
Standard Method of Test for Mechanical Testing of Steel Products

AASHTO Designation: T 244-24¹

Technically Revised: 2024

Technical Subcommittee: 4f, Metals

ASTM Designation: A370-22



**American Association of State Highway and Transportation Officials
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1.

SCOPE

- 1.1.
- These test methods cover procedures and definitions for the mechanical testing of steel, stainless steels, and related alloys. The various mechanical tests herein described are used to determine properties required in the product specifications. Variations in testing methods are to be avoided and standard methods of testing are to be followed to obtain reproducible and comparable results. In those cases in which the testing requirements for certain products are unique or at variance with these general procedures, the product specification testing requirements shall control.
- 1.2.
- The following mechanical tests are described:

	Sections
Tension	7 to 14
Bend	15
Hardness	16
Brinell	17
Rockwell	18
Portable	19
Impact	20 to 29
Izod Impact	30

- 1.3.
- Annexes covering details peculiar to certain products are appended to these test methods as follows:

Bar products	Annex A
Tubular products	Annex B
Fasteners	Annex C
Round wire products	Annex D
Significance of notched-bar impact testing	Annex E
Converting percentage elongation of round specimens to equivalents for flat specimens	Annex F
Testing multiwire strand	Annex G
Rounding of test data	Annex H
Methods for testing steel reinforcing bars	Annex I
Procedure for use and control of heat-cycle simulation	Annex J
Mechanical Pull Testing of Wire and Welded Wire	Annex K

- 1.4. The values stated in SI (MPa) units are to be regarded as the standard.
- 1.5. When this document is referenced in a metric product specification, the yield and tensile values may be determined in inch-pound (ksi) units then converted into SI (MPa) units. The elongation determined in inch-pound gauge lengths of 2 or 8 in. may be reported in SI unit gauge lengths of 50 or 200 mm, respectively, as applicable. Conversely, when this document is referenced in an inch-pound product specification, the yield and tensile values may be determined in SI units and then converted into inch-pound units. The elongation determined in SI unit gauge lengths of 50 or 200 mm may be reported in inch-pound gauge lengths of 2 or 8 in., respectively, as applicable.
- 1.6. The specimen used to determine the original units must conform to the applicable tolerances of the original unit system given in the dimension table not that of the converted tolerance dimensions.
Note 1—This is due to the specimen SI dimensions and tolerances being hard conversions when this is not a dual standard. The user is directed to Test Methods A1058 if the tests are required in SI units.
- 1.7. Attention is directed to R 18 when there may be a need for information on criteria for evaluation of testing laboratories.
- 1.8. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*
- 1.9. *The quality of the results produced by this standard is dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
- M 170, Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe

- M 170M, Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe [Metric]
- M 206M/M 206, Standard Specification for Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories

2.2. *ASTM Standards:*

- A623, Standard Specification for Tin Mill Products, General Requirements
- A623M, Standard Specification for Tin Mill Products, General Requirements [Metric]
- A833, Standard Test Method for Indentation Hardness of Metallic Materials by Comparison Hardness Testers
- A956/A956M, Standard Test Method for Leeb Hardness Testing of Steel Products
- A1038, Standard Test Method for Portable Hardness Testing by the Ultrasonic Contact Impedance Method
- E4, Standard Practices for Force Verification of Testing Machines
- E6, Standard Terminology Relating to Methods of Mechanical Testing
- E8/E8M, Standard Test Methods for Tension Testing of Metallic Materials
- E10, Standard Test Method for Brinell Hardness of Metallic Materials
- E18, Standard Test Methods for Rockwell Hardness of Metallic Materials
- E23, Standard Test Methods for Notched Bar Impact Testing of Metallic Materials
- E29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E83, Standard Practice for Verification and Classification of Extensometer Systems
- E110, Standard Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers
- E190, Standard Test Method for Guided Bend Test for Ductility of Welds
- E290, Standard Test Methods for Bend Testing of Material for Ductility

2.3. *ASME Code:*

- ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Part UG-84.²

3. TERMINOLOGY

- 3.1. For definitions of terms pertaining to tension testing, including tensile strength, yield point, yield strength, elongation, and reduction of area, reference shall be made to ASTM E6.
- 3.2. *Definitions of Terms Specific to This Standard:*
- 3.2.1. *fixed-location hardness testing machine*—Hardness testing machine that is designed for routine operations in a fixed location by the users and is not designed to be transported, carried, or moved.
- 3.2.2. *longitudinal test*—Unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is parallel to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a longitudinal test specimen is in the direction of the greatest extension, and the axis of the fold of a longitudinal bend test specimen is at right angles to the direction of greatest extension (Figures 1, 2(a), and 2(b)).
- 3.2.3. *Portable hardness testing machine*—Hardness testing machine that is designed to be transported, carried, and set up, and that measures hardness in accordance with the test methods in Section 19.

- 3.2.4. *radial test*—Unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to the axis of the product and coincident with one of the radii of a circle drawn with a point on the axis of the product as a center (Figure 2(a)).
- 3.2.5. *tangential test*—Unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a center (Figures 2(a), 2(b), 2(c), and 2(d)).
- 3.2.6. *transition temperature*—The temperature at which the designated material test value equals or exceeds a specified minimum test value.
- 3.2.7. *transverse test*—Unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is at right angles to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a transverse tension test specimen is at right angles to the greatest extension, and the axis of the fold of a transverse bend test specimen is parallel to the greatest extension (Figure 1).

4. SIGNIFICANCE AND USE

- 4.1. The primary use of these test methods is to determine the specified mechanical properties of steel, stainless steel, and related alloy products for the evaluation of conformance of such products to a material specification as designated by a purchaser in a purchase order or contract.
- 4.1.1. The material condition at the time of testing, sampling frequency, specimen location and orientation, reporting requirements, and other parameters are contained in the pertinent material specification or in a General Requirement Specification for the particular product form.
- 4.1.2. Some material specifications require the use of additional test methods not described herein; in such cases, the required test method is described in the material specification or by reference to another appropriate test method standard.
- 4.2. These test methods are also suitable to be used for testing steel, stainless steel, and related alloy materials for other purposes, such as incoming material acceptance testing by the purchaser or evaluation of components after service exposure.
- 4.2.1. As with any mechanical testing, deviations from either specification limits or expected as-manufactured properties can occur for valid reasons besides deficiency of the original as-fabricated product. These reasons include, but are not limited to: subsequent service degradation from environmental exposure (for example, temperature, corrosion); static or cyclic service stress effects, mechanically-induced damage, material inhomogeneity, anisotropic structure, natural aging of select alloys, further processing not included in the specification, sampling limitations, and measuring equipment calibration uncertainty. There is statistical variation in all aspects of mechanical testing and variations in test results from prior tests are expected. An understanding of possible reasons for deviation from specified or expected test values should be applied in interpretation of test results.

5. GENERAL PRECAUTIONS

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

- 5.2. Improperly machined specimens should be discarded and other specimens substituted.
- 5.3. Flaws in the specimen may also affect results. If any test specimen develops flaws, the retest provision of the applicable product specification shall govern.
- 5.4. If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

6. ORIENTATION OF TEST SPECIMENS

- 6.1. The terms “longitudinal test” and “transverse test” are used only in material specifications for wrought products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:
 - 6.1.1. *Longitudinal Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is parallel to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a longitudinal tension test specimen is in the direction of the greatest extension, and the axis of the fold of a longitudinal bend test specimen is at right angles to the direction of greatest extension (Figures 1, 2(a), and 2(b)).
 - 6.1.2. *Transverse Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is at right angles to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a transverse tension test specimen is at right angles to the greatest extension, and the axis of the fold of a transverse bend test specimen is parallel to the greatest extension (Figure 1).

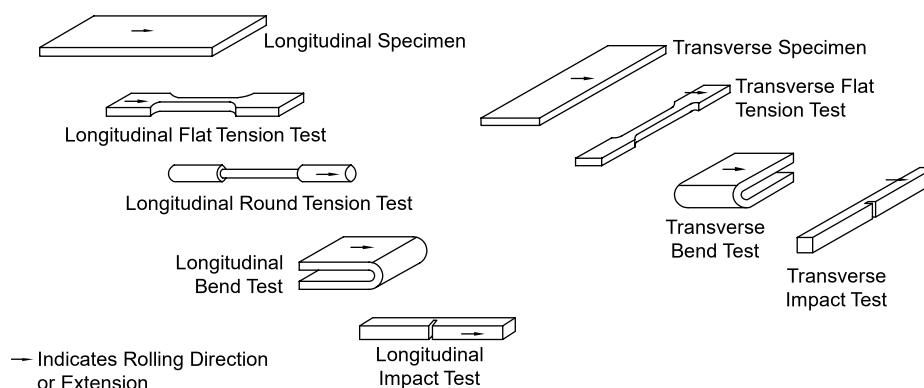


Figure 1—The Relation of Test Coupons and Test Specimens to Rolling Direction or Extension (Applicable to General Wrought Products)

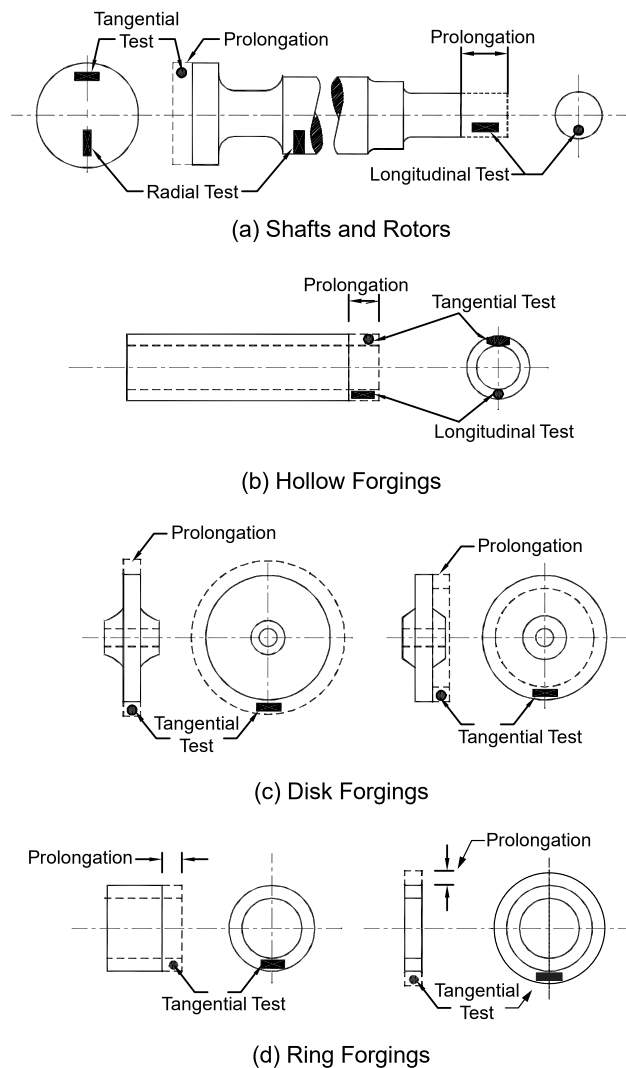


Figure 2—Locations of Longitudinal Tension Test Specimens in Rings Cut from Tubular Products

- 6.2. The terms “radial test” and “tangential test” are used in material specifications for some wrought circular products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:
- 6.2.1. *Radial Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to the axis of the product and coincident with one of the radii of a circle drawn with a point on the axis of the product as a center (Figure 2(a)).
- 6.2.2. *Tangential Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a center (Figures 2(a), 2(b), 2(c), and 2(d)).

TENSION TEST

7. DESCRIPTION
- 7.1.

The tension test related to the mechanical testing of steel products subjects a machined or full-section specimen of the material under examination to a measured load sufficient to cause rupture. The resulting properties sought are defined in ASTM E6.
- 7.2.

In general, the testing equipment and methods are given in ASTM E8/E8M. However, there are certain exceptions to ASTM E8/E8M practices in the testing of steel, and they are covered in these test methods.

8. TESTING APPARATUS AND OPERATIONS

- 8.1.

Loading Systems—There are two general types of loading systems, mechanical (screw power) and hydraulic. These differ chiefly in the variability of the rate of load application. The older screw power machines are limited to a small number of fixed free-running crosshead speeds. Some modern screw power machines and all hydraulic machines permit stepless variation throughout the range of speeds.
- 8.2.

The tension testing machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision to ASTM E4.
Note 2—Many machines are equipped with stress–strain recorders for autographic plotting of stress–strain curves. It should be noted that some recorders have a load measuring component entirely separate from the load indicator of the testing machine. Such recorders are calibrated separately.
- 8.3.

Loading—It is the function of the gripping or holding device of the testing machine to transmit the load from the heads of the machine to the specimen under test. The essential requirement is that the load shall be transmitted axially. This implies that the centers of the action of the grips shall be in alignment, insofar as practicable, with the axis of the specimen at the beginning and during the test, and that bending or twisting be held to a minimum. For specimens with a reduced section, gripping of the specimen shall be restricted to the grip section. In the case of certain sections tested in full size, nonaxial loading is unavoidable and, in such cases, shall be permissible.
- 8.4.

Speed of Testing—The speed of testing shall not be greater than that at which load and strain readings can be made accurately. In production testing, speed of testing is commonly expressed (1) in terms of free-running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), or (2) in terms of rate of separation of the two heads of the testing machine under load, or (3) in terms of rate of stressing the specimen, or (4) in terms of rate of straining the specimen. The following limitations on the speed of testing are recommended as adequate for most steel products:
Note 3—Tension tests using closed-loop machines (with feedback control of rate) should not be performed using load control, as this mode of testing will result in acceleration of the crosshead on yielding and elevation of the measured yield strength.
- 8.4.1.

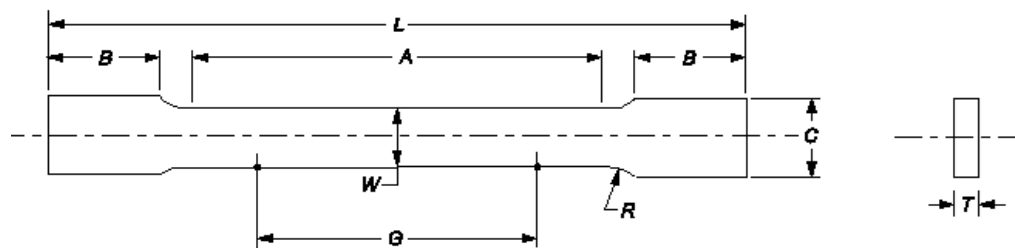
Any convenient speed of testing may be used up to one-half the specified yield point or yield strength. When this point is reached, the free-running rate of separation of the crossheads shall be adjusted so as not to exceed 0.063 mm per minute per millimeter ($\frac{1}{16}$ in. per minute per inch) of reduced section or the distance between the grips for test specimens not having reduced sections. This speed shall be maintained through the yield point or yield strength. In determining the tensile strength, the free-running rate of separation of the heads shall not exceed 0.5 mm per minute per

millimeter ($1/2$ in. per minute per inch) of reduced section or the distance between the grips for test specimens not having reduced sections. In any event, the minimum speed of testing shall not be less than $1/10$ the specified maximum rates for determining yield point or yield strength and tensile strength.

- 8.4.2. It shall be permissible to set the speed of the testing machine by adjusting the free-running crosshead speed to the above specified values, inasmuch as the rate of separation of heads under load at these machine settings is less than the specified values of free-running crosshead speed.
- 8.4.3. As an alternative, if the machine is equipped with a device to indicate the rate of loading, the speed of the machine from half the specified yield point or yield strength through the yield point or yield strength may be adjusted so that the rate of stressing does not exceed 690 MPa (100,000 psi)/min. However, the minimum rate of stressing shall not be less than 70 MPa (10,000 psi)/min.

9. TEST SPECIMEN PARAMETERS

- 9.1. *Selection*—Test coupons shall be selected in accordance with the applicable product specifications.
- 9.1.1. *Wrought Steels*—Wrought steel products are usually tested in the longitudinal direction, but in some cases, where size permits and the service justifies it, testing is in the transverse, radial, or tangential direction. (See Figures 1 and 2.)
- 9.1.2. *Forged Steels*—For open die forgings, the metal for tension testing is usually provided by allowing extensions or prolongations on one or both ends of the forgings, either on all or a representative number as provided by the applicable product specifications. Test specimens are normally taken at mid-radius. Certain product specifications permit the use of a representative bar or the destruction of a production part for test purposes. For ring or disk-like forgings, test metal is provided by increasing the diameter, thickness, or length of the forging. Upset disk or ring forgings, which are worked or extended by forging in a direction perpendicular to the axis of the forging, usually have their principal extension along concentric circles and, for such forgings, tangential tension specimens are obtained from extra metal on the periphery or end of the forging. For some forgings, such as rotors, radial tension tests are required. In such cases, the specimens are cut or trepanned from specified locations.
- 9.2. *Size and Tolerances*—Test specimens shall be (1) the full cross section of material or (2) machined to the form and dimensions shown in Figures 3 through 6. The selection of size and type of specimen is prescribed by the applicable product specification. Full cross-section specimens shall be tested in 200-mm (8-in.) gauge lengths unless otherwise specified in the product specification.
- 9.3. *Procurement of Test Specimens*—Specimens shall be extracted by any convenient method, taking care to remove all distorted, cold-worked, or heat-affected areas from the edges of the section used in evaluating the material. Specimens usually have a reduced cross section at to ensure uniform distribution of the stress over the cross section and localize the zone of fracture.



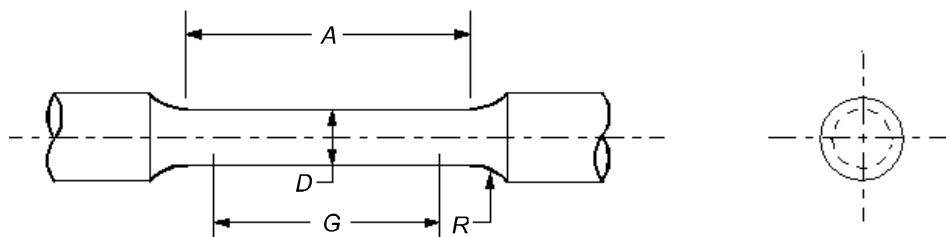
Dimensions

	Standard Specimens						Subsize Specimens	
	Plate-Type, 40-mm (1½ in.) Wide						Sheet Type, 12.5-mm (½ in.) Wide	
	200-mm (8-in.) Gauge Length		50-mm (2-in.) Gauge Length		Sheet Type, 12.5-mm (½ in.) Wide		6-mm (¼-in.) Wide	
	mm	in.	mm	in.	mm	in.	mm	in.
G—Gauge length (Notes 1 and 2)	200 ± 0.25	8.00 ± 0.01	50.0 ± 0.10	2.000 ± 0.005	50.0 ± 0.10	2.000 ± 0.005	25.0 ± 0.08	1.000 ± 0.003
W—Width (Notes 3, 5, and 6)	40 + 3 – 6	1½ + ⅛ – ¼	40 + 3 – 6	1½ + ⅛ – ¼	12.5 ± 0.25	0.500 ± 0.010	6.25 ± 0.05	0.250 ± 0.002
T—Thickness (Note 7)	Thickness of Material							
R—Radius of fillet, min (Note 4)	13	½	13	½	13	½	6	¼
L—Overall length, min (Notes 2 and 8)	450	18	200	8	200	8	100	4
A—Length of reduced section, min	225	9	60	2¼	60	2¼	32	1¼
B—Length of grip section, min (Note 9)	75	3	50	2	50	2	32	1¼
C—Width of grip section, approximate (Notes 4, 10, and 11)	50	2	50	2	20	¾	10	⅜

Notes:

- For the 40-mm (1½-in.) wide specimen, punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the reduced section. For the 200-mm (8-in.) gauge length specimen, a set of nine or more punch marks 25 mm (1 in.) apart or one or more pairs of punch marks 200 mm (8 in.) apart may be used. For the 50-mm (2-in.) gauge length specimen, a set of three or more punch marks 25 mm (1 in.) apart or one or more pairs of punch marks 50 mm (2 in.) apart may be used.
- For the 12.5-mm (½-in.) wide specimen, punch marks for measuring the elongation after fracture shall be made on the flat face or edge of the specimen and within the reduced section. Either a set of three or more punch marks 25 mm (1 in.) apart or one or more pairs of punch marks 50 mm (2 in.) apart may be used.
- For the four sizes of specimens, the ends of the reduced section shall not differ in width by more than 0.10, 0.10, 0.05, or 0.025 mm (0.004, 0.004, 0.002, or 0.001 in.), respectively. Also, there may be a gradual decrease in width from the ends to the center, but the width at either end shall not be more than 0.40, 0.40, 0.10, or 0.06 mm (0.015, 0.015, 0.005, 0.003 in.), respectively, larger than the width at the center.
- For each specimen type, the radii of all fillets shall be equal to each other with a tolerance of 1.25 mm (0.05 in.), and the centers of curvature of the two fillets at a particular end shall be located across from each other (on a line perpendicular to the centerline) within a tolerance of 2.5 mm (0.10 in.).
- For each of the four sizes of specimens, narrower widths (W or C) may be used when necessary. In such cases, the width of the reduced section should be as large as the width of the material being tested permits; however, unless stated specifically, the requirements for elongation in a product specification shall not apply when these narrower specimens are used. If the width of the material is less than W, the sides may be parallel throughout the length of the specimen.
- The specimen may be modified by making the sides parallel throughout the length of the specimens, the width and tolerances being the same as those specified above. When necessary, a narrower specimen may be used, in which case the width should be as great as the width of the material being tested permits. If the width is 38 mm (1½ in.) or less, the sides may be parallel throughout the length of the specimen.
- The dimension T is the thickness of the test specimen as provided for in the applicable product specifications. Minimum nominal thickness of 40-mm (1- to 1½-in.) wide specimens shall be 5 mm (⅜ in.), except as permitted by the product specification. Maximum nominal thickness of 12.5-mm (½-in.) and 6.25-mm (¼-in.) wide specimens shall be 19 mm and 6 mm (¾ and ¼ in.), respectively.
- To aid in obtaining axial loading during testing of 6.25-mm (¼-in.) wide specimens, the overall length should be as the material will permit.
- It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips. If the thickness of 12.5-mm (½-in.) wide specimens is greater than 10 mm (⅜ in.), longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.
- For standard sheet type specimens and subsize specimens, the ends of the specimen shall be symmetrical with the centerline of the reduced section within 0.25 and 0.13 mm (0.01 and 0.005 in.), respectively, except that, for steel, if the ends of the 12.5-mm (½-in.) wide specimen are symmetrical within 1.0 mm (0.05 in.), a specimen may be considered satisfactory for all but referee testing.
- For standard plate-type specimens, the ends of the specimen shall be symmetrical with the centerline of the reduced section within 6.4 mm (0.25 in.) except for referee testing, in which case the ends of the specimen shall be symmetrical with the centerline of the reduced section within 2.5 mm (0.10 in.).

Figure 3—Rectangular Tension Test Specimens



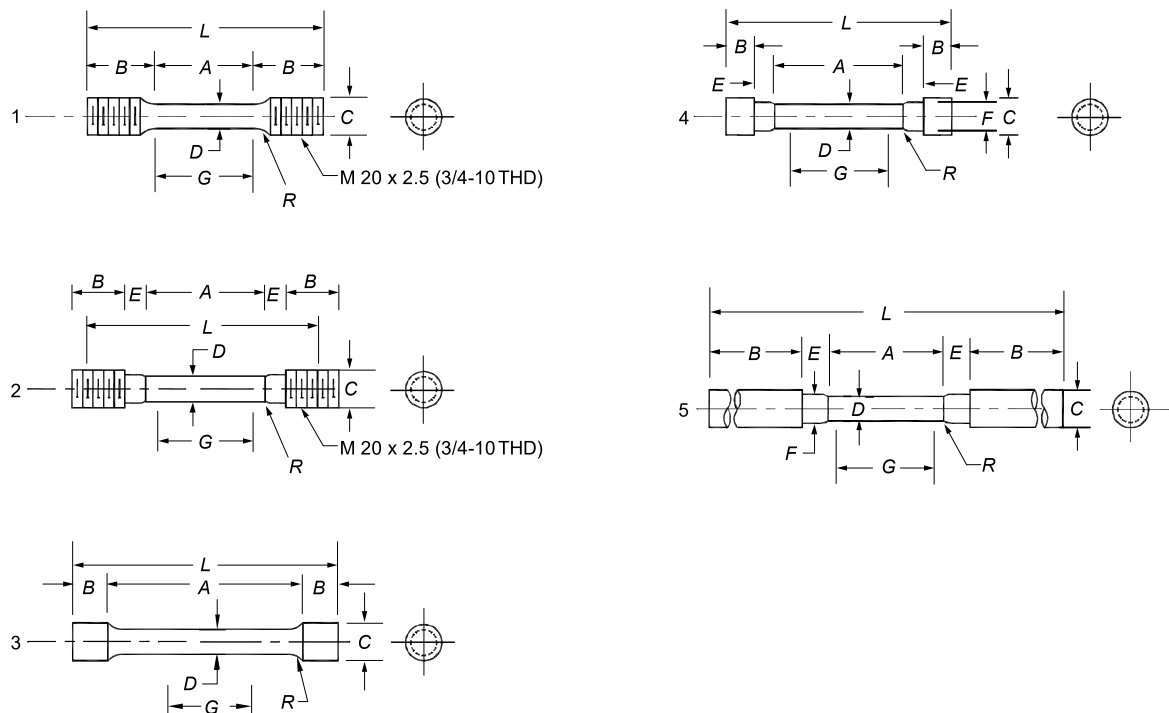
Dimensional Equivalents

	Standard Specimen		Small-Size Specimen Projectional to Standard							
	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
Nominal Diameter	12.50	0.500	8.75	0.350	6.25	0.250	4.00	0.160	2.50	0.113
G—Gauge length	50.00 ± 0.10	2.000 ± 0.005	35.00 ± 0.10	1.400 ± 0.005	25.00 ± 0.10	1.000 ± 0.005	16.00 ± 0.10	0.640 ± 0.005	10.00 ± 0.10	0.450 ± 0.005
D—Diameter (Note 1)	12.50 ± 0.25	0.500 ± 0.010	8.75 ± 0.18	0.350 ± 0.007	6.25 ± 0.12	0.250 ± 0.005	4.00 ± 0.08	0.160 ± 0.003	2.50 ± 0.05	0.113 ± 0.002
R—Radius of fillet, minimum	10	³ / ₈	6	¹ / ₄	5	³ / ₁₆	4	⁵ / ₃₂	2	³ / ₃₂
A—Length of reduced section, minimum (Note 2)	60	2 ¹ / ₄	45	1 ³ / ₄	32	1 ¹ / ₄	20	³ / ₄	16	⁵ / ₈

Notes:

1. The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 percent larger in diameter than the center (controlling dimension).
2. If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gauge length. Reference marks for the measurement of elongation should, nevertheless, be spaced at the indicated gauge length.
3. The gauge length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. (See Figure 5.) If the ends are to be held in wedge grips, it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.
4. On the round specimens in Figures 5 and 6, the gauge lengths are equal to four times the nominal diameter. In some product specifications, other specimens may be provided for, but unless the 4:1 ratio is maintained within dimensional tolerances, the elongation values may not be comparable with those obtained from the standard test specimen.
5. The use of specimens smaller than 6.25-mm (0.250-in.) diameter shall be restricted to cases in which the material to be tested is of sufficient size to obtain larger specimens or when all parties agree to their use for acceptance testing. Smaller specimens require suitable equipment and greater skill in both matching and testing.
6. Five sizes of specimens often used have diameters of approximately 0.505, 0.357, 0.252, 0.160, and 0.113 in., the reason being to permit easy calculations of stresses from loads, because the corresponding cross-sectional areas are equal to 0.200, 0.100, 0.0500, 0.0200, and 0.0100 in.², respectively. Thus, when the actual diameters agree with these values, the stresses (or strengths) may be computed using the simple multiplying factors 5, 10, 20, 50, and 100, respectively. (The metric equivalents of these fixed diameters do not result in correspondingly convenient cross-sectional area and multiplying factors.)

Figure 4—Standard 12.5-mm (0.500-in.) Round Tension Test Specimen with 50-mm (2-in.) Gauge Length and Examples of Small-Size Specimens Proportional to the Standard Specimen



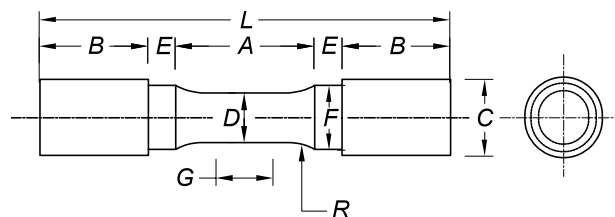
Dimensional Equivalents

	Specimen 1		Specimen 2		Specimen 3		Specimen 4		Specimen 5	
	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
G—Gauge length	50.00 ± 0.10	2.000 ± 0.005	50.00 ± 0.10	2.000 ± 0.005	50.00 ± 0.10	2.000 ± 0.005	50.00 ± 0.10	2.000 ± 0.005	50.00 ± 0.10	2.000 ± 0.005
D—Diameter (Note 1)	12.50 ± 0.25	0.500 ± 0.010	12.50 ± 0.25	0.500 ± 0.010	12.50 ± 0.25	0.500 ± 0.010	12.50 ± 0.25	0.500 ± 0.010	12.50 ± 0.25	0.500 ± 0.010
R—Radius of fillet, min	10	³ / ₈	10	³ / ₈	2	¹ / ₁₆	10	³ / ₈	10	³ / ₈
A—Length of reduced section	60, min	2 ¹ / ₄ , min	60, min	2 ¹ / ₄ , min	100, approximately	4, approximately	60, min	2 ¹ / ₄ , min	60, min	2 ¹ / ₄ , min
L—Overall length, approximate	125	5	140	5 ¹ / ₂	140	5 ¹ / ₂	120	4 ³ / ₄	240	9 ¹ / ₂
B—Length grip section (Note 2)	35, approximately	1 ³ / ₈ , approximately	25, approximately	1, approximately	20, approximately	³ / ₄ , approximately	13, approximately	¹ / ₂ , approximately	75, min	3, min
C—Diameter of end section	20	³ / ₄	20	³ / ₄	18	²³ / ₃₂	22	⁷ / ₈	20	³ / ₄
E—Length of shoulder and fillet section, approximate	—	—	16	⁵ / ₈	—	—	20	³ / ₄	16	⁵ / ₈
F—Diameter of shoulder	—	—	16	⁵ / ₈	—	—	16	⁵ / ₈	15	¹⁹ / ₃₂

Notes:

- The reduced section may have a gradual taper from the ends towards the center, with the ends not more than 0.10 mm (0.005 in.) larger in diameter than the center.
- On Specimen 5, it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.
- The types of ends shown are applicable for the standard 0.500-in. round tension test specimen; similar types can be used for subsize specimens. The use of UNF series of threads (³/₄ by 16, ¹/₂ by 20, ³/₈ by 24, and ¹/₄ by 28) is suggested for high-strength brittle materials to avoid fracture in the thread portion.

Figure 5—Suggested Types of Ends for Standard Round Tension Test Specimen



Dimensional Equivalents

	Specimen 1		Specimen 2		Specimen 3	
	mm	in.	mm	in.	mm	in.
G—Length of parallel	Shall be equal to or greater than diameter <i>D</i>					
D—Diameter	12.50 ± 0.25	0.500 ± 0.010	20.00 ± 0.40	0.750 ± 0.015	30.00 ± 0.60	1.250 ± 0.025
R—Radius of fillet, min	25	1	25	1	50	2
A—Length of reduced section, min	32	1 1/4	38	1 1/2	60	2 1/4
L—Overall length, min	95	3 3/4	100	4	160	6 3/8
B—Length of grip section, approximate	25	1	25	1	45	1 3/4
C—Diameter of end section, approximate	20	3/4	30	1 1/8	48	1 7/8
E—Length of shoulder, min	6	1/4	6	1/4	8	5/16
F—Diameter of shoulder	16.00 ± 0.40	5/8 ± 1/64	24.00 ± 0.40	1 5/16 ± 1/64	36.50 ± 0.40	1 7/16 ± 1/64

Note: The reduced section and shoulders (dimensions A, D, E, F, G, and R) shall be shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. Commonly, the ends are threaded and have the dimensions *B* and *C* given above.

Figure 6—Standard Tension Test Specimens for Cast Iron

- 9.4. *Aging of Test Specimens*—Unless otherwise specified, it shall be permissible to age tension test specimens. The time–temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature for 24 to 48 h, or in a shorter time at moderately elevated temperatures by boiling in water, or heating in oil or in an oven.
- 9.5. *Measurement of Dimensions of Test Specimens:*
 - 9.5.1. *Standard Rectangular Tension Test Specimens*—These forms of specimens are shown in Figure 3. To determine the cross-sectional area, the center width dimension shall be measured to the nearest 0.13 mm (0.005 in.) for the 200-mm (8-in.) gauge length specimen and 0.025 mm (0.001 in.) for the 50-mm (2-in.) gauge length specimen in Figure 3. The center thickness dimension shall be measured to the nearest 0.025 mm (0.001 in.) for both specimens.
 - 9.5.2. *Standard Round Tension Test Specimens*—These forms of specimens are shown in Figures 4 and 5. To determine the cross-sectional area, the diameter shall be measured at the center of the gauge length to the nearest 0.025 mm (0.001 in.). (See Tables 1 and 2.)
- 9.6. *General*—Test specimens shall be either substantially full-size or machined, as prescribed in the product specifications for the material being tested.
 - 9.6.1. It is desirable to have the cross-sectional area of the specimen smallest at the center of the gauge length to ensure fracture within the gauge length. This is provided for by the taper in the gauge length permitted for each of the specimens described in the following sections.
 - 9.6.2. For brittle materials, it is desirable to have fillets of a large radius at the ends of the gauge length.

Table 1—Multiplying Factors to Be Used for Various Diameters of Round Test Specimens

Standard Specimen			Small-Sized Specimens Proportional to Standard					
12.5-mm Round			8.75-mm Round			6.25-mm Round		
Actual Dia, mm	Area, 10 ⁻⁶ m ²	Factor, 10 ³ /m ²	Actual Dia, mm	Area, 10 ⁻⁶ m ²	Factor, 10 ³ /m ²	Actual Dia, mm	Area, 10 ⁻⁶ m ²	Factor, 10 ³ /m ²
12.25	117.9	8.485	8.57	57.68	17.34	6.13	29.51	33.88
12.26	118.1	8.471	8.58	57.82	17.30	6.14	29.61	33.77
12.27	118.2	8.457	8.59	57.95	17.26	6.15	29.71	33.66
12.28	118.4	8.443	8.60	58.09	17.22	6.16	29.80	33.55
12.29	118.6	8.430	8.61	58.22	17.18	6.17	29.90	33.45
12.30	118.8	8.416	8.62	58.36	17.14	6.18	30.00	33.34
12.31	119.0	8.402	8.63	58.49	17.10	6.19	30.09	33.23
12.32	119.2	8.389	8.64	58.63	17.06	6.20	30.19	33.12
12.33	119.4	8.375	8.65	58.77	17.02	6.21	30.29	33.02
12.34	119.6	8.361	8.66	58.90	16.98	6.22	30.39	32.91
12.35	119.8	8.348	8.67	59.04	16.94	6.23	30.48	32.80
12.36	120.0	8.334	8.68	59.17	16.90	6.24	30.58	32.70
12.37	120.2	8.321	6.69	59.31	16.86	6.25	30.68	32.59
12.38	120.4	8.307	8.70	59.45	16.82	6.26	30.78	32.49
12.39	120.6	8.294	8.71	59.58	16.78	6.27	30.88	32.39
12.40	120.8	8.281	8.72	59.72	16.74	6.28	30.97	32.28
12.41	121.0	8.267	8.73	59.86	16.71	6.29	31.07	32.18
12.42	121.2	8.254	8.74	59.99	16.67	6.30	31.17	32.08
12.43	121.3	8.241	8.75	60.13	16.63	6.31	31.27	31.98
12.44	121.5	8.228	8.76	60.27	16.59	6.32	31.37	31.88
12.45	121.7	8.214	8.77	60.41	16.55	6.33	31.47	31.78
12.46	121.9	8.201	8.78	60.55	16.52	6.34	31.57	31.68
12.47	122.1	8.188	8.79	60.68	16.48	6.35	31.67	31.58
12.48	122.3	8.175	8.80	60.82	16.44	6.36	31.77	31.48
12.49	122.5	8.162	8.81	60.96	16.40	6.37	31.87	31.38
12.50	122.7	8.149	8.82	61.10	16.37			
12.51	122.9	8.136	8.83	61.24	16.33			
12.52	123.1	8.123	8.84	61.38	16.29			
12.53	123.3	8.110	8.85	61.51	16.26			
12.54	123.5	8.097	8.86	61.65	16.22			
12.55	123.7	8.084	8.87	61.79	16.18			
12.56	123.9	8.071	8.88	61.93	16.15			
12.57	124.1	8.058	8.89	62.07	16.11			
12.58	124.3	8.045	8.90	62.21	16.07			
12.59	124.5	8.033	8.91	62.35	16.04			
12.60	124.7	8.020	8.92	62.49	16.00			
12.61	124.9	8.007	8.93	62.63	15.97			
12.62	125.1	7.995						
12.63	125.3	7.982						
12.64	125.5	7.969						
12.65	125.7	7.957						
12.66	125.9	7.944						
12.67	126.1	7.932						
12.68	126.3	7.919						
12.69	126.5	7.907						
12.70	126.7	7.894						
12.71	126.9	7.882						
12.72	127.1	7.869						
12.73	127.3	7.857						
12.74	127.5	7.845						
12.75	127.7	7.832						

Table 2—Multiplying Factors to Be Used for Various Diameters of Round Test Specimens

Standard Specimen 0.500-in. Round			Small-Sized Specimens Proportional to Standard					
Actual Dia, in.	Area, in. ²	Multiplying Factor	0.350-in. Round			0.250-in. Round		
			Actual Dia, in.	Area, in. ²	Multiplying Factor	Actual Dia, in.	Area, in. ²	Multiplying Factor
0.490	0.1886	5.30	0.343	0.0924	10.82	0.245	0.0471	21.21
0.491	0.1893	5.28	0.344	0.0929	10.76	0.246	0.0475	21.04
0.492	0.1901	5.26	0.345	0.0935	10.70	0.247	0.0479	20.87
0.493	0.1909	5.24	0.346	0.0940	10.64	0.248	0.0483	20.70
0.494	0.1917	5.22	0.347	0.0946	10.57	0.249	0.0487	20.54
0.495	0.1924	5.20	0.348	0.0951	10.51	0.250	0.0491	20.37
							0.0495	20.21
0.496	0.1932	5.18	0.349	0.0957	10.45	0.251	(0.05) ^a	(20.0) ^a
							0.0499	20.05
0.497	0.1940	5.15	0.350	0.0962	10.39	0.252	(0.05) ^a	(20.0) ^a
							0.0503	19.89
0.498	0.1948	5.13	0.351	0.0968	10.33	0.253	(0.05) ^a	(20.0) ^a
0.499	0.1956	5.11	0.352	0.0973	10.28	0.254	0.0507	19.74
0.500	0.1963	5.09	0.353	0.0979	10.22	0.255	0.0511	19.58
0.501	0.1971	5.07	0.354	0.0984	10.16			
0.502	0.1979	5.05	0.355	0.0990	10.10			
				0.0995	10.05			
0.503	0.1987	5.03	0.356	(0.1) ^a	(10.0) ^a			
	0.1995	5.01		0.1001	9.99			
0.504	(0.2) ^a	(5.0) ^a	0.357	(0.1) ^a	(10.0) ^a			
	0.2003	4.99						
0.505	(0.2) ^a	(5.0) ^a						
	0.2011	4.97						
0.506	(0.2) ^a	(5.0) ^a						
0.507	0.2019	4.95						
0.508	0.2027	4.93						
0.509	0.2035	4.91						
0.510	0.2043	4.90						

^a The values in parentheses may be used for ease in calculation of stresses, in pounds per square inch, as permitted in Note 6 of Figure 4.

10. PLATE-TYPE SPECIMENS

- 10.1. The standard plate-type test specimens are shown in Figure 3. Such specimens are used for testing metallic materials in the form of plate, structural and bar-sized shapes, and flat material having a nominal thickness of 5 mm ($\frac{3}{16}$ in.) or more. When product specifications so permit, other types of specimens may be used.

Note 4—When called for in the product specification, the 200-mm (8-in.) gauge length specimen of Figure 3 may be used for sheet and strip material.

11. SHEET-TYPE SPECIMEN

- 11.1. The standard sheet-type test specimen is shown in Figure 3. This specimen is used for testing metallic materials in the form of sheet, plate, flat wire, strip, band, and hoop ranging in nominal thickness from 0.13 to 25 mm (0.005 to 1 in.). When product specifications so permit, other types of specimens may be used, as provided in Section 10. (See Note 4.)

12. ROUND SPECIMENS

- 12.1. The standard 12.5-mm (0.500-in.) diameter round test specimen shown in Figure 4 is used quite generally for testing metallic materials.
- 12.2. Figure 4 also shows small-sized specimens proportional to the standard specimen. These may be used when it is necessary to test material from which the standard specimen or specimens shown in Figure 3 cannot be prepared. Other sizes of small round specimens may be used. In any such small-sized specimen, it is important that the gauge length for measurement of elongation be four times the diameter of the specimen. (See Note 4 in Figure 4.)
- 12.3. The type of specimen ends outside of the gauge length shall accommodate the shape of the product tested and shall properly fit the holders or grips of the testing machine so that axial loads are applied with a minimum of load eccentricity and slippage. Figure 5 shows specimens with various types of ends that have given satisfactory results.

13. GAUGE MARKS

- 13.1. The specimens shown in Figures 3 through 6 shall be gauge-marked with a center punch, scribe marks, multiple device, or drawn with ink. The purpose of these gauge marks is to determine the percentage elongation. Punch marks shall be light, sharp, and accurately spaced. The localization of stress at the marks makes a hard specimen susceptible to starting fracture at the punch marks. The gauge marks for measuring elongation after fracture shall be made on the flat or on the edge of the flat tension test specimen and within the parallel section; for the 200-mm (8-in.) gauge length specimen, Figure 3; one or more sets of 200-mm (8-in.) gauge marks may be used, intermediate marks within the gauge length being optional. Rectangular 50-mm (2-in.) gauge length specimens, Figure 3, and round specimens, Figure 4, are gauge-marked with a double-pointed center punch or scribe marks. One or more sets of gauge marks may be used; however, one set must be approximately centered in the reduced section. These same precautions shall be so observed when the test specimen is full section.

14. DETERMINATION OF TENSILE PROPERTIES

- 14.1. *Yield Point*—Yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. Yield point is intended for application only for materials that may exhibit the unique characteristic of showing an increase in strain without an increase in stress. The stress–strain diagram is characterized by a sharp knee or discontinuity. Determine yield point by one of the following methods:
- 14.1.1. *Drop of the Beam or Halt-of-the-Pointer Method*—In this method, apply an increasing load to the specimen at a uniform rate. When a lever and poise machine is used, keep the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of the load will stop; but run the poise a trifle beyond the balance position, and the beam of the machine will drop for a brief, but appreciable, interval of time. When a machine equipped with a load-indicating dial is used, there is a halt or hesitation of the load-indicating pointer corresponding to the drop of the beam. Note the load at the “drop of the beam” or the “halt of the pointer” and record the corresponding stress as the yield point.
- 14.1.2. *Autographic Diagram Method*—When a sharp-kneed stress–strain diagram is obtained by an autographic recording device, take the stress corresponding to the top of the knee (Figure 7), or the stress at which the curve drops as the yield point.

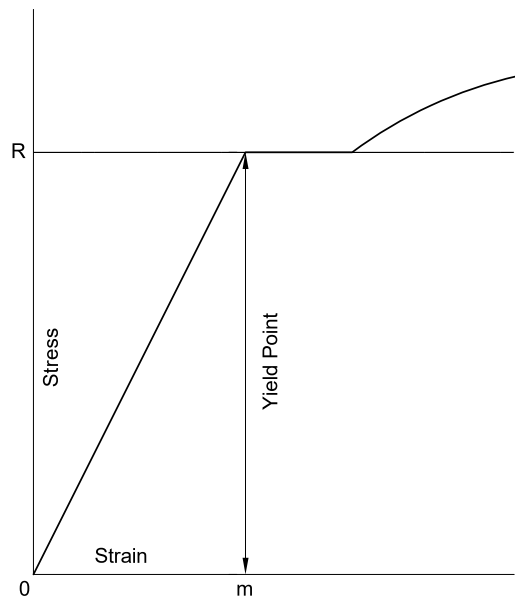


Figure 7—Stress–Strain Diagram Showing Yield Point Corresponding with Top of Knee

- 14.1.3. *Total Extension-under-Load Method*—When testing material for yield point and the test specimens may not exhibit a well-defined disproportionate deformation that characterizes a yield point as measured by the drop of the beam, halt-of-the-pointer, or autographic diagram methods described in Sections 14.1.1 and 14.1.2, a value equivalent to the yield point in its practical significance may be determined by the following method and may be recorded as yield point: Attach a Class C or better extensometer (Notes 5 and 6) to the specimen. When the load producing a specified extension (Note 7) is reached, record the stress corresponding to the load as the yield point (Figure 8).

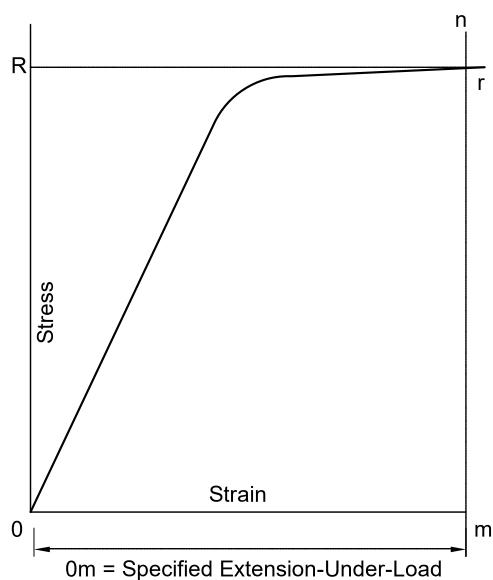


Figure 8—Stress–Strain Diagram Showing Yield Point or Yield Strength by Extension-Under-Load Method

Note 5—Automatic devices are available that determine the load at the specified total extension without plotting a stress–strain curve. Such devices may be used if their accuracy has been demonstrated. Multiplying calipers and other such devices are acceptable for use provided their accuracy has been demonstrated to be equivalent to a Class C extensometer.

Note 6—Reference should be made to ASTM E83.

Note 7—For steel with a yield point specified not over 550 MPa (80,000 psi), an appropriate value is 0.12 mm/mm (0.005 in./in.) of gauge length. For values above 550 MPa (80,000 psi), this method is not valid unless the limiting total extension is increased.

Note 8—The shape of the initial portion of an autographically determined stress–strain (or a load–elongation) curve may be influenced by numerous factors, such as the seating of the specimen in the grips, the straightening of a specimen bent due to residual stresses, and the rapid loading permitted in Section 8.4.1. Generally, the aberrations in this portion of the curve should be ignored when fitting a modulus line, such as that used to determine the extension-under-load yield, to the curve.

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

14.2.1. *Offset Method*—To determine the yield strength by the “offset method,” it is necessary to secure data (autographic or numerical) from which a stress–strain diagram with a distinct modulus characteristic of the material being tested may be drawn. Then, on the stress–strain diagram (Figure 9), lay off Om equal to the specified value of the offset, draw mn parallel to OA , and thus locate r , the intersection of mn with the stress–strain curve corresponding to load R , which is the yield strength load. In recording values of yield strength obtained by this method, the value of offset specified or used, or both, shall be stated in parentheses after the term “yield strength”; for example:

Yield strength (0.2% offset) = 360 MPa (52,000 psi) (1)

When the offset is 0.2 percent or larger, the extensometer used shall qualify as a Class B2 device over a strain range of 0.05 to 1.0 percent. If a smaller offset is specified, it may be necessary to specify a more accurate device (that is, a Class B1 device) or reduce the lower limit of the strain range (for example, to 0.01 percent) or both. See also Note 9 for automatic devices.

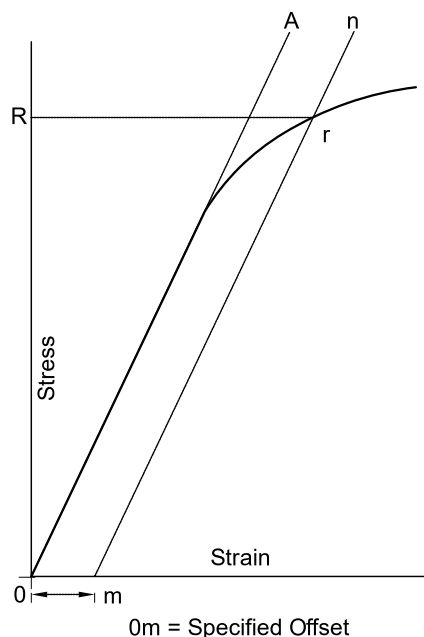


Figure 9—Stress–Strain Diagram for Determination of Yield Strength by the Offset Method

Note 9—For stress–strain diagrams not containing a distinct modulus, such as for some cold-worked materials, it is recommended that the extension-under-load method be utilized. If the offset method is used for materials without a distinct modulus, a modulus value appropriate for the material being tested should be used: 207 000 MPa (30,000,000 psi) for carbon steel; 200 000 MPa (29,000,000 psi) for ferritic stainless steel; 193 000 MPa (28,000,000 psi) for austenitic stainless steel. For special alloys, the producer should be contacted to discuss appropriate modulus values.

- 14.2.2. *Extension-under-Load Method*—For tests to determine the acceptance or rejection of material for which stress–strain characteristics are well known from previous tests of similar material in which stress–strain diagrams were plotted, the total strain corresponding to the stress at which the specified offset (Notes 10 and 11) occurs will be known within satisfactory limits. The stress on the specimen, when this total strain is reached, is the value of the yield strength. In recording values of yield strength obtained by this method, the value of “extension” specified or used, or both, shall be stated in parentheses after the term “yield strength”; for example:
- Yield strength (0.5% EUL) = 360 MPa (52,000 psi) (2)

The total strain can be obtained satisfactorily by use of a Class B1 extensometer (Notes 5, 6, and 8).

Note 10—Automatic devices are available that determine offset yield strength without plotting a stress–strain curve. Such devices may be used if their accuracy has been demonstrated.

Note 11—The appropriate magnitude of the extension under load obviously will vary with the strength range of the particular steel under test. In general, the value of extension under load applicable to steel at any strength level may be determined from the sum of the proportional strain and the plastic strain expected at the specified yield strength. The following equation is used:

$$\text{Extension under load mm/mm (in./in.) of gauge length} = (YS/E) + r \quad (3)$$

where:

YS = specified yield strength, MPa (psi);

E = modulus of elasticity, MPa (psi); and
 r = limiting plastic strain, mm/mm (in./in.).

- 14.3. *Tensile Strength*—Calculate the tensile strength by dividing the maximum load the specimen sustains during a tension test by the original cross-sectional area of the specimen. If the upper yield strength is the maximum stress recorded and if the stress-strain curve resembles that of Test Method ASTM E8/E8M Figure 25, the maximum stress after discontinuous yielding shall be reported as the tensile strength unless otherwise stated by the purchaser.
- 14.4. *Elongation:*
- 14.4.1. Fit the ends of the fractured specimen together carefully and measure the distance between the gauge marks to the nearest 0.25 mm (0.01 in.) for gauge lengths of 50 mm (2 in.) and less and to the nearest 0.5 percent of the gauge length for gauge lengths greater than 50 mm (2 in.). A percentage scale reading to 0.5 percent of the gauge length may be used. The elongation is the increase in length of the gauge length expressed as a percentage of the original gauge length. In recording elongation values, give both the percentage increase and the original gauge length.
- 14.4.2. If any part of the fracture takes place outside of the middle half of the gauge length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is indicated, but if the elongation is less than the minimum requirements, discard the test and retest.
- 14.4.3. Automated tensile testing methods using extensometers allow for the measurement of elongation in a method described below. Elongation may be measured and reported either this way or as in the method described above, fitting the broken ends together. Either result is valid.
- 14.4.4. “Elongation at fracture” is defined as the elongation measured just prior to the sudden decrease in force associated with fracture. For many ductile materials not exhibiting a sudden decrease in force, the elongation at fracture can be taken as the strain measured just prior to when the force falls below 10 percent of the maximum force encountered during the test.
- 14.4.4.1. Elongation at fracture shall include elastic and plastic elongation and may be determined with autographic or automated methods using extensometers verified over the strain range of interest. Use a Class B2 or better extensometer for materials having less than 5 percent elongation; a Class C or better extensometer for materials having an elongation greater than or equal to 5 percent but less than 50 percent; and a Class D or better extensometer for materials having 50 percent or greater elongation. In all cases, the extensometer gauge length shall be the nominal gauge length required for the specimen being tested. Due to the lack of precision in fitting fractured ends together, the elongation after fracture using the manual methods of the preceding paragraphs may differ from the elongation at fracture determined with extensometers.
- 14.4.4.2. Percentage elongation at fracture may be calculated directly from elongation at fracture data and be reported instead of percentage elongation as calculated in Section 14.4.1. However, these two parameters are not interchangeable. Use of the elongation at fracture method generally provides more repeatable results.
- 14.5. *Reduction of Area*—Fit the ends of the fractured specimen together and measure the mean diameter or the width and thickness at the smallest cross section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area is the reduction of area.

BEND TEST

15.	DESCRIPTION
15.1.	The bend test is one method for evaluating ductility, but it cannot be considered as a quantitative means of predicting service performance in bending operations. The severity of the bend test is primarily a function of the angle of bend and the inside diameter to which the specimen is bent and of the cross section of the specimen. These conditions are varied according to location and orientation of the test specimen and the chemical composition, tensile properties, hardness, type, and quality of the steel specified. ASTM E190 and ASTM E290 may be consulted for methods of performing the test.
15.2.	Unless otherwise specified, it shall be permissible to age bend-test specimens. The time–temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature for 24 to 48 h, or in a shorter time at moderately elevated temperatures by boiling in water, or heating in oil or an oven.
15.3.	Bend the test specimen at room temperature to an inside diameter, as designated by the applicable product specification, to the extent specified. The speed of bending ordinarily is not an important factor.

HARDNESS TEST METHODS

16.	GENERAL
16.1.	A hardness test is a means of determining resistance to penetration and is occasionally employed to obtain a quick approximation of tensile strength. Tables 3, 4, 5, and 6 are for the conversion of hardness measurements from one scale to another or to approximate tensile strength. These conversion hardness numbers have been obtained using fixed-location hardness testing machines and computer-generated curves and are presented to the nearest 0.1 point to permit accurate reproduction of those curves. Because all converted hardness numbers must be considered approximate, however, all converted Rockwell hardness numbers shall be rounded to the nearest whole number.
16.2.	<i>Converted Hardness Numbers and Scales:</i>
16.2.1.	If the product specification permits alternative hardness testing to determine conformance to a specified hardness requirement, the conversions listed in Tables 2, 3, 4, and 5 shall be used.
16.2.2.	When recording converted hardness numbers and scales from fixed-location hardness testing machine measurements, the measured hardness and test scale shall be indicated in parentheses; for example: 353 HBW (38 HRC). This means that a hardness number of 38 was obtained using the Rockwell C scale and converted to a Brinell hardness of 353.

Table 3—Approximate Hardness Conversion Numbers for Non-austenitic Steels (Rockwell C to Other Hardness Numbers)^a

Rockwell C Scale, 1471-N (150-kgf) Load, Diamond Penetrator	Vickers Hardness Number	Brinell Hardness, 29.42-kN (3000-kgf) Load, 10-mm Ball	Knoop Hardness, 4.903-N (500-gf) Load and Over	Rockwell A Scale, 588-N (60-kgf) Load, Diamond Penetrator	Rockwell Superficial Hardness			Approximate Tensile Strength, MPa (ksi)
					15N Scale, 147-N (15- kgf) Load, Diamond Penetrator	30N Scale, 294-N (30- kgf) Load, Diamond Penetrator	45N Scale 441-N (45- kgf) Load, Diamond Penetrator	
68	940	—	920	85.6	93.2	84.4	75.4	—
67	900	—	895	85.0	92.9	83.6	74.2	—
66	865	—	870	84.5	92.5	82.8	73.3	—
65	832	739	846	83.9	92.2	81.9	72.0	—
64	800	722	822	83.4	91.8	81.1	71.0	—
63	772	706	799	82.8	91.4	80.1	69.9	—
62	746	688	776	82.3	91.1	79.3	68.8	—
61	720	670	754	81.8	90.7	78.4	67.7	—
60	697	654	732	81.2	90.2	77.5	66.6	—
59	674	634	710	80.7	89.8	76.6	65.5	2420 (351)
58	653	615	690	80.1	89.3	75.7	64.3	2330 (338)
57	633	595	670	79.6	88.9	74.8	63.2	2240 (325)
56	613	577	650	79.0	88.3	73.9	62.0	2160 (313)
55	595	560	630	78.5	87.9	73.0	60.9	2070 (301)
54	577	543	612	78.0	87.4	72.0	59.8	2010 (292)
53	560	525	594	77.4	86.9	71.2	58.6	1950 (283)
52	544	512	576	76.8	86.4	70.2	57.4	1880 (273)
51	528	496	558	76.3	85.9	69.4	56.1	1820 (264)
50	513	482	542	75.9	85.5	68.5	55.0	1760 (255)
49	498	468	526	75.2	85.0	67.6	53.8	1700 (246)
48	484	455	510	74.7	84.5	66.7	52.5	1640 (238)
47	471	442	495	74.1	83.9	65.8	51.4	1580 (229)
46	458	432	480	73.6	83.5	64.8	50.3	1520 (221)
45	446	421	466	73.1	83.0	64.0	49.0	1480 (215)
44	434	409	452	72.5	82.5	63.1	47.8	1430 (208)
43	423	400	438	72.0	82.0	62.2	46.7	1390 (201)
42	412	390	426	71.5	81.5	61.3	45.5	1340 (194)
41	402	381	414	70.9	80.9	60.4	44.3	1300 (188)
40	392	371	402	70.4	80.4	59.5	43.1	1250 (182)
39	382	362	391	69.9	79.9	58.6	41.9	1220 (177)
38	372	353	380	69.4	79.4	57.7	40.8	1180 (171)
37	363	344	370	68.9	78.8	56.8	39.6	1140 (166)
36	354	336	360	68.4	78.3	55.9	38.4	1110 (161)
35	345	327	351	67.9	77.7	55.0	37.2	1080 (156)
34	336	319	342	67.4	77.2	54.2	36.1	1050 (152)
33	327	311	334	66.8	76.6	53.3	34.9	1030 (149)
32	318	301	326	66.3	76.1	52.1	33.7	1010 (146)
31	310	294	318	65.8	75.6	51.3	32.5	970 (141)
30	302	286	311	65.3	75.0	50.4	31.3	950 (138)
29	294	279	304	64.6	74.5	49.5	30.1	930 (135)
28	286	271	297	64.3	73.9	48.6	28.9	900 (131)
27	279	264	290	63.8	73.3	47.7	27.8	880 (128)
26	272	258	284	63.3	72.8	46.8	26.7	860 (125)
25	266	253	278	62.8	72.2	45.9	25.5	850 (123)
24	260	247	272	62.4	71.6	45.0	24.3	820 (119)
23	254	243	266	62.0	71.0	44.0	23.1	810 (117)
22	248	237	261	61.5	70.5	43.2	22.0	790 (115)
21	243	231	256	61.0	69.9	42.3	20.7	770 (112)
20	238	226	251	60.5	69.4	41.5	19.6	760 (110)

^a This table gives the approximate interrelationships of hardness numbers and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness–tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels but have been shown to be applicable for ferritic and martensitic stainless steels. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part. Caution should be exercised if conversions from this table are used for the acceptance or rejection of product. The approximate interrelationships may affect acceptance or rejection.

Table 4—Approximate Hardness Conversion Numbers for Nonaustenitic Steels (Rockwell B to Other Hardness Numbers)^a

Rockwell B Scale, 981-N (100-kgf) Load, 1.588-mm (¹ / ₁₆ -in.) Ball	Vickers Hardness Number	Brinell Hardness, 24.92-kN (3000-kgf) Load, 10-mm Ball	Knoop Hardness, 4.903-N (500-gf) Load and Over	Rockwell A Scale, 588-N (60-kgf) Load, Diamond Penetrator	Rockwell F Scale, 588-N (60-kgf) Load, 1.588-mm (¹ / ₁₆ -in.) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength, MPa (ksi)
						15T Scale, 147-N (15-kgf) Load, 1.588-mm (¹ / ₁₆ -in.) Ball	30T Scale, 294-N (30-kgf) Load, 1.588-mm (¹ / ₁₆ -in.) Ball	45T Scale, 441-N (45-kgf) Load, 1.588-mm (¹ / ₁₆ -in.) Ball	
100	240	240	251	61.5	—	93.1	83.1	72.9	800 (116)
99	234	234	246	60.9	—	92.8	82.5	71.9	785 (114)
98	228	228	241	60.2	—	92.5	81.8	70.9	750 (109)
97	222	222	236	59.5	—	92.1	81.1	69.9	715 (104)
96	216	216	231	58.9	—	91.8	80.4	68.9	705 (102)
95	210	210	226	58.3	—	91.5	79.8	67.9	690 (100)
94	205	205	221	57.6	—	91.2	79.1	66.9	675 (98)
93	200	200	216	57.0	—	90.8	78.4	65.9	650 (94)
92	195	195	211	56.4	—	90.5	77.8	64.8	635 (92)
91	190	190	206	55.8	—	90.2	77.1	63.8	620 (90)
90	185	185	201	55.2	—	89.9	76.4	62.8	615 (89)
89	180	180	196	54.6	—	89.5	75.8	61.8	605 (88)
88	176	176	192	54.0	—	89.2	75.1	60.8	590 (86)
87	172	172	188	53.4	—	88.9	74.4	59.8	580 (84)
86	169	169	184	52.8	—	88.6	73.8	58.8	570 (83)
85	165	165	180	52.3	—	88.2	73.1	57.8	565 (82)
84	162	162	176	51.7	—	87.9	72.4	56.8	560 (81)
83	159	159	173	51.1	—	87.6	71.8	55.8	550 (80)
82	156	156	170	50.6	—	87.3	71.1	54.8	530 (77)
81	153	153	167	50.0	—	86.9	70.4	53.8	505 (73)
80	150	150	164	49.5	—	86.6	69.7	52.8	495 (72)
79	147	147	161	48.9	—	86.3	69.1	51.8	485 (70)
78	144	144	158	48.4	—	86.0	68.4	50.8	475 (69)
77	141	141	155	47.9	—	85.6	67.7	49.8	470 (68)
76	139	139	152	47.3	—	85.3	67.1	48.8	460 (67)
75	137	137	150	46.8	99.6	85.0	66.4	47.8	455 (66)
74	135	135	147	46.3	99.1	84.7	65.7	46.8	450 (65)
73	132	132	145	45.8	98.5	84.3	65.1	45.8	440 (64)
72	130	130	143	45.3	98.0	84.0	64.4	44.8	435 (63)
71	127	127	141	44.8	97.4	83.7	63.7	43.8	425 (62)
70	125	125	139	44.3	96.8	83.4	63.1	42.8	420 (61)
69	123	123	137	43.8	96.2	83.0	62.4	41.8	415 (60)
68	121	121	135	43.3	95.6	82.7	61.7	40.8	405 (59)
67	119	119	133	42.8	95.1	82.4	61.0	39.8	400 (58)
66	117	117	131	42.3	94.5	82.1	60.4	38.7	395 (57)
65	116	116	129	41.8	93.9	81.8	59.7	37.7	385 (56)
64	114	114	127	41.4	93.4	81.4	59.0	36.7	—
63	112	112	125	40.9	92.8	81.1	58.4	35.7	—
62	110	110	124	40.4	92.2	80.8	57.7	34.7	—
61	108	108	122	40.0	91.7	80.5	57.0	33.7	—
60	107	107	120	39.5	91.1	80.1	56.4	32.7	—
59	106	106	118	39.0	90.5	79.8	55.7	31.7	—
58	104	104	117	38.6	90.0	79.5	55.0	30.7	—
57	103	103	115	38.1	89.4	79.2	54.4	29.7	—
56	101	101	114	37.7	88.8	78.8	53.7	28.7	—
55	100	100	112	37.2	88.2	78.5	53.0	27.7	—
54	—	—	111	36.8	87.7	78.2	52.4	26.7	—
53	—	—	110	36.3	87.1	77.9	51.7	25.7	—

Continued on next page.

Table 4—Approximate Hardness Conversion Numbers for Non-austenitic Steels (Rockwell B to Other Hardness Numbers)^a (Continued)

Rockwell B Scale, 981-N (100-kgf) Load, 1.588-mm (1/16-in.) Ball	Vickers Hardness Number	Brinell Hardness, 24.92-kN (3000-kgf) Load, 10-mm Ball	Knoop Hardness, 4.903-N (500-gf) Load and Over	Rockwell A Scale, 588-N (60-kgf) Load, Diamond Penetrator	Rockwell F Scale, 588-N (60-kgf) Load, 1.588-mm (1/16-in.) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength, MPa (ksi)
						15T Scale, 147-N (15-kgf) Load, 1.588-mm (1/16-in.) Ball	30T Scale, 294-N (30-kgf) Load, 1.588-mm (1/16-in.) Ball	45T Scale, 441-N (45-kgf) Load, 1.588-mm (1/16-in.) Ball	
52	—	—	109	35.9	86.5	77.5	51.0	24.7	—
51	—	—	108	35.5	86.0	77.2	50.3	23.7	—
50	—	—	107	35.0	85.4	76.9	49.7	22.7	—
49	—	—	106	34.6	84.8	76.6	49.0	21.7	—
48	—	—	105	34.1	84.3	76.2	48.3	20.7	—
47	—	—	104	33.7	83.7	75.9	47.7	19.7	—
46	—	—	103	33.3	83.1	75.6	47.0	18.7	—
45	—	—	102	32.9	82.6	75.3	46.3	17.7	—
44	—	—	101	32.4	82.0	74.9	45.7	16.7	—
43	—	—	100	32.0	81.4	74.6	45.0	15.7	—
42	—	—	99	31.6	80.8	74.3	44.3	14.7	—
41	—	—	98	31.2	80.3	74.0	43.7	13.6	—
40	—	—	97	30.7	79.7	73.6	43.0	12.6	—
39	—	—	96	30.3	79.1	73.3	42.3	11.6	—
38	—	—	95	29.9	78.6	73.0	41.6	10.6	—
37	—	—	94	29.5	78.0	72.7	41.0	9.6	—
36	—	—	93	29.1	77.4	72.3	40.3	8.6	—
35	—	—	92	28.7	76.9	72.0	39.6	7.6	—
34	—	—	91	28.2	76.3	71.7	39.0	6.6	—
33	—	—	90	27.8	75.7	71.4	38.3	5.6	—
32	—	—	89	27.4	75.2	71.0	37.6	4.6	—
31	—	—	88	27.0	74.6	70.7	37.0	3.6	—
30	—	—	87	26.6	74.0	70.4	36.3	2.6	—

^a This table gives the approximate interrelationships of hardness numbers and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness–tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table was developed using fixed-location hardness testing machines. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

Table 5—Approximate Hardness Conversion Numbers for Austenitic Steels (Rockwell C to Other Hardness Numbers)

Rockwell C Scale, 1471-N (150-kgf) Load, Diamond Penetrator	Rockwell A Scale, 588-N (60-kgf) Load, Diamond Penetrator	Rockwell Superficial Hardness		
		15N Scale, 147-N (15-kgf) Load, Diamond Penetrator	30N Scale, 294-N (30-kgf) Load, Diamond Penetrator	45N Scale, 441-N (45-kgf) Load, Diamond Penetrator
48	74.4	84.1	66.2	52.1
47	73.9	83.6	65.3	50.9
46	73.4	83.1	64.5	49.8
45	72.9	82.6	63.6	48.7
44	72.4	82.1	62.7	47.5
43	71.9	81.6	61.8	46.4
42	71.4	81.0	61.0	45.2
41	70.9	80.5	60.1	44.1
40	70.4	80.0	59.2	43.0
39	69.9	79.5	58.4	41.8
38	69.3	79.0	57.5	40.7
37	68.8	78.5	56.5	39.6
36	68.3	78.0	55.7	38.4
35	67.8	77.5	54.9	37.3
34	67.3	77.0	54.0	36.1
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

Table 6—Approximate Hardness Conversion Numbers for Austenitic Steels (Rockwell B to Other Hardness Numbers)

Rockwell B Scale, 981-N (100-kgf) Load, 1.588-mm (/ -in.) Ball	Brinell Indentation Dia, mm	Brinell Hardness, 29.42-kN (3000-kgf) Load, 10-mm Ball	Rockwell A Scale, 588-N (60-kgf) Load, Diamond Penetrator	Rockwell Superficial Hardness		
				15 T Scale, 147-N (15- kgf) Load, 1.588-mm (/ -in.) Ball	30T Scale, 294-N (30- kgf) Load, 1.588-mm (/ -in.) Ball	45 T Scale, 441-N (45- kgf) Load, 1.588-mm (/ -in.) Ball
100	3.79	256	61.5	91.5	80.4	70.2
99	3.85	248	60.9	91.2	79.7	69.2
98	3.91	240	60.3	90.8	79.0	68.2
97	3.96	233	59.7	90.4	78.3	67.2
96	4.02	226	59.1	90.1	77.7	66.1
95	4.08	219	58.5	89.7	77.0	65.1
94	4.14	213	58.0	89.3	76.3	64.1
93	4.20	207	57.4	88.9	75.6	63.1
92	4.24	202	56.8	88.6	74.9	62.1
91	4.30	197	56.2	88.2	74.2	61.1
90	4.35	192	55.6	87.8	73.5	60.1
89	4.40	187	55.0	87.5	72.8	59.0
88	4.45	183	54.5	87.1	72.1	58.0
87	4.51	178	53.9	86.7	71.4	57.0
86	4.55	174	53.3	86.4	70.7	56.0
85	4.60	170	52.7	86.0	70.0	55.0
84	4.65	167	52.1	85.6	69.3	54.0
83	4.70	163	51.5	85.2	68.6	52.9
82	4.74	160	50.9	84.9	67.9	51.9
81	4.79	156	50.4	84.5	67.2	50.9
80	4.84	153	49.8	84.1	66.5	49.9

16.2.3. When reporting converted hardness numbers from a portable hardness testing machine, the measured hardness and test scale shall be indicated in parentheses, as shown in the examples in Table 7.

Note 12—Since the data in the hardness conversion tables in this standard were developed using fixed-location hardness testing machines, the use of these tables to convert hardness testing numbers may have a larger approximation range than the range for converting fixed-location hardness testing numbers.

Table 7—Reporting Converted Hardness Numbers and Scales from Portable Hardness Tests

Portable Hardness Test Method	Portable Hardness Test Number and Scale	Converted Hardness Number and Scale	Reported Converted Hardness Number and Scale
ASTM A883	353 HBC/340	38 HRC	38 HRC (353 HBC/340)
ASTM A956/A965M	353 HB (HLD)	38 HRC	38 HRC (353 HB (HLD))
ASTM A1038	373 HV (UCI)	38 HRC	38 HRC (3872 HV (UCI))
ASTM E110	353 HBW/P	38 HRC	38 HRC (353 HBW/P)

17. BRINELL HARDNESS FIXED-LOCATION TESTING

17.1. Description:

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

For applied loads in newtons of force:

$$HBW = \frac{2P}{\pi D \left(D - \sqrt{D^2 - d^2} \right)} \quad (4)$$

where:

HBW = Brinell hardness number;
 P = applied load, N;
 D = diameter of the ball, mm; and
 d = average diameter of the indentation, mm.

For applied loads in kilogram-force units:

$$HBW = \frac{2P}{\pi D \left(D - \sqrt{D^2 - d^2} \right)} \quad (5)$$

where:

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

Note 13—The Brinell hardness from a fixed-location testing machine is more conveniently secured from standard tables such as Table 10, which show numbers corresponding to the various indentation diameters, usually in increments of 0.05 mm.

Note 14—In Test Method ASTM E10; the values are in SI units, whereas in this section kg/m units are used.

17.1.2. The standard Brinell hardness from a fixed-location testing machine using a 10-mm tungsten carbide ball employs a 29.42-kN (3000-kgf) load for hard materials and a 14.71 or 4.903-kN (1500- or 500-kgf) load for thin sections or soft materials. (See Annex B on Steel Tubular Products.) Other loads and different size indenters may be used when specified. In recording hardness numbers, the diameter of the ball and the load must be stated when a 10-mm ball and 29.42-kN (3000-kgf) load are used.

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

17.1.4. Brinell hardness may be required when tensile properties are not specified.

17.2. *Apparatus*—Equipment shall meet the following requirements:

- 17.2.1. *Testing Machine*—A Brinell hardness fixed-location testing machine is acceptable for use over a loading range within which its load-measuring device is accurate to ± 1 percent.
- 17.2.2. *Measuring Microscope*—The divisions of the micrometer scale of the microscope or other measuring devices used for the measurement of the diameter of the indentations shall be such as to permit the direct measurement of the diameter to 0.1 mm and the estimation of the diameter to 0.05 mm.
- Note 15**—This requirement applies to the construction of the microscope only and is not a requirement for measurement of the indentation. See Section 17.4.4.
- 17.2.3. *Standard Ball*—The standard tungsten carbide ball for Brinell hardness fixed-location testing is 10 mm (0.3937 in.) in diameter with a deviation from this value of not more than 0.005 mm (0.0002 in.) in any diameter. A tungsten carbide ball suitable for use must not show a permanent change in diameter greater than 0.01 mm (0.0004 in.) when pressed with a force of 29.42 kN (3000 kgf) against the test specimen. Steel ball indenters are no longer permitted for use in Brinell hardness fixed-location testing machines in accordance with these test methods.
- 17.3. *Test Specimen*—Brinell hardness indentations are made on prepared areas and sufficient metal must be removed from the surface to eliminate decarburized metal and other surface irregularities. The thickness of the piece tested must be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the indentation.
- 17.4. *Test Procedure:*
- 17.4.1. For a detailed test procedure, refer to ASTM E10 for fixed-location hardness testing machines.
- 17.4.2. It is essential that the applicable product specification state clearly the position at which Brinell hardness indentations are to be made and the number of such indentations required. The distance of the center of the indentation from the edge of the specimen or edge of another indentation must be at least $2\frac{1}{2}$ times the diameter of the indentation.
- 17.4.3. Apply the load for 10 to 15 s.
- 17.4.4. Measure diameters of the indentation in accordance with ASTM E10.
- 17.4.5. Do not use a steel ball on steels having a hardness greater than 450 HBW nor a carbide ball on steels having a hardness more than 650 HBW. The Brinell hardness fixed-location testing machine is not recommended for materials having a hardness greater than 650 HBW.
- 17.4.5.1. If a ball is used in a test of a specimen that shows a Brinell hardness number greater than the limit for the ball as detailed in Section 17.4.5, the ball shall be either discarded and replaced with a new ball or remeasured to ensure conformance with the requirements of ASTM E10.
- 17.5. *Reporting Brinell Hardness Numbers:*
- 17.5.1. Brinell hardness numbers shall not be reported by a number alone because it is necessary to indicate which indenter and force have been employed in making the test. Reported Brinell hardness numbers shall always be followed by the scale symbol HBW, and be supplemented by an index indicating the test conditions in the following order:
- 17.5.1.1. Diameter of the ball, mm,
- 17.5.1.2. A value representing the applied load, kgf, and
- 17.5.1.3. The applied force dwell time, s, if other than 10 to 15 s.

- 17.5.1.4. The only exception to the above requirement is for the HBW 10/3000 scale when a 10 to 15 s dwell time is used. Only in the case of this one Brinell hardness scale may the designation be reported simply as HBW.
- 17.5.1.5. Examples: 220 HBW = Brinell hardness of 220 determined with a ball of 10 mm diameter and with a test force of 3000 kgf applied for 10 to 15 s; 350 HBW 5/1500 = Brinell hardness of 350 determined with a ball of 5 mm diameter and with a test force of 1500 kgf applied for 10 to 15 s.

18. ROCKWELL FIXED-LOCATION HARDNESS TESTING

18.1. Description:

- 18.1.1. In this test, a hardness number is obtained by determining the depth of penetration of a diamond point or a tungsten carbide ball into the specimen using a fixed-location hardness testing machine. A minor load of 98 N (10 kgf) is first applied, which causes an initial penetration, sets the penetrator on the material, and holds it in position. A major load that depends on the scale being used is applied, increasing the depth of indentation. The major load is removed and, with the minor load still acting, the Rockwell number, which is proportional to the difference in penetration between the major and minor loads, is determined; this is usually done by the machine and shows on a dial, digital display, printer, or other device. This is an arbitrary number that increases with increasing hardness. The scales most frequently used appear in Table 8.

Table 8—Scales I

Scales I			
Scale Symbol	Penetrator	Major Load, N (kgf)	Minor Load, N (kgf)
B	1.588-mm ($1/16$ -in.) tungsten carbide ball	981 (100)	98 (10)
C	Diamond brale	1471 (150)	98 (10)

- 18.1.2. Rockwell superficial fixed-location hardness testing machines are used for testing very thin steel or thin surface layers. Loads of 147, 294, or 441 N (15, 30, or 45 kgf) are applied on a tungsten carbide (or a hardened steel) ball or diamond penetrator to cover the same range of hardness values as for the heavier loads. Use of a hardened steel ball is permitted only for testing thin sheet tin mill products as found in ASTM A623 and A623M using HR15T and HR30T scales with a diamond spot anvil. (Testing of this product using a tungsten carbide indenter may give significantly different results as compared to historical test data obtained using a hardened steel ball.) The superficial hardness scales appear in Table 9.

Table 9—Scales II

Scales II			
Scale Symbol	Penetrator	Major Load, N (kgf)	Minor Load, N (kgf)
15T	1.588-mm ($1/16$ -in.) tungsten carbide ball	147 (15)	29 (3)
30T	1.588-mm ($1/16$ -in.) tungsten carbide ball	294 (30)	29 (3)
45T	1.588-mm ($1/16$ -in.) tungsten carbide ball	441 (45)	29 (3)
15N	Diamond brale	147 (15)	29 (3)
30N	Diamond brale	294 (30)	29 (3)
45N	Diamond brale	441 (45)	29 (3)