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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Guide Describing the General Principles for Determination of Tensile Properties of Plastics[1]

This standard is issued under the fixed designation D 5938; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide specifies the general principles for determining the tensile properties of plastics under defined conditions.

1.2 Several different types of test specimen are defined to suit different types of material that are detailed in other standards.

1.3 This guide is used to investigate the tensile behaviour of the test specimens and for determining the tensile strength, tensile modulus and other aspects of the tensile stress/strain relationship under the conditions defined.

1.4 This guide is selectively suitable for use with the following range of materials:

1.4.1 Rigid and semirigid thermoplastics moulding and extrusion materials, including filled and reinforced compounds in addition to unfilled types, rigid and semirigid thermoplastics sheets and films,

1.4.2 Rigid and semirigid thermosetting moulding materials, including filled and reinforced compounds, rigid and semirigid thermosetting sheets, including laminates,

1.4.3 Fibre-reinforced thermoset and thermoplastics composites incorporating unidirectional or nonunidirectional reinforcements such as mat, woven fabrics, woven rovings, chopped strands, combination and hybrid reinforcements, rovings and milled fibres, sheets made from pre-impregnated materials (prepregs), and

1.4.4 Thermotropic liquid crystal polymers.

1.5 This guide is not suitable normally for use with rigid cellular materials or sandwich structures containing cellular material.

1.6 This guide is applied using specimens that may be either moulded to the chosen dimensions or machined, cut, or punched from finished and semifinished products such as mouldings, laminates, films, and extruded or cast sheet. In some cases, a multipurpose test specimen (see ISO 3167:1993 (Specification D 5936)), may be used.

1.7 This guide specifies preferred dimensions for the test specimens. Tests that are carried out on specimens of different dimensions, or on specimens that are prepared under different conditions, may produce results that are not comparable. Other factors, such as the speed of testing and the conditioning of the specimens, also can influence the results. Consequently, when comparative data are required, these factors must be carefully controlled and recorded.

1.8 This guide is identical to ISO 527-1. This standard is comparable to Test Method D 638 but neither standard should be substituted for the other. The two standards may differ with respect to test specimen dimensions, test specimen conditioning, test equipment, testing conditions, etc. The two methods may not give the same results.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 638 Test Method for Tensile Properties of Plastics[2]

D 5936 Specification for Multipurpose Test Specimens Used for Testing Plastics[3]

2.2 *ISO Standards:*[4]

ISO 291:1977 Plastics—Standard Atmospheres for Conditioning and Testing

ISO 527-1 Determination of Tensile Properties—Part 1: General Principles

ISO 2602:1980 Statistical Interpretation of Test Results—Estimation of the Mean—Confidence Interval

ISO 5893:1985 Rubber and Plastics Test Equipment—Tensile, Flexural and Compression Types (Constant Rate of Traverse)—Description

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *gage length, L_o, n*—initial distance between the gage marks on the central part of the test specimen. See figures of the test specimens in the relevant part of ISO 527. It is expressed in millimetres (mm).

3.2 *modulus of elasticity in tension, Young's modulus,*

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.03.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

E_t—ratio of the stress difference σ_2 minus σ_1 to the corresponding strain difference values $\epsilon_2 = 0.0025$ minus $\epsilon_1 = 0.0005$ (see Fig. 1, curve d and 11.3, Eq 8). It is expressed in megapascals, (MPa). This definition does not apply to films and rubber.

3.2.1 *Discussion*—With computer-aided equipment, the determination of the modulus E_t using two distinct stress/strain points can be replaced by a linear regression procedure applied on the part of the curve between these mentioned points.

3.3 *nominal tensile strain,* ϵ_t, *n*—increase in length per unit original length of the distance between grips (grip separation). It is expressed as a dimensionless ratio or in percentage (%) (see 11.2, Eq 6 and Eq 7).

3.3.1 It is used for strains beyond yield point (see 3.8.3). For strains up to yield point, see 3.7. It represents the total relative elongation that takes place along the free length of the test specimen.

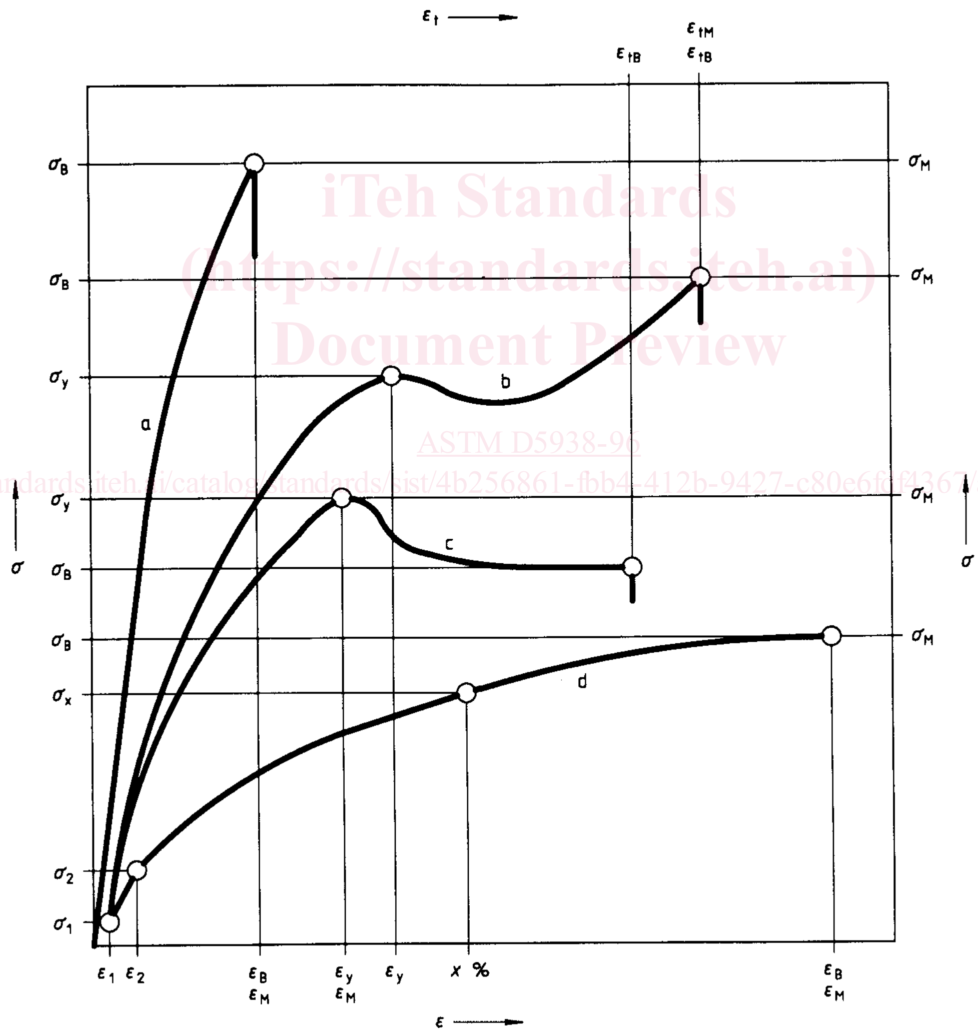
3.3.1.1 *nominal tensile strain at break,* ϵ_{tB}, *n*—nominal tensile strain at the tensile stress at break (see 3.8.2), if the specimen breaks after yielding (see Fig. 1, curves b and c). It is expressed as a dimensionless ratio, or in percentage (%). For breaking without yielding, see 3.7.3.

3.4 *nominal tensile strain at tensile strength,* ϵ_{tM}, *n*—nominal tensile strain at tensile strength (see 3.8.1), if this occurs after yielding (see Fig. 1, curve b). It is expressed as a dimensionless ratio or in percentage (%). For strength values without or at yielding, see 3.7.2.

3.5 *speed of testing,* *v*—rate of separation of the grips of the testing machine during the test. It is expressed in millimetres per minute (mm/min).

3.6 *Poisson's ratio,* μ, *n*—negative ratio of the tensile strain ϵ_n, in one of the two axes normal to the direction of pull, to the corresponding strain ϵ in the direction of pull, within the initial linear portion of the longitudinal versus normal strain curve. It is expressed as a dimensionless ratio.

3.6.1 Poisson's ratio is indicated as μ_b (width direction) or



Curve a	Brittle materials
Curves b and c	Tough materials with yield point
Curve d	Tough materials without yield point

The points for the calculation of Young's modulus E_t according to 11.3 are indicated by (σ_1, ϵ_1) and (σ_2, ϵ_2), shown only for Curve d ($\epsilon_1 = 0.0005$, $\epsilon_2 = 0.0025$).

FIG. 1 Typical Stress/Strain Curves

μ_h (thickness direction) according to the relevant axis. Poisson's ratio is used preferentially for long-fibre-reinforced materials.

3.7 *tensile strain*, ϵ, *n*—increase in length per unit original length of the gage. It is expressed as a dimensionless ratio or in percentage (%) (see 11.2, Eq 4 and Eq 5). It is used for strains up to yield point (see 3.7.3). For strains beyond yield point, see 3.3).

3.7.1 *tensile strain at break*, ϵ_B, *n*—tensile strain at the tensile stress at break (see 3.7.2), if it breaks without yielding (see Fig. 1, curves a and d). It is expressed as a dimensionless ratio or in percentage (%). For breaking after yielding, see 3.3.1.

3.7.2 *tensile strain at tensile strength*, ϵ_M, *n*—tensile strain at the point corresponding to tensile strength (see 3.7.1), if this occurs without or at yielding (see Fig. 1, curves a and d). It is expressed as a dimensionless ratio or in percentage (%). For strength values higher than the yield stress, see 3.4.

3.7.3 *tensile strain at yield*, ϵ_Y, *n*—tensile strain at the yield stress (see 3.8.3 and Fig. 1, curves b and c). It is expressed as a dimensionless ratio or in percentage (%).

3.7.4 *tensile stress at* χ *% strain*, σ_x, *n*—stress at which the strain reaches the specified value expressed in percentage. It is expressed in megapascals (MPa). See 3.6.

3.7.4.1 It may be measured, for example, if the stress/strain curve does not exhibit a yield point (see Fig. 1, curve d). In this case, take χ from the relevant product standard or as agreed upon by the interested parties. However, χ must be lower than the strain corresponding to the tensile strength, in any case.

3.8 *tensile stress*, σ *(engineering)*, *n*—tensile force per unit area of the original cross-section within the gage length carried by the test specimen at any given moment. It is expressed in megapascals (MPa) (see 11.1, Eq 3).

3.8.1 *tensile strength*, σ_M, *n*—maximum tensile stress sustained by the test specimen during a tensile test (see Fig. 1). It is expressed in megapascals (MPa).

3.8.2 *tensile stress at break*, σ_B, *n*—the tensile stress at which the test specimen ruptures (see Fig. 1). It is expressed in megapascals (MPa).

3.8.3 *tensile stress at yield, yield stress*, σ_Y, *n*—first stress at which an increase in strain occurs without an increase in stress. It is expressed in megapascals (MPa). It may be less than the maximum attainable stress (see Fig. 1, curves b and c).

4. Principle

4.1 The test specimen is extended along its major longitudinal axis at constant speed until the specimen fractures or until the stress (load) or the strain (elongation) reaches some predetermined value. During this procedure, the load sustained by the specimen and the elongation are measured.

5.

6. Apparatus

6.1 *Testing Machine*:

6.1.1 *General*—Ensure that the machine complies with ISO 5893 and meets the specifications given as follows:

6.1.2 *Speeds of Testing*—Ensure that the tensile-testing machine is capable of maintaining the speeds of testing (see 3.5) as specified in Table 1.

TABLE 1 Recommended Testing Speeds

Speed	Tolerance
mm/min	%
1	±20[A]
2	±20[A]
5	±20
10	±20
20	±10
50	±10
100	±10
200	±10
500	±10

[A] These tolerances are smaller than those indicated in ISO 5893.

6.1.3 *Grips*—Attach the grips for holding the test specimen to the machine so that the major axis of the test specimen coincides with the direction of pull through the centerline of the grip assembly. Attachment can be achieved, for example, by using centering pins in the grips. Hold the test specimen so that slip relative to the grips is prevented as far as possible. Slip prevention preferably is effected with the type of grip that maintains or increases pressure on the test specimen, as the force applied to the test specimen increases. Ensure that the clamping system does not cause premature fracture at the grips.

6.1.4 *Load Indicator*—Incorporate the load indicator with a mechanism capable of showing the total tensile load carried by the test specimen when held by the grips. Ensure that the mechanism is free from inertia lag at the specified rate of testing and indicates the load with an accuracy of at least 1 % of the actual value. Attention is drawn to ISO 5893.

6.1.5 *Extensometer*—Use an extensometer that complies with ISO 5893. Use one that is capable of determining the relative change in the gage length on the test specimen at any time during the test. It is desirable, but not essential, that this instrument should automatically record this change. Ensure that the instrument is essentially free from inertia lag at the specified speed of testing and capable of measuring the change of gage length with an accuracy of 1 % of the relevant value or better. This corresponds to ±1 µm for the measurement of the modulus, based on a gage length of 50 mm. When an extensometer is attached to the test specimen, take care to ensure that any distortion of or damage to the test specimen is minimal. It is essential that there is no slippage between the extensometer and the test specimen.

6.1.5.1 The specimens also may be instrumented with longitudinal strain gages, the accuracy of which shall be 1 % of the relevant value or better. This corresponds to a strain accuracy of 20×10^{-6} (20 microstrain) for the measurement of the modulus. Choose the gages, surface preparation, and bonding agents, to exhibit adequate performance on the subject material.

6.2 *Devices for Measuring Width and Thickness of the Test Specimens*:

6.2.1 *Rigid Materials*—Use a micrometer, or its equivalent, capable of reading to 0.02 mm or less, and provided with means for measuring the thickness and width of the test specimens. Ensure that the dimensions and shape of the anvils are suitable for the specimens being measured and do not exert a force on the specimen such as to detectably alter the dimension being measured.