INTERNATIONAL STANDARD ISO 527-1:1993
TECHNICAL CORRIGENDUM 1

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Plastics — Determination of tensile properties —

Part 1:
General principles

TECHNICAL CORRIGENDUM 1

Plastiques — Détermination des propriétés en traction —

Partie 1: Principes généraux

RECTIFICATIF TECHNIQUE 1

Technical corrigendum 1 to International Standard ISO 527-1:1993 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical properties.*

Throughout the text, delete the expression "Young's modulus" or replace it by "tensile modulus of elasticity", depending on the context. This concerns definition 4.6, subclause 10.3 (twice), figure 1 and annex A (title plus second paragraph).

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INTERNATIONAL STANDARD

ISO 527-1

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Plastics — Determination of tensile properties —

Part 1:
General principles

Plastiques — Détermination des propriétés en traction —
Partie 1: Principes généraux

Reference number
ISO 527-1:1993(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 527-1 was prepared by Technical Committee ISO/TC 61, *Plastics*, Sub-Committee SC 2, *Mechanical properties*.

Together with the other parts of ISO 527, it cancels and replaces ISO Recommendation R 527:1966, which has been technically revised.

ISO 527 consists of the following parts, under the general title *Plastics — Determination of tensile properties*:

- *Part 1: General principles*
- *Part 2: Test conditions for moulding and extrusion plastics*
- *Part 3: Test conditions for sheet and film*
- *Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*
- *Part 5: Test conditions for unidirectional fibre-reinforced plastic composites*

Annex A of this part of ISO 527 is for information only.

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Plastics — Determination of tensile properties —

Part 1:
General principles

1 Scope

1.1 This part of ISO 527 specifies the general principles for determining the tensile properties of plastics and plastic composites under defined conditions.

Several different types of test specimen are defined to suit different types of material which are detailed in subsequent parts of ISO 527.

1.2 The methods are 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.

1.3 The methods are selectively suitable for use with the following range of materials:

— 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;

— rigid and semirigid thermosetting moulding materials, including filled and reinforced compounds; rigid and semirigid thermosetting sheets, including laminates;

— fibre-reinforced thermoset and thermoplastics composites incorporating unidirectional or non-unidirectional 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);

— thermotropic liquid crystal polymers.

The methods are not normally suitable for use with rigid cellular materials or sandwich structures containing cellular material.

1.4 The methods are applied using specimens which 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, *Plastics — Preparation and use of multipurpose test specimens*), may be used.

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

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 527. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 527 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 291:1977, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 2602:1980, *Statistical interpretation of test re-*

sults — 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 Principle

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.

4 Definitions

For the purposes of this part of ISO 527, the following definitions apply.

4.1 gauge length, L_o: Initial distance between the gauge 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).

4.2 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).

4.3 tensile stress, σ (engineering): Tensile force per unit area of the original cross-section within the gauge length, carried by the test specimen at any given moment.

It is expressed in megapascals (MPa) [see 10.1, equation (3)].

4.3.1 tensile stress at yield; yield stress, σ_y: 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 figure 1, curves b and c).

4.3.2 tensile stress at break, σ_B: The tensile stress at which the test specimen ruptures (see figure 1).

It is expressed in megapascals (MPa).

4.3.3 tensile strength, σ_M: Maximum tensile stress sustained by the test specimen during a tensile test (see figure 1).

It is expressed in megapascals (MPa).

4.3.4 tensile stress at x **% strain** (see 4.4), σ_x: Stress at which the strain reaches the specified value x expressed in percentage.

It is expressed in megapascals (MPa).

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

4.4 tensile strain, ε: Increase in length per unit original length of the gauge.

It is expressed as a dimensionless ratio, or in percentage (%) [see 10.2, equations (4) and (5)].

It is used for strains up to yield point (see 4.3.1); for strains beyond yield point see 4.5.

4.4.1 tensile strain at yield, ε_y: Tensile strain at the yield stress (see 4.3.1 and figure 1, curves b and c).

It is expressed as a dimensionless ratio, or in percentage (%).

4.4.2 tensile strain at break, ε_B: Tensile strain at the tensile stress at break (see 4.3.2), if it breaks without yielding (see figure 1, curves a and d).

It is expressed as a dimensionless ratio, or in percentage (%).

For breaking after yielding, see 4.5.1.

4.4.3 tensile strain at tensile strength, ε_M: Tensile strain at the point corresponding to tensile strength (see 4.3.3), if this occurs without or at yielding (see figure 1, curves a and d).

It is expressed as a dimensionless ratio or in percentage (%).

For strength values higher than the yield stress, see 4.5.2.

4.5 nominal tensile strain, ε_t: 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 10.2, equations (6) and (7)].

It is used for strains beyond yield point (see 4.3.1). For strains up to yield point, see 4.4. It represents the total relative elongation which takes place along the free length of the test specimen.

4.5.1 nominal tensile strain at break, ε_{tB}: Nominal tensile strain at the tensile stress at break (see 4.3.2), if the specimen breaks after yielding (see figure 1, curves b and c).

It is expressed as a dimensionless ratio, or in percentage (%).

For breaking without yielding, see 4.4.2.

4.5.2 nominal tensile strain at tensile strength, ε_{tM}: Nominal tensile strain at tensile strength (see 4.3.3), if this occurs after yielding (see figure 1, curve b).

It is expressed as a dimensionless ratio, or in percentage (%).

For strength values without or at yielding, see 4.4.3.

4.6 modulus of elasticity in tension; Young's modulus, E_t: Ratio of the stress difference σ_2 minus σ_1 to the corresponding strain difference values $\varepsilon_2 = 0{,}002\,5$ minus $\varepsilon_1 = 0{,}000\,5$ (see figure 1, curve d and 10.3, equation (8)].

It is expressed in megapascals, (MPa).

This definition does not apply to films and rubber.

NOTE 1 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.

4.7 Poisson's ratio, μ: 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.

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

5 Apparatus

5.1 Testing machine

5.1.1 General

The machine shall comply with ISO 5893, and meet the specifications given in 5.1.2 to 5.1.5, as follows.

5.1.2 Speeds of testing

The tensile-testing machine shall be capable of maintaining the speeds of testing (see 4.2) as specified in table 1.

Table 1 — Recommended testing speeds

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

1) These tolerances are smaller than those indicated in ISO 5893.

5.1.3 Grips

Grips for holding the test specimen shall be attached to the machine so that the major axis of the test specimen coincides with the direction of pull through the centreline of the grip assembly. This can be achieved, for example, by using centring pins in the grips. The test specimen shall be held such that slip relative to the grips is prevented as far as possible and this shall preferably be effected with the type of grip that maintains or increases pressure on the test specimen as the force applied to the test specimen increases. The clamping system shall not cause premature fracture at the grips.

5.1.4 Load indicator

The load indicator shall incorporate a mechanism capable of showing the total tensile load carried by the test specimen when held by the grips. The mechanism shall be essentially free from inertia lag at the specified rate of testing, and shall indicate the load with an accuracy of at least 1 % of the actual value. Attention is drawn to ISO 5893.

5.1.5 Extensometer

The extensometer shall comply with ISO 5893. It shall be capable of determining the relative change in the gauge 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. The instrument shall be essentially free from inertia lag at the specified speed of testing, and shall be capable of measuring the change of gauge 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 gauge length of 50 mm.

When an extensometer is attached to the test specimen, care shall be taken 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.

The specimens may also be instrumented with longitudinal strain gauges, 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. The gauges, surface preparation and bonding agents should be chosen to exhibit adequate performance on the subject material.

5.2 Devices for measuring width and thickness of the test specimens

5.2.1 Rigid materials

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, shall be used. The dimensions and shape of the anvils shall be suitable for the specimens being measured and shall not exert a force on the specimen such as to detectably alter the dimension being measured.

5.2.2 Flexible materials

A dial-gauge, capable of reading to 0,02 mm or less and provided with a flat circular foot which applies a pressure of 20 kPa ± 3 kPa, shall be used for measuring the thickness.

6 Test specimens

6.1 Shape and dimensions

See that part of ISO 527 relevant to the material being tested.

6.2 Preparation of specimens

See that part of ISO 527 relevant to the material being tested.

6.3 Gauge marks

If optical extensometers are used, especially for thin sheet and film, gauge marks on the specimen are necessary to define the gauge length. These shall be approximately equidistant from the midpoint, and the distance between the marks shall be measured to an accuracy of 1 % or better.

Gauge marks shall not be scratched, punched or impressed upon the test specimen in any way that may damage the material being tested. It must be ensured that the marking medium has no detrimental effect on the material being tested and that, in the case of parallel lines, they are as narrow as possible.

6.4 Checking the test specimens

The specimens shall be free of twist and shall have mutually perpendicular pairs of parallel surfaces. The surfaces and edges must be free from scratches, pits, sink marks and flash. The specimens shall be checked for conformity with these requirements by visual observation against straightedges, squares and flat plates, and with micrometer calipers. Specimens showing observed or measured departure from one or more of these requirements shall be rejected or machined to proper size and shape before testing.

6.5 Anisotropy

See that part ISO 527 relevant to the material being tested.

7 Number of test specimens

7.1 A minimum of five test specimens shall be tested for each of the required directions of testing and for the properties considered (modulus of elasticity, tensile strength etc.). The number of measurements may be more than five if greater precision of the mean value is required. It is possible to evaluate this by means of the confidence interval (95 % probability, see ISO 2602).

7.2 Dumb-bell specimens that break within the shoulders or the yielding of which spreads to the width of the shoulders shall be discarded and further specimens shall be tested.

7.3 Data from parallel-sided specimens where jaw slippage occurs, or where failure occurs within 10 mm of either jaw, or where an obvious fault has resulted in premature failure, shall not be included in the analysis. Repeat tests shall be carried out on new test specimens.

Data, however variable, shall not be excluded from the analysis for any other reason, as the variability in such data is a function of the variable nature of the material being tested.

NOTE 2 When the majority of failures falls outside the criteria for an acceptable failure, the data may be analysed statistically, but it should be recognized that the final result is likely to be conservative. In such instances, it is preferable for the tests to be repeated with the dumb-bell specimens to reduce the possibility of unacceptable results.

8 Conditioning

The test specimen shall be conditioned as specified in the appropriate standard for the material concerned. In the absence of this information, the most appropriate condition from ISO 291 shall be selected, unless otherwise agreed upon by the interested parties.

9 Procedure

9.1 Test atmosphere

Conduct the test in the same atmosphere used for conditioning the test specimen, unless otherwise agreed upon by the interested parties, e.g. for testing at elevated or low temperatures.

9.2 Dimensions of test specimen

Measure the width b to the nearest 0,1 mm and the thickness h to the nearest 0,02 mm at the centre of each specimen and within 5 mm of each end of the gauge length.

Record the minimum and maximum values for width and thickness of each specimen and make sure that they are within the tolerances indicated in the standard applicable for the given material.

Calculate the arithmetic means for the width and thickness of each specimen, which shall be used for calculation purposes.

NOTES

3 In the case of injection-moulded specimens, it is not necessary to measure the dimensions of each specimen. It is sufficient to measure one specimen from each lot to make sure that the dimensions correspond to the specimen type selected (see the relevant part of ISO 527). With multiple-cavity moulds, ensure that the dimensions of the specimens are the same for each cavity.

4 For test specimens stamped from sheet or film material, it is permissible to assume that the mean width of the central parallel portion of the die is equivalent to the corresponding width of the specimen. The adoption of such a procedure should be based on comparative measurements taken at periodic intervals.

9.3 Clamping

Place the test specimen in the grips, taking care to align the longitudinal axis of the test specimen with the axis of the testing machine. To obtain correct alignment when centring pins are used in the grips, it is necessary to tension the specimen only slightly before tightening the grips (see 9.4). Tighten the grips evenly and firmly to avoid slippage of the test specimen.

9.4 Prestresses

The specimen shall not be stressed substantially prior to test. Such stresses can be generated during centring of a film specimen, or can be caused by the clamping pressure, especially with less rigid materials.

The residual stress σ_0 at the start of a test shall not exceed the following value, for modulus measurement:

$$|\sigma_0| \leqslant 5 \times 10^{-4} E_t \qquad \ldots (1)$$

which corresponds to a prestrain of $\varepsilon_0 \leqslant 0,05$ %, and for measuring relevant stresses σ, e.g. $\sigma = \sigma_y$, σ_M or σ_B:

$$\sigma_0 \leqslant 10^{-2} \sigma \qquad \ldots (2)$$

9.5 Setting of extensometers

After balancing the prestresses, set and adjust a calibrated extensometer to the gauge length of the test specimen, or provide longitudinal strain gauges, in accordance with 5.1.5. Measure the initial distance (gauge length) if necessary. For the measurement of Poisson's ratio, two elongation- or strain-measuring devices shall be provided to act in the longitudinal and normal axes simultaneously.

For optical measurements of elongation, place gauge marks on the specimen in accordance with 6.3.

The elongation of the free length of the test specimen, measured from the movement of the grips, is used for the values of the nominal tensile strain ε_t (see 4.5).

9.6 Testing speed

Set the speed of testing in accordance with the appropriate standard for the material concerned. In the absence of this information, the speed of testing should be agreed between the interested parties in accordance with table 1.

It may be necessary or desirable to adopt different speeds for the determination of the elastic modulus, of the stress/strain properties up to the yield point, and for the measurement of tensile strength and maximum elongation. For each testing speed, seperate specimens shall be used.

For the measurement of the modulus of elasticity, the selected speed of testing shall provide a strain rate as near as possible to 1 % of the gauge length per minute. The resulting testing speed for different types of specimens is given in that part of ISO 527 relevant to the material being tested.

9.7 Recording of data

Record the force and the corresponding values of the increase of the gauge length and of the distance between grips during the test. It is preferable to use an automatic recording system which yields complete stress/strain curves for this operation [see clause 10, equations (3), (4) and (5)].

Determine all relevant stresses and strains defined in clause 4 from the stress/strain curve (see figure 1), or using other suitable means.

For failures outside the criteria for an acceptable failure, see 7.2 and 7.3.

10 Calculation and expression of results

10.1 Stress calculations

Calculate all stress values defined in 4.3 on the basis of the initial cross-sectional area of the test specimen:

$$\sigma = \frac{F}{A} \qquad \dots (3)$$

where

- σ is the tensile stress value in question, expressed in megapascals;
- F is the measured force concerned, in newtons;
- A is the initial cross-sectional area of the specimen, expressed in square millimetres.

10.2 Strain calculations

Calculate all strain values defined in 4.4 on the basis of the gauge length:

$$\varepsilon = \frac{\Delta L_0}{L_0} \qquad \dots (4)$$

$$\varepsilon\ (\%) = 100 \times \frac{\Delta L_0}{L_0} \qquad \dots (5)$$

where

- ε is the strain value in question, expressed as a dimensionless ratio, or in percentage;
- L_0 is the gauge length of the test specimen, expressed in millimetres;
- ΔL_0 is the increase in the specimen length between the gauge marks, expressed in millimetres.

The values of the nominal tensile strain, defined in 4.5, shall be calculated on the basis of the initial distance between the grips:

$$\varepsilon_t = \frac{\Delta L}{L} \qquad \dots (6)$$

$$\varepsilon_t\ (\%) = 100 \times \frac{\Delta L}{L} \qquad \dots (7)$$

where

- ε_t nominal tensile strain, expressed as a dimensionless ratio or percentage, %;
- L initial distance between grips, expressed in millimetres;
- ΔL increase of the distance between grips, expressed in millimetres.

10.3 Modulus calculation

Calculate the modulus of elasticity (Young's modulus), defined in 4.6 on the basis of two specified strain values:

$$E_t = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \qquad \dots (8)$$

where

- E_t is Young's modulus of elasticity, expressed in megapascals;
- σ_1 is the stress, in megapascals, measured at the strain value $\varepsilon_1 = 0{,}000\ 5$;
- σ_2 is the stress, in megapascals, measured at the strain value $\varepsilon_2 = 0{,}002\ 5$;

For computer-aided equipment, see 4.6, note 1.

10.4 Poisson's ratio

If required, calculate Poisson's ratio defined in 4.7 on the basis of two corresponding strain values perpendicular to each other:

$$\mu_n = -\frac{\varepsilon_n}{\varepsilon} \qquad \dots (9)$$

where

- μ_n is Poisson's ratio, expressed as a dimensionless ratio with $n = b$ (width) or h (thickness) indicating the normal direction chosen;
- ε is the strain in the longitudinal direction;
- ε_n is the strain in the normal direction, with $n = b$ (width) or h (thickness).

10.5 Statistical parameters

Calculate the arithmetic means of the test results and, if required, the standard deviations and the 95 % confidence intervals of the mean values according to the procedure given in ISO 2602.

10.6 Significant figures

Calculate the stresses and the modulus to three significant figures. Calculate the strains and Poisson's ratio to two significant figures.

11 Precision

See that part of ISO 527 relevant to the material being tested.

12 Test report

The test report shall include the following information:

a) a reference to the relevant part of ISO 527;

b) all the data necessary for identification of the material tested, including type, source, manufacturer's code number and history, where these are known;

c) description of the nature and form of the material in terms of whether it is a product, semifinished product, test panel or specimen. It should include the principal dimensions, shape, method of manufacture, succession of layers and any pretreatment;

d) type of test specimen, the width and thickness of the parallel section, including mean, minimum and maximum values;

e) method of preparing the test specimens, and any details of the manufacturing method used;

f) if the material is in product or semifinished product form, the orientation of the specimen in relation to the product or semifinished product from which it is cut;

g) number of test specimens tested;

h) standard atmosphere for conditioning and testing, plus any special conditioning treatment, if required by the relevant standard for the material or product concerned;

i) accuracy grading of the test machine (see ISO 5893);

j) type of elongation or strain indicator;

k) type of clamping device and clamping pressure, if known;

l) testing speeds;

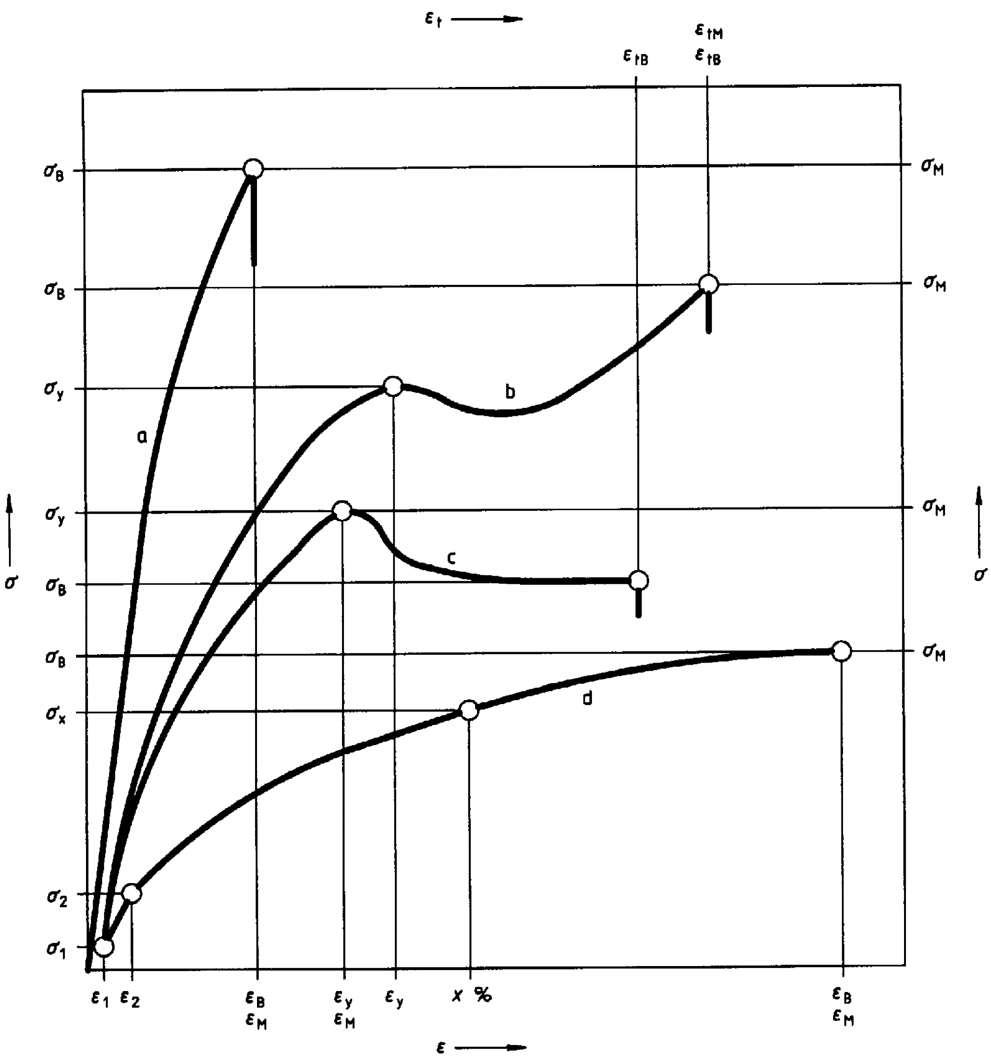
m) individual test results;

n) mean value(s) of the measured property(ies), quoted as the indicative value(s) for the material tested;

o) standard deviation, and/or coefficient of variation, and/or confidence limits of the mean, if required;

p) statement as to whether any test specimens have been rejected and replaced, and, if so, the reasons;

q) date of measurement.



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 10.3 are indicated by (σ_1, ε_1) and (σ_2, ε_2), shown only for curve d ($\varepsilon_1 = 0{,}000\ 5$; $\varepsilon_2 = 0{,}002\ 5$).

Figure 1 — Typical stress/strain curves

Annex A
(informative)

Young's modulus and related values

Due to their viscoelastic behaviour many properties of polymer materials depend not only on temperature but also on time. With regard to the tensile test, this causes nonlinear stress/strain curves (bending towards the strain axis) even within the range of linear viscoelasticity. This effect is pronounced in the case of tough polymers. Consequently, the values of the tangent modulus of tough materials taken from the initial part of the stress/strain curves often depend strongly on the scales used. Thus the conventional method (tangent at the initial point of the stress/strain curve) does not give reliable moduli for these materials.

The method for the measurement of Young's modulus prescribed in this part of ISO 527 is based, therefore, on two specified strain values, i.e. 0,25 % and 0,05 %. (The lower strain value has been set at not zero in order to avoid errors in the measured modulus caused by possible onset effects at the beginning of the stress/strain curve.)

In the case of brittle polymers, both the new and the conventional methods give the same values for the modulus. The new method, however, allows accurate and reproducible measurement of the moduli of tough plastics. The definition of the initial tangent modulus, therefore, has been deleted in the present part of ISO 527.

The aspects mentioned above for the modulus similarly relate to the "offset yield point", which in ISO/R 527 was defined by the deviation of the stress/strain curve from its initial linearity. The offset yield point, therefore, is replaced by a point of specified strain (stress at x % strain, σ_x, see 4.3.4). Since the definition of such a "substitute" yield point is significant for tough materials only, the specified strain shall be chosen near the yield strain commonly found.

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