Standard Method of Test for

Mechanical Testing of Steel Products

AASHTO Designation: T 244-20[1]

Technical Subcommittee: TS 4f, Metals

Release: Group 2 (June)

ASTM Designation: A370-18

AASHTO

American Association of State Highway and Transportation Officials
555 12th Street NW, Suite 1000
Washington, DC 20004

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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	6 to 14
Bend	15
Hardness	16
Brinell	17
Rockwell	18
Portable	19
Impact	20 to 29
Keywords	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*.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standard*:

- M170/M170M, Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
- M199/M199M, Standard Specification for Precast Reinforced Concrete Manhole Sections
- M206/M206M, Standard Specification for Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe
- M207/M207M, Standard Specification for Reinforced Concrete Elliptical 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
- A1064/A1064M, Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
- C76, Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
- C506/506M, Standard Specification for Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe
- C507/507M, Standard Specification for Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe
- 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. SIGNIFICANCE AND USE

3.1. 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.

3.1.1. 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.

3.1.2. 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.

3.2. 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.

3.2.1. 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.

4. GENERAL PRECAUTIONS

4.1. 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.

4.2. Improperly machined specimens should be discarded and other specimens substituted.

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

4.4. 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.

5. ORIENTATION OF TEST SPECIMENS

5.1. 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:

5.1.1. *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)).

5.1.2. *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).

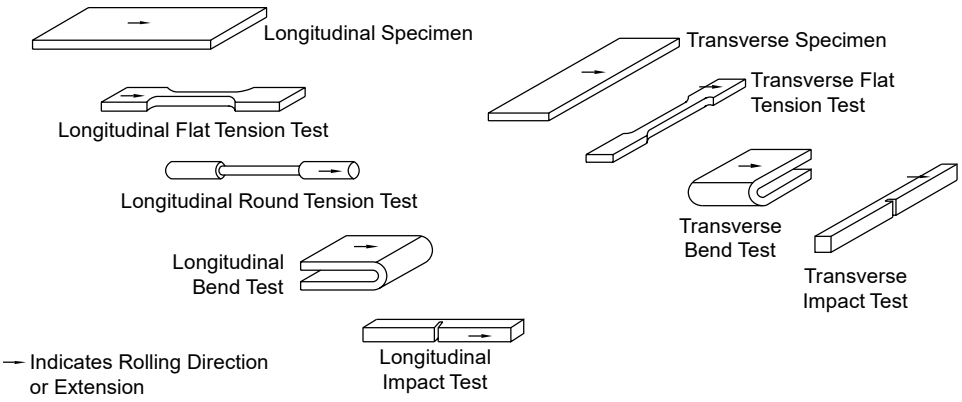
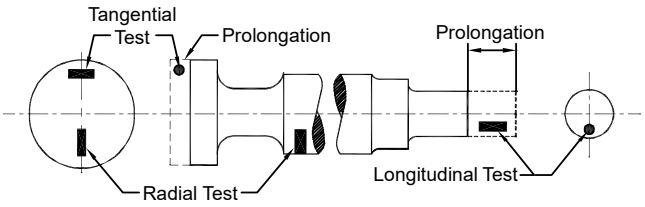
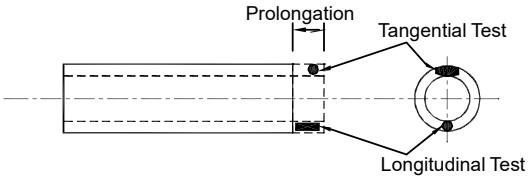


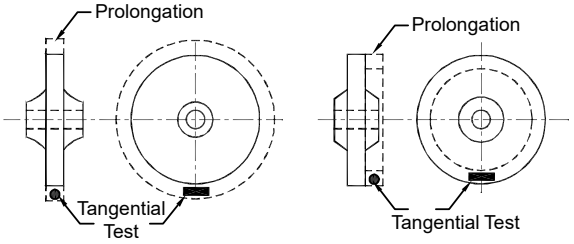
Figure 1—The Relation of Test Coupons and Test Specimens to Rolling Direction or Extension (Applicable to General Wrought Products)



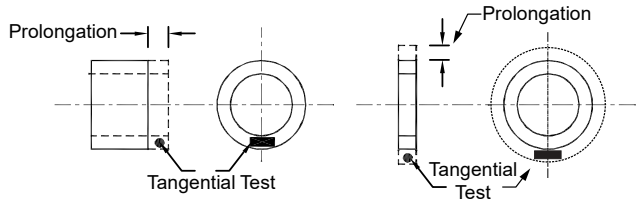
(a) Shafts and Rotors



(b) Hollow Forgings



(c) Disk Forgings



(d) Ring Forgings

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

5.2. 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:

5.2.1. *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)).

5.2.2. *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

6. DESCRIPTION

6.1. 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.

6.2. 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.

7. TERMINOLOGY

7.1. For definitions of terms pertaining to tension testing, including tensile strength, yield point, yield strength, elongation, and reduction of area, reference should be made to ASTM E6.

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 ($^1/_{16}$ 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

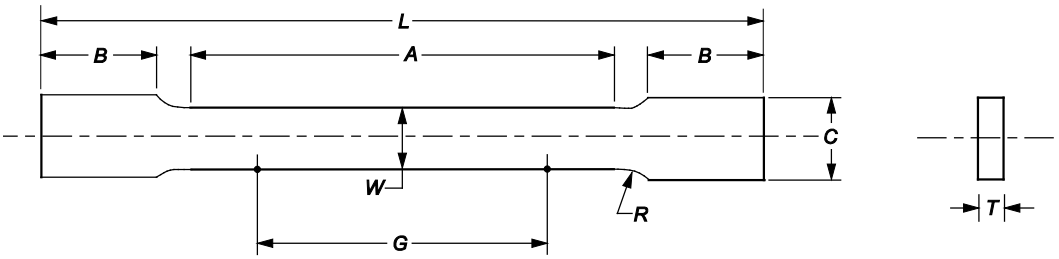
9.1. *Selection*—Test coupons shall be selected in accordance with the applicable product specifications.

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 ($1^1/_2$ in.) Wide							
	200-mm (8-in.) Gauge Length		50-mm (2-in.) Gauge Length		Sheet Type, 12.5-mm ($^1/_2$ in.) Wide		6-mm ($^1/_4$-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	$1^1/_2 + {}^1/_8 - {}^1/_4$	40 + 3 – 6	$1^1/_2 + {}^1/_8 - {}^1/_4$	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	$^1/_2$	13	$^1/_2$	13	$^1/_2$	6	$^1/_4$
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	$2^1/_4$	60	$2^1/_4$	32	$1^1/_4$
B–Length of grip section, min (Note 9)	75	3	50	2	50	2	32	$1^1/_4$
C–Width of grip section, approximate (Notes 4, 10, and 11)	50	2	50	2	20	$^3/_4$	10	$^3/_8$

Notes:

1. For the 40-mm ($1^1/_2$-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.
2. For the 12.5-mm ($^1/_2$-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.
3. 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.
4. 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.).
5. 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.
6. 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 ($1^1/_2$ in.) or less, the sides may be parallel throughout the length of the specimen.
7. 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 $1^1/_2$-in.) wide specimens shall be 5 mm ($^3/_{16}$ in.), except as permitted by the product specification. Maximum nominal thickness of 12.5-mm ($^1/_2$-in.) and 6.25-mm ($^1/_4$-in.) wide specimens shall be 19 mm and 6 mm ($^3/_4$ and $^1/_4$ in.), respectively.
8. To aid in obtaining axial loading during testing of 6.25-mm ($^1/_4$-in.) wide specimens, the overall length should be as the material will permit.
9. 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 ($^1/_2$-in.) wide specimens is greater than 10 mm ($^3/_8$ in.), longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.
10. 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 ($^1/_2$-in.) wide specimen are symmetrical within 1.0 mm (0.05 in.), a specimen may be considered satisfactory for all but referee testing.
11. 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