TECHNICAL REPORT

ISO TR 8285

First edition
1990-02-01

Plain bearings — Evaluation of the tribological properties of polymer-based materials

Paliers lisses — Évaluation des propriétés tribologiques des matériaux à base de polymères

Reference number
ISO/TR 8285 : 1990 (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.

The main task of ISO technical committees is to prepare International Standards. In exceptional circumstances a technical committee may propose the publication of a technical report of one of the following types:

— type 1, when the necessary support within the technical committee cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development requiring wider exposure;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical reports are accepted for publication directly by ISO Council. Technical reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical reports type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 8285, which is a technical report of type 2, was prepared by Technical Committee ISO/TC 123, *Plain bearings.*

Annexes A and B of this Technical Report are for information only.

Two versions of this Technical Report have been prepared since 1983. Most of the comments from the member bodies have been incorporated in this version.

It covers the subject dealt with in ISO/TR 7147 : 1985, *Plain bearings — Testing of the tribological behaviour of plastics.* There was a strong feeling among ISO/TC 123 members (Austria, Germany, F.R., United Kingdom) that both documents should be published as International Standards because of their importance.

It was therefore decided to publish DP 8285 as a Technical Report in order to collect any further comments. At the same time, a new version is being prepared by the USSR member body that combines both Technical Reports. A new round of tests will be conducted and, if approved, an International Standard will be prepared.

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

Plain bearings — Evaluation of the tribological properties of polymer-based materials

1 Scope

This Technical Report deals with the tribological testing of bulk plastic specimens under specified working conditions, i.e. load, sliding velocity and temperature, without lubrication. From the test results, data are obtained about the tribological behaviour of steel-plastic rubbing pairs which can be used in practice for predicting the working capacity of a friction unit.

It specifies the test conditions, equipment and programmes that allow reproducibility of the results at particular conditions of the specimen preparation and testing.

This Technical Report specifies the specimen shape, conditions of the rubbed surfaces of the plastic and steel, tolerable run-out of the rotating counterface, heat transfer between the device housing and counterface, the range of variations in the friction process parameters in order to reach the reproducibility of the results in the tribological testing of plastics. It proposes technical solutions for the standard equipment used for the tribological testing of plastics.

2 Symbols and units

See table 1.

Table 1

Symbol	Parameter	SI unit
f	Coefficient of friction	—
F_n	Normal force	N
F_f	Friction force	N
p	Normal specific load	N/mm²
σ_s	Compression strength of polymer	N/mm²
Q	Thermal constant of a friction unit	°C·m·s/N
T	Temperature in the friction zone	°C
ΔT	Difference between the temperature in the contact zone and the ambient temperature	°C
u	Sliding velocity	m/s
t	Testing period	h
s	Sliding distance	km
w_l	Linear wear	µm
w_t	Wear rate	µm/h
w_s	Wear intensity	µm/km
k	Wear factor	mm²/N
T_m, T_s	Melting and softening temperatures of polymer, respectively	°C

3 Definitions

3.1 coefficient of friction, f: Ratio of the friction force resulting from the sliding of a plastic against a steel to the normal force pressing the two bodies together:

$$f = \frac{F_f}{F_n}$$

3.2 wear rate, w_t: Ratio of the linear wear of the tested plastic block to the testing period:

$$w_t = \frac{w_l}{t}$$

3.3 wear intensity, w_s: Ratio of the linear wear to the sliding distance:

$$w_s = \frac{w_l}{s}$$

3.4 wear factor, k: Ratio of the wear intensity to the normal specific load:

$$k = \frac{w_s}{p}$$

4 Shape and manufacture of test specimens

To estimate the tribological properties of plastics in accordance with this Technical Report, a tribosystem should consist of a steel roller and a plastic block with mateable friction surfaces (see figure 1). The possible material combinations for the block and the roller are given in table 2.

Table 2

No.	Combination	
	Block	Roller
I	Plastic	Metal
II	Metal	Plastic
III	Plastic	Plastic

The basic mating combination complying with this Technical Report is combination I.

4.1 Plastic block

The block can be made by moulding, injection moulding, turning or by milling, making use of the near surface structure effects formed by moulding or machining (see figures 2 and 3).

The block is 10 mm high, 10 mm wide and 20 mm long (see figure 2).

The roughness of the plastic block depends on the machining conditions; in case of moulding or injection moulding, it depends on the roughness of the moulding parts (R_a = 0,3 µm to 0,6 µm).

4.2 Test roller

A test roller complying with this Technical Report is a combination of a steel bushing and a heat-insulating bushing. The heat-insulating bushing is made of textolite and is pressed into the steel bushing. The dimensions of the mating parts are shown in figure 4.

The steel bushing is made of steel with a carbon content of between 0,45 % and 0,8 %, of hardness 45 HRC to 50 HRC, for example steel complying with ISO 683 (all published parts).

The thermally insulated roller is designed for comparative tests; it provides reproducibility of the results when testing equipment of different designs is employed.

For certificate testing, the temperature control of the test roller is important. A schematic representation of the thermal regulation is shown in figure 5.

The surface roughness, R_a, of the roller may have the following values, depending on the machining or preparation of the roller friction surfaces:

a) R_a = 0,63 µm to 0,8 µm;

b) R_a = 0,25 µm to 0,32 µm;

c) R_a = 0,04 µm to 0,05 µm.

Alternative b) is preferred when estimating the tribological properties of plastics.

5 Preparation of test specimens

The specimens (block and roller) should be cleaned before the tests to remove various contaminants with liquids that do not dissolve the specimen material.

5.1 Polymeric block

The block surface should be cleaned with a liquid at a temperature of 23 °C ± 5 °C, at a relative humidity of 50 %. The blocks should be dried in air and then placed in a vacuum at 10^{-3} torr for 2 h.

Liquids easily volatile at 23 °C ± 5 °C that do not dissolve plastics or their components, for example petrol, acetone, ethanol or cyclohexane, shall be used for cleaning. Cleaning should be carried out in a bath of one of the above liquids.

The recommendations of the plastics manufacturer should be taken into account when choosing a liquid for cleaning.

5.2 Test roller

One of the liquids given in 5.1 should be used for cleaning the roller surface. The roller should be dried in an oven at 50 °C to 60 °C without ventilation.

6 Test equipment

Testing according to this Technical Report may be carried out with block-roller devices presently available. They need to be modernized and some technological limitations have to be observed to ensure the reproducibility of the results.

The technological limitations are as follows.

6.1 The comparative tests should be carried out with a heat-insulating bushing between the test shaft and roller (see figures 4 and 6). The heat dissipation will improve the reproducibility of the test results obtained with equipment of different designs.

6.2 The certification tests shall be carried out with thermally regulated rollers (see figure 5) or a multistep device with a thermally regulated shaft (see figure 7). The thermostatic regulation is done to estimate the tribological properties of plastics at a constant counterface bulk temperature.

6.3 The radial run-out of the roller working surface should not be greater than 25 µm.

The test rig should allow

a) the smooth control and maintenance of the sliding velocity at a given level within 2,5 % of the existing value;

b) continuous loading of the specimen (block) within 2,5 % of the existing value;

c) measurement of the friction coefficient, temperature of the roller sliding surface, and the linear wear of the block.

The continuous control of the linear wear is realized with a special instrument with an accuracy of ± 0,5 µm [the use of such an instrument cuts the testing period of the specimens after running-in (see figure 6)].

To measure average temperatures of the plastic and metal friction surfaces, a thermocouple is located within a through-hole in the plastic block 0,2 mm above the friction surface.

At the stage of thermostatic regulation, the required bulk temperature of the roller and the shaft in a multistep machine is controlled by variations in the operating conditions of the liquid thermostat.

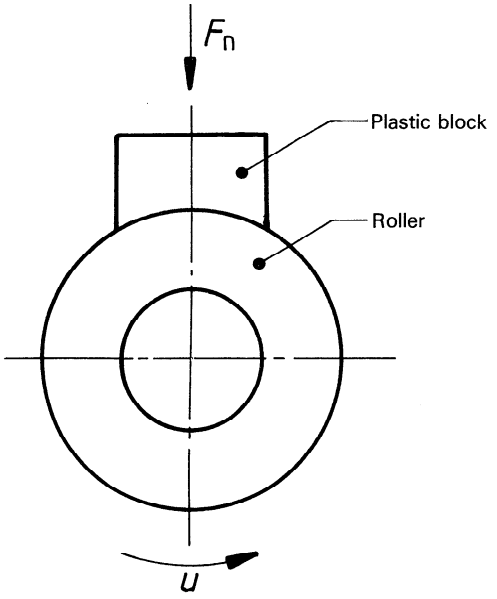
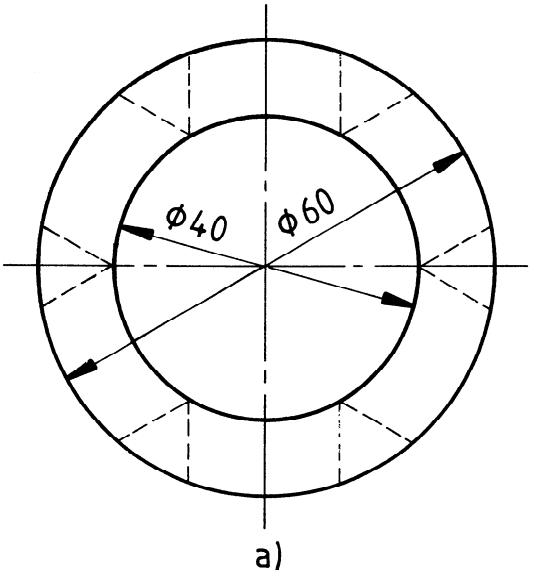


Figure 1 — Tribological contact between a plastic block and a roller

Dimensions in millimetres



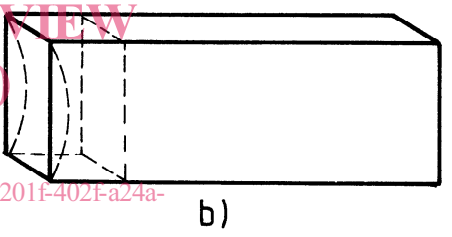


Figure 3 — Ways of obtaining plastic blocks for testing

Dimensions in millimetres

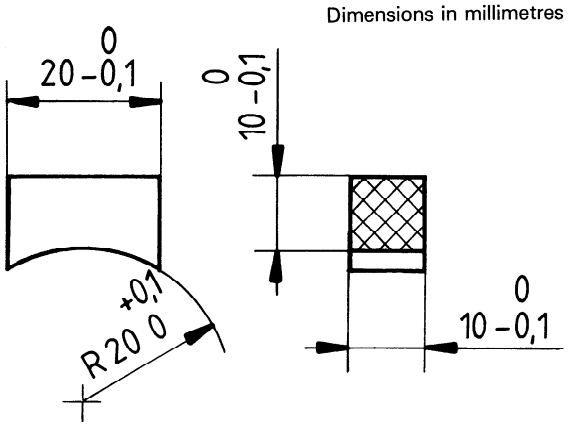


Figure 2 — Plastic block

Dimensions in millimetres,
surface roughness value in micrometres

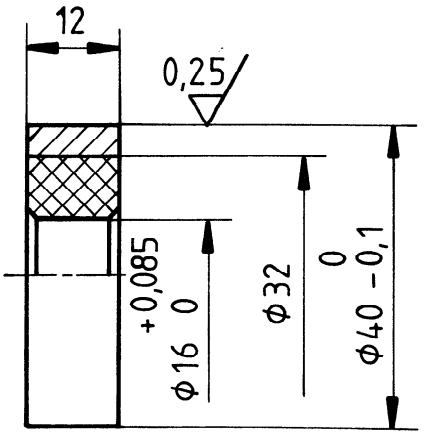


Figure 4 — Test roller

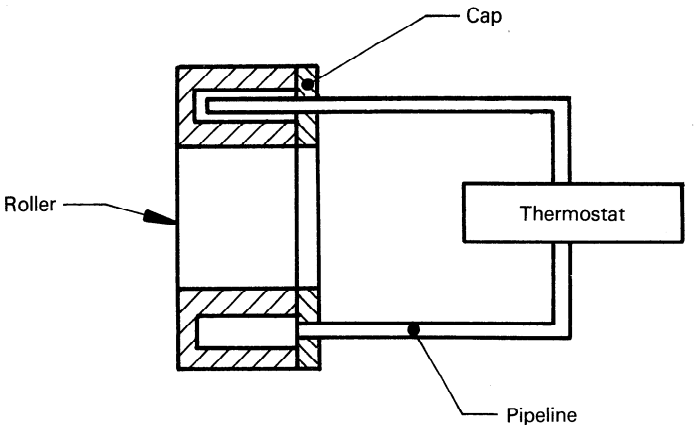


Figure 5 — Roller thermal regulation

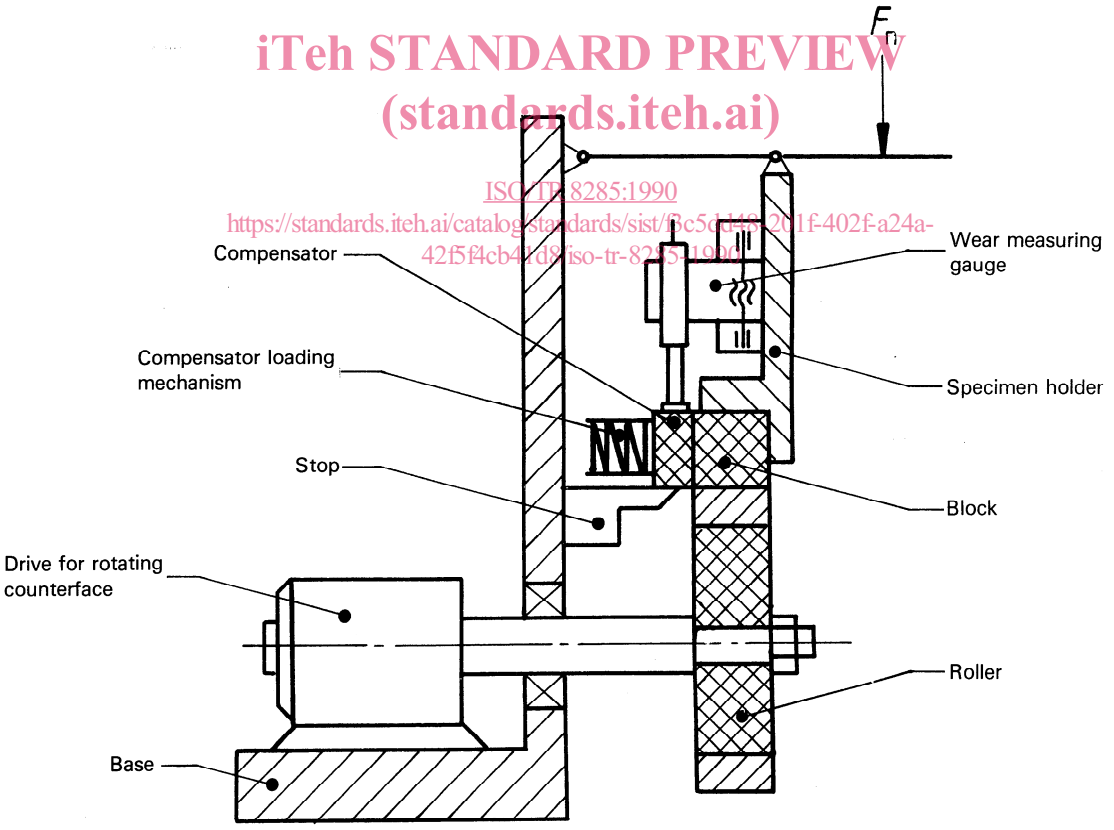
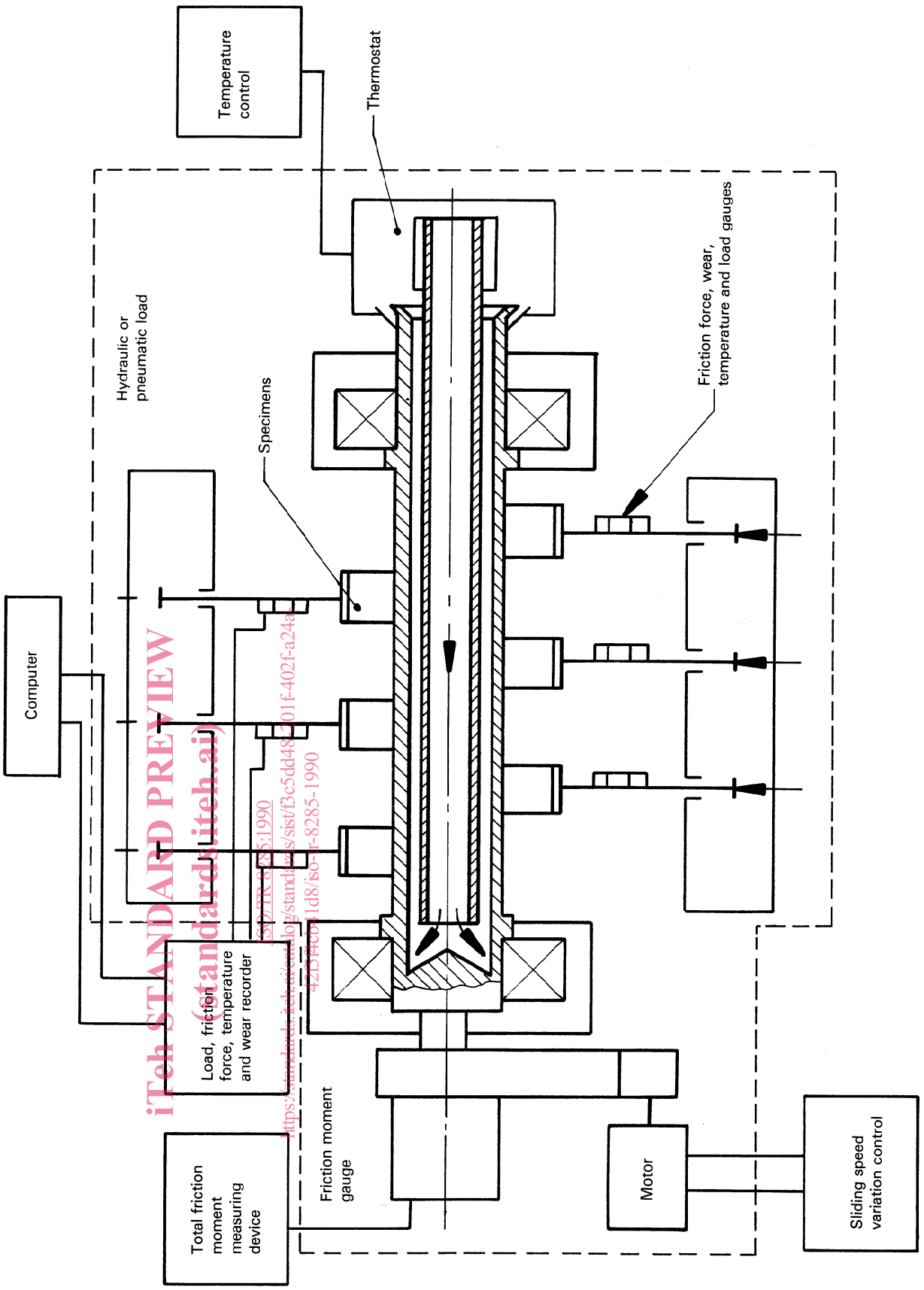


Figure 6 — Wear measurement system



NOTE — The basic system is shown within the dash line.

Figure 7 — Multistep stand with a thermally regulated shaft

7 Test procedure

7.1 Environmental conditions

Ambient conditions for the tests should be a temperature of 23 °C ± 5 °C and a relative humidity of 40 % to 60 %. Deviation from these conditions should be noted in the test report. In order to reproduce a required environmental regime, the pair tested should be placed in a confined space.

7.2 Mounting of the specimen

Mount the roller with the prepared sliding surface on the shaft of the test machine and fix it. Measure its radial run-out with a mechanical indicator graduated to 1 µm.

Place the cleaned block of plastic in the holder without a clearance (see figure 6). The tangential friction force is taken by the wall of the holder housing, which has a high bending strength.

The protruding part of the specimen shall measure at least 3 mm.

7.3 Running-in of the block

The plastic specimen should be run in on the roller surface before the test. The purpose of the running-in procedure is to achieve full contact along the rubbed surface of the plastic block.

The running-in period depends on the accuracy of manufacture and relative mounting of the specimens, block materials, conditions of the running-in, friction transfer processes and secondary structures formed on the block surfaces. The friction transfer produces a plastic film 0,5 µm to 3 µm thick over the metallic surface.

With accurate manufacture and mounting of the block and roller, the running-in period lasts 3 h to 7 h. The basic criteria of the completion of the run-in are a steady-state wear, a constant friction coefficient, f, and full contact between the block and roller surfaces.

7.4 Test programmes

This Technical Report specifies two special programmes.

7.4.1 Programme C

The programme is used to compare the material properties. The tribological properties of plastics are estimated under conditions similar to operating regimes.

The loading-velocity regimes of testing are arbitrarily divided into low, medium and heavy (see table 3). Each loading zone is confined to the maximum load and temperature in the contact zone associated with the compression strength σ_s and the melting point T_m (or softening point T_s) of the plastic.

In comparative testing, the thermal constant of the friction test unit, Q, should be taken into account:

$$Q = \frac{\Delta T}{fpu}$$

Q is estimated experimentally and given in the test report. The value of Q is maintained within the range 7×10^{-4} °C·m·s/N to 12×10^{-4} °C·m·s/N by means of a thermal insulator between the test roller and the shaft.

At the first stage of the comparative programme, load values are taken from table 3, i.e. one value for each loading zone. Next, minimum and maximum sliding velocities are calculated (see table 3) to compile a matrix for the loading-velocity regimes.

Table 3 — Loading-velocity regimes for plastics testing

Loading zone	Normal specific load, p N/mm²	Average contact temperature, T °C	Sliding velocity, u m/s
Low regime	0,000 3 σ_s to 0,001 σ_s	up to 23 ± 5 + 0,2 T_m (or T_s)	$\frac{0{,}2\ T_m}{fp_iQ}$
Medium regime	0,001 3 σ_s to 0,005 σ_s	up to 23 ± 5 + 0,4 T_m (or T_s)	$\frac{0{,}4\ T_m}{fp_iQ}$
Heavy regime	0,005 3 σ_s to 0,01 σ_s	up to 23 ± 5 + 0,6 T_m (or T_s)	$\frac{0{,}6\ T_m}{fp_iQ}$

$$\left(\frac{p}{u}\right)_{ij} = \begin{pmatrix} \frac{p_1}{u_1} & \frac{p_1}{u_2} & \frac{p_1}{u_3} \\ \frac{p_2}{u_1} & \frac{p_2}{u_2} & \frac{p_2}{-} \\ \frac{p_3}{u_1} & \frac{p_3}{-} & \frac{p_3}{-} \end{pmatrix}$$

The matrix columns and rows are used as the programme. Tests are carried out three times at each regime with recording of the friction force, wear and temperature in the contact zone. The value of wear measured during tests should be of one order higher than the error of the measurements.

After the specimen has been tested at one of the regimes, polish the surface of the test roller with emery cloth and clean it according to 5.6. Emery cloth is placed on a piece of wood of dimensions 200 mm × 50 mm × 10 mm with vulcanized rubber cemented onto it. Polishing, carried out on the test machine or specifically designed test rig, should give the roller surface its initial roughness (see 4.2) before starting testing at the next regime.

7.4.2 Programme P

Certification tests are carried out to obtain reference data for the tribological properties of plastics.

The certification tests cover from 9 to 27 loading-velocity regimes. The values of p_i, u_j and T_i are determined from table 3, and a matrix of the test results is compiled:

$$\left(\frac{p}{u}\right)_{ij} = \begin{pmatrix} \frac{p_1}{u_1} & \frac{p_1}{u_2} & \frac{p_1}{u_3} \\ \frac{p_2}{u_1} & \frac{p_2}{u_2} & \frac{p_2}{u_3} \\ \frac{p_3}{u_1} & \frac{p_3}{u_2} & \frac{p_3}{u_3} \end{pmatrix}$$

at temperatures of thermal regulation T_1, T_2 and T_3.

Friction force and wear at the preset temperature are recorded during the tests. If thermal regulation of the test shaft is carried out, the thermal constant Q should be qualified, with its value given in the test report.

The tests are carried out three times at each loading-velocity regime. Continuous measurements of the wear amount are taken with a special rig, having a error of not more than ± 0,5 µm (see figure 6).

Carry out the tests at temperatures T_i at the nine regimes with a single specimen. Then change the specimen and repeat the tests. When the regime is changed to a heavier one, do not clean the roller surface; this saves time of non-steady wear necessary for the formation of the friction transfer film.

When the specimen is changed, scoure the roller surface with emery cloth to obtain the initial roughness as in 4.2 and then clean it according to 5.2.

8 Analysis and test report

8.1 General

The following test conditions should be included in the test report:

a) environmental conditions (temperature and humidity);

b) type of test programme and loading regimes;

c) details about the plastic (see 4.1), its compression strength and melting temperature (softening point of the polymer);

d) details about the roller (see 4.2) (steel grade, Rockwell hardness and surface roughness);

e) details about cleaning and running-in of the rubbed plastic and roller surfaces.

8.2 Test results

At steady friction and wear with the plastics, the following parameters shall be given as functions of normal specific load p, sliding velocity u, and temperature T:

a) average value of the friction coefficient;

b) wear rate of the plastics;

c) wear coefficient of the plastics.