual Book of ASTM Standards*, Part 4.

TABLE 1 Chemical Requirements

	Heat Analysis, %
Carbon, max	0.22
Manganese	0.85–1.25
Phosphorus, max	0.04
Sulfur, max	0.05
Silicon, max	0.30
Copper, min	0.20
Vanadium, min	0.02

TABLE 2 Tensile Requirements

	Plates and Bars				Structural Shapes		
	For Thicknesses ¾ in. (19 mm) and under	For Thicknesses over ¾ to 1½ in. (19 to 38 mm), incl	For Thicknesses over 1½ to 4 in. (38 to 102 mm), incl	For Thicknesses over 4 to 8 in. (102 to 203 mm), incl	Groups 1 and 2[a]	Group 3[a]	Groups 4 and 5[a]
Tensile strength min, psi (MPa)[b]	70 000 (485)	67 000 (460)	63 000 (435)	60 000 (415)	70 000 (485)	67 000 (460)	63 000 (435)
Yield point min, psi (MPa)[b]	50 000 (345)	46 000 (315)	42 000 (290)	40 000 (275)	50 000 (345)	46 000 (315)	42 000 (290)
Elongation in 8 in. or 200 mm, min, %	18[c, d]	18[d]	18[d]	...	18[c]	18	18
Elongation in 2 in. or 50 mm, min, %	...	21[d]	21[d]	21[d]	...	...	21[e]

[a] See Specification A 6, Table A.

[b] When the material is normalized the minimum yield point and minimum tensile strength required shall be reduced 5000 psi (35 MPa).

[c] See 5.2.

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

[e] For wide flange shapes over 426 lb/ft elongation in 2 in. or 50 mm of 19% minimum applies.

TABLE 3 Bend Test Requirements

Thickness of Material, in. (mm)	Ratio of Bend Diameter to Thickness of Specimen[a]
To ¾ (19), incl	1
Over ¾ to 1 (19 to 25), incl	1½
Over 1 to 1½ (25 to 38), incl	2
Over 1½ to 2 (38 to 51), incl	2½
Over 2 to 4 (51 to 102), incl	3

[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.

Designation: A 435 – 74a

American National Standard G60.2
American National Standards Institute

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Standard Specification for STRAIGHT-BEAM ULTRASONIC EXAMINATION OF STEEL PLATES FOR PRESSURE VESSELS[1]

This Standard is issued under the fixed designation A 435; 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[2] covers the procedure and acceptance standards for straight-beam, pulse-echo, ultrasonic examination of rolled carbon and alloy steel plates, ½ in. (12.7 mm) and over in thickness, of fully killed pressure vessel quality. It was developed to assure delivery of steel plates free of gross internal discontinuities such as pipe, ruptures, or laminations and is to be used whenever the inquiry, contract, order, or specification states that the plates are to be subjected to ultrasonic examination.

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

2. Apparatus

2.1 The manufacturer shall furnish suitable ultrasonic equipment and qualified personnel necessary for performing the test. The equipment shall be of the pulse-echo straight beam type. The transducer shall be 1 to 1⅛-in. (25.4 to 28.6-mm) diameter or 1-in. (25.4-mm) square. The test shall be performed by one of the following methods: direct contact, immersion, or liquid column coupling.

2.2 Other search units may be used for evaluating and pinpointing indications.

3. Test Conditions

3.1 Conduct the examination in an area free of operations that interfere with proper functioning of the equipment.

3.2 Clean and smooth the plate surface sufficiently to maintain a reference back reflection from the opposite side of the plate at least 50% of full scale during scanning.

3.3 The surface of plates inspected by this method may be expected to contain a residue of oil or rust or both. Any specified identification which is removed when grinding to achieve proper surface smoothness shall be restored.

4. Procedure

4.1 Ultrasonic examination shall be made on either major surface of the plate. Acceptance of defects in close proximity may require inspection from the second major surface. Plates ordered in the quenched and tempered condition shall be tested following heat treatment.

4.2 A nominal test frequency of 2¼ MHz is recommended. Thickness, grain size, or microstructure of the material and nature of the equipment or method may require a higher or lower test frequency. However, frequencies less than 1 MHz may be used only on agreement with the purchaser. A clear, easily interpreted trace pattern should be produced during the examination.

4.3 Conduct the examination with a test frequency and instrument adjustment that will produce a minimum 50 to a maximum 75% of full scale reference back reflection from the opposite side of a sound area of the plate.

4.4 Scanning shall be continuous along perpendicular grid lines on nominal 9-in. (230-mm) centers, or at the manufacturer's option, shall be continuous along parallel paths, transverse to the major plate axis, on

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

Current edition approved Sept. 27, 1974. Published November 1974. Originally published as A 435 – 59 T. Last previous edition A 435 – 74.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-435 in Section II of that Code.

nominal 4-in. (100-mm) centers, or shall be continuous along parallel paths parallel to the major plate axis, on 3-in. (75-mm) or smaller centers. A suitable couplant such as water, soluble oil, or glycerin, shall be used.

4.5 Scanning lines shall be measured from the center or one corner of the plate. An additional path shall be scanned within 2 in. (50 mm) of all edges of the plate on the scanning surface.

4.6 Where grid scanning is performed and complete loss of back reflection accompanied by continuous indications is detected along a given grid line, the entire surface area of the squares adjacent to this indication shall be scanned continuously. Where parallel path scanning is performed and complete loss of back reflection accompanied by continuous indications is detected, the entire surface area of a 9 by 9-in (230 by 230-mm) square centered on this indication shall be scanned continuously. The true boundaries where this condition exists shall be established in either method by the following technique: Move the transducer away from the center of the discontinuity until the heights of the back reflection and discontinuity indications are equal. Mark the plate at a point equivalent to the center of the transducer. Repeat the operation to establish the boundary.

5. Acceptance Standards

5.1 Any discontinuity indication causing a total loss of back reflection which cannot be contained within a circle, the diameter of which is 3 in. (75 mm) or one half of the plate thickness, whichever is greater, is unacceptable.

5.2 The manufacturer reserves the right to discuss rejectable ultrasonically tested plates with the purchaser with the object of possible repair of the ultrasonically indicated defect before rejection of the plate.

5.3 The purchaser's representative may witness the test.

6. Marking

6.1 Plates accepted in accordance with this specification shall be identified by stamping or stenciling UT 435 adjacent to marking required by ASTM Specification A 20, for General Requirements for Delivery of Steel Plates for Pressure Vessels.[3]

[3] *1974 Annual Book of ASTM Standards*, Part 4.

SUPPLEMENTARY REQUIREMENTS

The following shall apply only if specified in the order:

S1. Instead of the scanning procedure specified by 4.4 and 4.5, and as agreed upon between manufacturer and purchaser, 100% of one major plate surface shall be scanned. Scanning shall be continuous along parallel paths, transverse or parallel to the major plate axis, with not less than 10% overlap between each path.

Designation: A 446 – 72

American National Standard G8.27
American National Standards Institute

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Standard Specification for STEEL SHEET, ZINC COATED (GALVANIZED) BY THE HOT-DIP PROCESS, PHYSICAL (STRUCTURAL) QUALITY[1]

This Standard is issued under the fixed designation A 446; 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 sheet of physical (structural) quality in coils and cut lengths, zinc coated (galvanized). Sheet of this quality is intended primarily where mechanical or structural properties of the base metal are specified or required. Such properties or values include those indicated by tension, hardness, or other commonly accepted mechanical tests. Sheet of this quality can be produced in six grades, A through F, according to the base metal mechanical requirements prescribed in Table 2. Physical (structural) quality galvanized sheet is produced with any of the types of coating and coating designations listed in the latest revision of Specification A 525.

1.2 Sheet supplied under this specification shall meet all applicable requirements of the last revision of Specification A 525 unless otherwise specified herein.

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

3. Basis of Purchase

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

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

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

3.2.2 ASTM designation number, date of issue, and grade of product,

3.2.3 Coating designation and type of coating,

3.2.4 Specify whether chemically treated or non-chemically treated,

3.2.5 Specify whether oiled or not oiled,

3.2.6 Extra smooth (if required),

3.2.7 Phosphatized (if required),

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

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

3.2.10 End use (show part identification and description), and

3.2.11 Exceptions to the specification or special requirements.

NOTE 2—A typical ordering description is as follows: Galvanized Sheet, Physical (Structural) Quality, ASTM A 446 (date) Grade A, Coating Designation G 90, Minimized Spangle, Chemically Treated, Oiled. 0.0387 in. by 36.25 in. by Coil. 24 in. ID, 20,000 lb Maximum for Roof Deck.

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

Current edition approved Oct. 27, 1972. Published December 1972. Originally published as A 446 – 60 T. Last previous edition A 446 – 71.

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

4. Chemical Requirements

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

5. Mechanical Requirements

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

5.2 The base metal bend test shall be made on coated material. The specimen shall be capable of being bent at room temperature through 180 deg, longitudinal or transverse without major cracking of the base metal on the outside of the bent portion. The inside diameter of the bend shall have a relation to the thickness of the specimen as prescribed in Table 3. Due to the limited ductility of Grades D, E, and F, there are no bend test requirements, but they will withstand limited forming.

5.3 Two tension tests and two bend tests for base metal shall be made on random specimens of finished material from each heat. These specimens are prepared and tested in accordance with the methods specified in Specification A 525. When material rolled from one heat differs 0.050 in. (1.27 mm) or more in thickness, one tension test and one bend test shall be made from both the thickest and thinnest material rolled regardless of the weight represented.

6. Coating Bend Test

6.1 Material of this quality in Grades A, B, and C with coatings designated by the 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 (or mandrel equivalent) as shown in Table 4. Flaking of coating within ¼ in. (6.4 mm) of the edge of the bend specimen shall not be cause of rejection.

6.2 Since the base metal of Grades D, E, and F is not subject to the bend test, there are no coating bend requirements assigned to these grades.

6.3 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.

7. Dimensions and Tolerances

7.1 Except for flatness tolerances, all dimensions and tolerances are subject to the requirements of Specification A 525. Flatness tolerances of material supplied as physical (structural) quality shall conform to those prescribed in Table 5.

Explanatory Note

Note 1—The retest provisions of Specification A 525 are applicable to both base metal and coating tests.

TABLE 1 Chemical Requirements

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

TABLE 2 Mechanical Requirements, Base Metal

Grade	Yield Point, min	Tensile Strength, min	Elongation in 2 in. or 50 mm, min, percent
	psi (MPa)	psi (MPa)	
A	33 000 (228)	45 000 (310)	20
B	37 000 (255)	52 000 (359)	18
C	40 000 (276)	55 000 (380)	16
D	50 000 (345)	65 000 (448)	12
E	80 000[a] (552)	82 000 (565)	...
F	50 000 (345)	70 000 (483)	12

[a] The yield point approaches the tensile strength and since there is no halt in the gage or drop in the beam, the yield point should be taken as the stress at 0.5 percent elongation, under load.

TABLE 3 Base Metal Bend Tests

Grade	Ratio of the Bend Diameter to Thickness of the Specimen
A	1½
B	2
C	2½
D	[a]
E	[a]
F	[a]

[a] Base metal bend tests are not required for Grades D, E, and F.

TABLE 4 Coating Bend Test

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

Coating Designation	Ratio of the Bend Diameter to Thickness of the Specimen		
	Grade A	Grade B	Grade C
G 235	3	3	3
G 210	2	2	2½
G 185	2	2	2½
G 165	2	2	2½
G 140	2	2	2½
G 115	1½	2	2½
G 90	1½	2	2½
G 60	1½	2	2½
G 01	1½	2	2½

TABLE 5 Flatness Tolerances[a, b, c]

(Cut lengths only, not specified to stretcher leveled standard of flatness)

Specified Thickness, in. (mm)	Specified Width, in. (m)	Flatness Tolerance (Max Deviation From a Horizontal Flat Surface, in. (mm)
0.0606 (1.54) and thicker	To 60 (1.52) incl,	½ (12.7)
	Over 60 (1.52) to 72 (1.83) incl	¾ (19.1)
0.0605 (1.53) and thinner	To 36 (0.91) incl,	½ (12.7)
	Over 36 (0.91) to 60 (1.52) incl	¾ (19.1)
	Over 60 (1.52) to 72 (1.83) incl	1 (25.4)

[a] This table also applies to sheets cut to length from coils by the consumer when adequate flattening measures are performed.

[b] For Grade D and F use 1½ times the values given in this table.

[c] For Grade E, there are no defined flatness standards.