UDC 678.5 / .8 : 620.17

Ref. No.: ISO / R 537 - 1967 (E)

ISO

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO RECOMMENDATION
R 537

PLASTICS
TESTING OF PLASTICS WITH THE TORSION PENDULUM

1st EDITION
January 1967

For each individual country the only valid standard is the national standard of that country.

Printed in Switzerland

Also issued in French and Russian. Copies to be obtained through the national standards organizations.

BRIEF HISTORY

The ISO Recommendation R 537, *Testing of Plastics with the Torsion Pendulum*, was drawn up by Technical Committee ISO/TC 61, *Plastics*, the Secretariat of which is held by the American Standards Association, Inc. (ASA).

Work on this question by the Technical Committee began in 1958 and led, in 1961, to the adoption of a Draft ISO Recommendation.

In June 1963, this Draft ISO Recommendation (No. 533) was circulated to all the ISO Member Bodies for enquiry. It was approved by the following Member Bodies:

Argentina	Germany	Portugal
Australia	Hungary	Republic of South Africa
Austria	India	Romania
Belgium	Iran	Spain
Chile	Japan	Sweden
Czechoslovakia	Netherlands	Switzerland
Finland	New Zealand	U.S.A.
France	Poland	Yugoslavia

One Member Body opposed the approval of the Draft:
United Kingdom.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in January 1967, to accept it as an ISO RECOMMENDATION.

ISO Recommendation R 537

ISO/R 537-1967 (E)
ERRATUM
August 1969

PLASTICS

TESTING OF PLASTICS WITH THE TORSION PENDULUM

1st Edition – January 1967

ERRATUM

Page 8, clause 6.2

In the formula giving the shear modulus replace "μ^2" by "π^2".

Thus, the corrected formula reads :

$$G = J f^2 \underbrace{\left[\frac{12\ \pi^2\ l}{b\ h^3\ C}\right]}_{F_g} - \underbrace{\left[\frac{m\ g\ b}{4\ h^3\ C}\right]}_{S_E}$$

ISO Recommendation R 537

ISO/R 537-1967 (E)
ERRATUM
June 1972

PLASTICS

TESTING OF PLASTICS WITH THE TORSION PENDULUM

1st Edition – January 1967

ERRATUM

Page 4, Clause 4.1.1, 18th line :

Replace "310 g/cm^2" by "310 g·cm^2".

Page 8, Clause 6.2 : In the definition of *J*, replace "grammes per square centimetre" by "gramme centimetres squared".

ISO Recommendation R 537 January 1967

PLASTICS

TESTING OF PLASTICS WITH THE TORSION PENDULUM

1. SCOPE

This method of test is designed to enable the shear modulus and the mechanical damping to be measured as a function of temperature using free torsion oscillations. By means of this method, measurements are made over a frequency range from 0.1 to 10 Hz. It is thus possible to determine the mechanical properties of plastics materials at low deformation stresses and low stressing speeds over a wide temperature range.

This method is also employed for determining the temperature range over which a plastics material appears rigid, visco-elastic or rubber-like, and it also gives information concerning the commencement of plastic flow. The method provides a means of easily distinguishing thermoplastic, thermosetting and other cross-linked polymers and between crystalline and amorphous polymers.

When carried out at one temperature, the method is only of use as a control test of plastics whose general properties are known. It can thus be employed to determine whether a given plastics material is " soft " or " rigid " at a given temperature and stressing speed.

The shear modulus and the mechanical damping are physical constants which are independent of the test method, the apparatus employed and the shape of the test specimen.

2. DEFINITIONS

2.1 **Shear modulus.** Quotient of the shearing stress and the resulting elastic angular deformation for very small deformations within the elastic limit of stress to corresponding strain.

2.2 **Logarithmic decrement.** Mechanical damping resulting from the dissipation of internal energy in the torsion pendulum test measured by the logarithmic decrement Λ. The logarithmic decrement is defined as the natural logarithm of the ratio of the amplitudes of 2 successive oscillations.

2.3 **Mechanical loss factor.** Internal energy dissipation causing damping expressed by the mechanical loss factor d which is related to the logarithmic decrement Λ by an equation, which for $\Lambda \leqslant 2$ reduces to

$$d = \frac{\Lambda}{\pi}$$

3. TEST SPECIMEN

3.1 The test specimen is prepared and conditioned under the specific conditions required for each material.

NOTE. — The conditions employed in the preparation of a test specimen should be very accurately observed in the case of materials whose mechanical properties are influenced by previous thermal and mechanical treatment. This applies to partially crystalline plastics such as polyamides.

In tests for the characterization of the nature of a material, the preparation by cutting of test specimens from commercial plastics such as rod or sheet is only possible with amorphous material when the latter is free from internal stresses.

The preparation of test specimens by cutting from rod or sheet is not possible in the case of plastics which tend to crystallize. Here the test specimen should be brought into the desired shape by pressing and the crystallization completed by controlled cooling from the viscous state.

When the properties of a particular material, e.g. a piece of stressed plastic, are to be tested, the test specimen should be prepared by punching or careful machining with precautions to avoid heating. With such material it is advisable to carry out tests in the direction of stressing and perpendicular to this direction.

3.2 The most suitable test specimen is a flat rod of length (l) 60 mm, width (b) 10 mm and thickness (h) 1 mm. Other dimensions of test specimen can be employed, provided that they ensure sufficiently rapid transfer of heat. With test specimens of thickness 0.15 down to 0.05 mm, the oscillating system should be enclosed in a vacuum. The testing of test specimens with a thickness less than 0.05 mm is not recommended.

NOTE. — The shear modulus and logarithmic decrement Λ are independent of the shape of the test specimen which can therefore be varied as desired. The equation given in section 6, however, applies only to a test specimen of rectangular cross-section and where the test specimen is of uniform cross-section over its entire length (see section 5).

4. APPARATUS

4.1 Torsion pendulum

Any suitable torsion pendulum can be employed which enables the shear modulus and the damping of free torsional oscillations of plastics to be determined as a function of temperature and which provides for uniform temperature over the entire test specimen at any given test temperature.

Two methods are described in this ISO Recommendation:

Method A (Fig. 1 and 2, page 5): Test specimen supporting inertia member ;

Method B (Fig. 3, page 7): Test specimen not supporting inertia member.

4.1.1 *Method A.* The test specimen is held at its upper end in a clamp and is attached at its lower end to a disc of known moment of inertia (see Fig. 2). In order to obtain a constant temperature over the whole length of the test specimen, the axes passing through the top and bottom of the constant temperature chamber should be constructed of a poor conductor of heat such as glass.

NOTE.—By means of a slight twist of the upper axis, a torque is transferred to the disc via the test specimen and the system thus brought into a state of free oscillation. A small mirror is mounted immediately above the disc so that the reflecting surface lies in the axis of the oscillating system. The oscillation is transferred by means of the light beam which falls on the mirror from the light source onto a photographic strip. The frequency and amplitude of the oscillations can be determined from the trace on the photographic strip. The apparatus is provided with an arresting device to remove the stress on the test specimen during the heating period between measurements. The apparatus also incorporates a scale by means of which any elongation of test specimen can be measured.

A disc with a total mass of 30 g (24.8 g for a light metal disc and 5.2 g for the lower axis with clamp and mirror) has been found to be most suitable for test specimens as described in clause 3.2. This corresponds to a moment of inertia of 310 g/cm^2.

The dimensions of the disc are such that the total tensile stress on the test specimen does not exceed 1 kgf/cm^2. If the value of the correction term S_E yields a negative value for the shear modulus (see clause 6.2) the load is reduced.

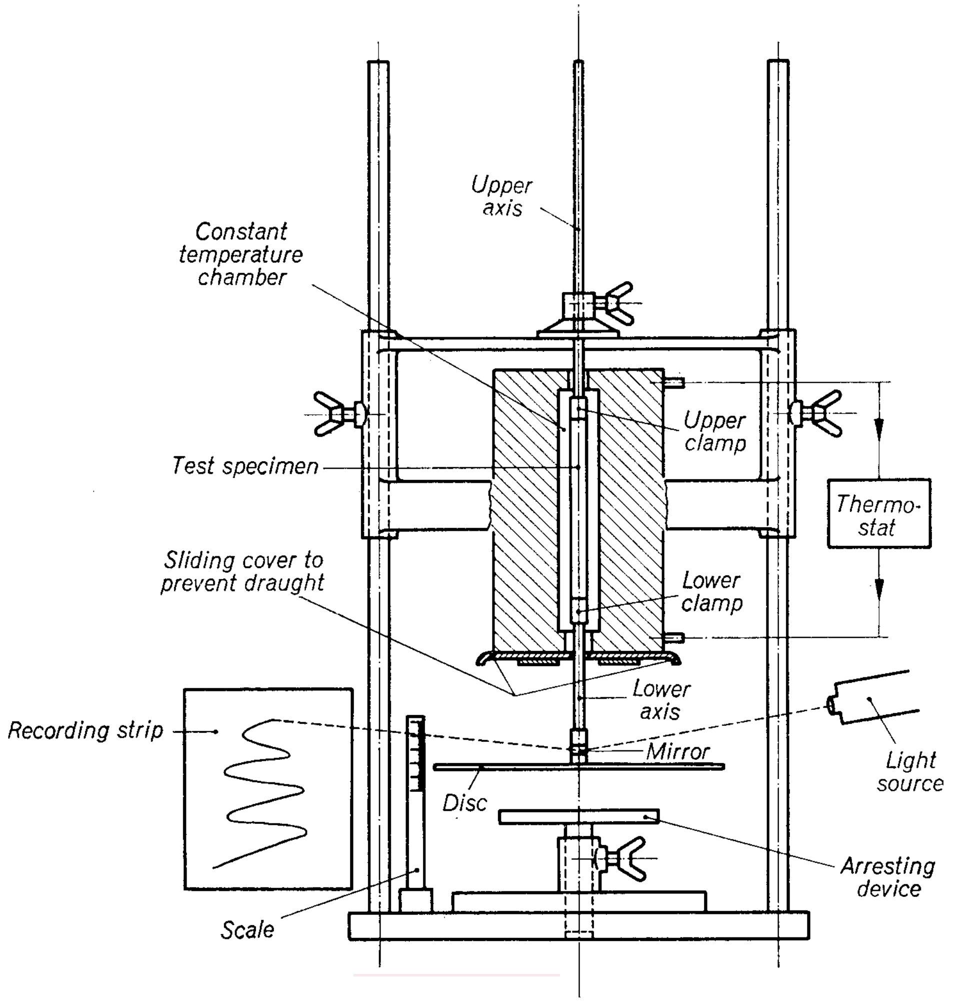

FIG. 1. — Example of a torsion pendulum (Method A)

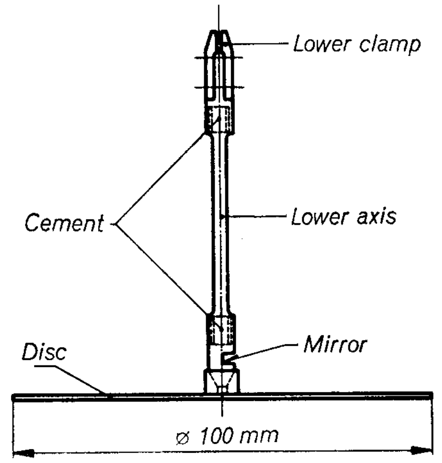

FIG. 2. — Moment of inertia disc including the lower clamp and the lower axis with mirror

4.1.2 *Method B.* The difference from Method A is that the clamp for the upper end of the test specimen and the disc of known moment of inertia are suspended by a fine wire (or band) and are balanced by means of a counterweight. The lower clamp is fixed (see Fig. 3).

4.2 Apparatus for temperature control

The test specimen and the clamps are enclosed in a constant temperature chamber containing air or inert gas and provided with an arrangement for varying the temperature. The constant temperature chamber should provide for a temperature range of at least −60 °C to +250 °C. The temperature in the immediate vicinity of the test specimen will not vary by more than ± 1 °C.

NOTE.—A suitable form of constant temperature chamber for test specimens as described in clause 3.2 consists of a double-walled cylinder of approximately 100 mm height and an internal diameter of approximately 25 mm. The inner and outer walls of the cylinder are about 10 mm apart and are suitably insulated on the outside. The chamber is so arranged that a liquid at constant temperature can be circulated through the annular space. The opening for the upper axis should prevent air circulation from the interior of the chamber to the outside but at the same time permit movement and rotation of the axis. The opening of the chamber at the lower end should be as small as possible and consistent with free movement of the oscillating system. The experimental arrangement described eliminates draught effects.
When tests are carried out in inert or dry gases, a stream of gas is passed in at a rate of about 20 ml/min. The temperature in the vicinity of the test specimen is measured with a thermocouple or resistance thermometer.

4.3 Apparatus for measurement of thickness, width and length

The measuring apparatus is such that the thickness of the test specimen can be measured to an accuracy of ± 0.003 mm, the width of the test specimen to an accuracy of ± 0.05 mm and the length of the test specimen between the clamps to an accuracy of ± 0.1 mm; the test specimen should not be deformed during the measurement.

4.4 Apparatus for recording the oscillations

The oscillation can be recorded by any suitable apparatus which permits exact determination of the period and the amplitude and which exerts no perceptible additional damping effect on the oscillating system. When recorders are employed, the recording strip should move with a speed which does not vary by more than ± 1 per cent.

In the apparatus shown in Figure 1, the recording device can be replaced by a scale for the measurement of oscillation with a large period. The data required for the calculations are then read off during the experiment.

5. PROCEDURE

5.1 Measurement of the thickness and width of the test specimen

The thickness and width of the test specimen are measured before the test at not less than 5 places along its length. In the case of test specimens as described in clause 3.2, the thickness is measured with an accuracy of $\pm$ 0.003 mm and the width with an accuracy of $\pm$ 0.05 mm (see clause 4.3). For calculation of modulus G (see clause 6.2) the arithmetic means of these measurements are used.

Test specimens in which the maximum thicknesses vary by more than 3 per cent are rejected.

5.2 Clamping the test specimen

The test specimen is clamped between the upper and lower clamps. The longitudinal axis of the test specimen should lie in the axis of rotation of the oscillating system.

NOTE.—The clamping of the test specimen is particularly important. Sinusoidal oscillations are only obtained when the test specimen is exactly centred. Any eccentricity will cause lateral oscillation and thus interfere with the normal oscillation process.

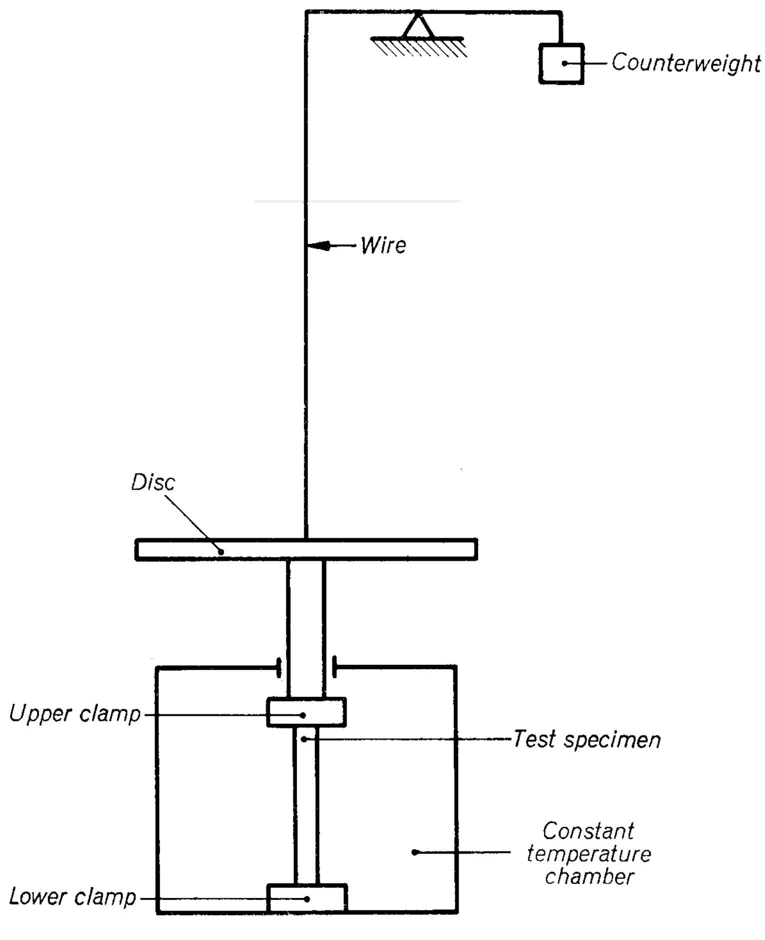

FIG. 3. — **Illustration of Method B**

5.3 Measurement of the length of test specimen

The length of the test specimen, i.e. between the two clamps, is measured to an accuracy of $\pm$ 0.1 mm.

5.4 Introduction of the test specimen

When the test specimen is introduced into the constant temperature chamber (Fig. 1 and 3), care should be taken that it is not stressed in any way.

5.5 Temperature treatment of the test specimen

The rate of heating in the constant temperature chamber should not exceed 50 °C per hour. The heating should ensure a uniform temperature throughout the test specimen. The temperature of the test specimen should not vary by more than 0.25 °C during any one measurement.

5.6 Torsional oscillation test

The movable system is brought into a state of free oscillation by slight twisting of the upper axis. The angle of twist should not to exceed 3° in either direction. The period and the amplitude are measured.
A suitable method is to record the oscillations on a photographic recording strip from which the frequency and the amplitude of successive oscillations can be obtained.

6. CALCULATION AND EXPRESSION OF RESULTS

6.1 Logarithmic decrement Λ

If A_1, A_2, A_3 . . . . A_n are the amplitudes of successive oscillations in the same direction, then the logarithmic decrement of mechanical damping is given by

$$\Lambda = l_n \frac{A_1}{A_2}$$

or, in general

$$\Lambda = l_n \frac{A_n}{A_{n+1}}$$

where Λ = logarithmic decrement.

6.2 Shear modulus

For test specimens of rectangular cross-section, for which the logarithmic decrement Λ is less than 1, the shear modulus is calculated from the following equation:

$$G = J f^2 \underbrace{\left[\frac{12\,\mu^2\; l}{b\; h^3\; C}\right]}_{F_g} - \underbrace{\left[\frac{m\; g\; b}{4\; h^3\; C}\right]}_{S_E}$$

where

G = Shear modulus in dynes per square centimetre
J = Moment of inertia of the disc in grammes per square centimetre
f = Frequency of oscillation per second
b = Width of the specimen in centimetres
l = Length of the specimen in centimetres
m = Mass of the tensile force in grammes
g = Acceleration due to gravity in centimetres per second squared
μ = Shape factor depending upon the ratio $\frac{b}{h}$ (see Table, page 9)
C = Correction factor
h = Thickness of the specimen in centimetres

NOTE.— $C = \frac{3\mu}{16}$ or, if $\frac{h}{b} < 0.4$, $C = (1 - 0.632\,\frac{h}{b})$

TABLE

Ratio of specimen " Width to thickness "	Shape factor μ	Ratio of specimen " Width to thickness "	Shape factor μ
1.00	2.249	4.00	4.493
1.20	2.658	4.50	4.586
1.40	2.990	5.00	4.662
1.60	3.250	6.00	4.773
1.80	3.479	7.00	4.853
2.00	3.659	8.00	4.913
2.25	3.842	10.00	4.997
2.50	3.990	20.00	5.165
2.75	4.111	50.00	5.266
3.00	4.213	100.00	5.300
3.50	4.373		

The factor F_g incorporates the dimensions of the specimen. The correction term S_E incorporates the effect of gravity on the restoring torque. This term is taken into account with rigid plastics if its value is greater than 10^8 dyn/cm^2.

The term S_E is taken into account in all measurements with rubber-like plastics. Annex A (pp. 10-11) contains a table showing values of S_E for test specimen thicknesses between 0.001 and 0.204 cm, where $m = 30$ g and $b = 1$ cm.

Other equations are necessary for the calculation of the shear modulus of test specimens of shapes other than those treated in this ISO Recommendation. Information concerning such calculations will be found in the literature cited in Appendix Z (page 12) (cf. B. de Saint-Venant and J. W. Geckeler).

7. TEST REPORT

The test report should give the following information:

(*a*) Nature, form supplied and designation of the material; testing method and tensile force.

(*b*) Thermal and other conditions employed in shaping, preparation and conditioning of the test specimen, dimensions of the specimen, and the tolerances if they diverge from those given in this ISO Recommendation.

(*c*) Plots of the shear modulus G and the logarithmic decrement of the mechanical damping Λ as a function of the temperature. It is recommended that the shear modulus G be plotted as a logarithm.

(*d*) Date of test.