International Standard 4649

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Rubber — Determination of abrasion resistance using a rotating cylindrical drum device

Caoutchouc — Détermination de la résistance à l'abrasion à l'aide d'un dispositif à tambour tournant

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 4649 was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*.

Rubber — Determination of abrasion resistance using a rotating cylindrical drum device

1 Scope and field of application

This International Standard specifies a method for the determination of the resistance of rubber to abrasion by means of a rotating cylindrical drum device.

The method involves determination of the volume loss of a rubber test piece through abrasive action by rubbing over a specified grade of abrasive cloth. Because factors such as the grade of abrasive particles and adhesive used in the manufacture of the cloth, and contamination and wear by previous testing, lead to variations in the absolute values of abrasion loss, all tests must be comparative, standard rubbers being included so that the results may be expressed either as a relative volume loss referred to a calibrated abrasive cloth or an abrasion resistance index referred to a standard rubber.

No close relation between the results of this abrasion test and service performance can be inferred.

2 References

ISO 48, *Vulcanized rubbers — Determination of hardness (Hardness between* 30 *and* 85 IRHD*).*

ISO/R 275, *Zinc oxide for paints.*

ISO 471, *Rubber — Standard temperatures, humidities and times for the conditioning and testing of test pieces.*

ISO 2393, *Rubber test mixes — Preparation, mixing and vulcanization — Equipment and procedures.*

ISO 2781, *Vulcanized rubber — Determination of density.*

ASTM D 1765, *Standard classification system for carbon blacks used in rubber products.*

3 Principle

Subjection of a cylindrical rubber test piece to the action of an abrasive cloth of specified abrasive grade at a specified contact pressure over a given area.

Abrasion takes place over one of the flat end surfaces of the cylindrical test piece, the abrasive cloth being attached to the surface of a rotating cylindrical drum against which the test piece is held and across which it is traversed.

Determination of the loss in mass of the test piece and calculation of the volume loss from the density of the material.

4 Definitions

For the purposes of this International Standard, the following definitions apply.

4.1 abrasion resistance : The resistance to wear by mechanical action upon a surface.

NOTE — For the purpose of this International Standard, the abrasion resistance is expressed either as a relative volume loss referred to a calibrated abrasive cloth or as an abrasion resistance index referred to a standard rubber.

4.2 relative volume loss : The volume loss, in cubic millimetres, of the test rubber after being subjected to abrasion by an abrasive cloth will cause the appropriate standard rubber (see clause B.1 in annex B) to lose a mass of 200 mg under the preferred conditions of test for method A, namely a distance of 40 m, a load of 10 N and using a non-rotating test piece.

NOTE — The higher the relative volume loss, the lower is the abrasion resistance.

4.3 abrasion resistance index : The ratio of the volume loss of a standard rubber to the volume loss of the test rubber measured under the same specified conditions and expressed as a percentage.

5 Apparatus and materials

5.1 Abrasion machine

The test apparatus (see figure 1) consists of a laterally movable test piece holder and a rotatable cylinder to which the abrasive cloth (5.2) is fixed.

The cylinder shall have a diameter of 150 ± 0,2 mm and a length of about 500 mm and shall be rotated at a frequency of 40 ± 1 min^{-1}, the directions of rotation being as indicated in figure 1.

The test piece holder shall consist of a cylindrical opening, the diameter of which can be adjusted from 15,5 to 16,3 mm, and a device for adjusting the length of the test piece protruding from the opening to 2 ± 0,2 mm. The holder shall be mounted on a swivel arm which in turn is attached to a sledge which can be moved laterally on a spindle. The lateral displacement of the holder shall be 4,20 ± 0,04 mm per revolution of the drum. Suitable attachments may be provided to rotate the test piece during the test run by rotation of the test piece holder preferably, at the rate of 1 revolution per 50 revolutions of the drum.

NOTE — With this lateral movement, the test piece passes over any one area of the abrasive cloth four times.

The centre axis of the holder shall have an inclination of 3° to the perpendicular in the direction of rotation (see figure 1), and shall be placed directly above the longitudinal axis of the cylinder to within ± 1mm.

The swivel arm and test piece holder shall be free from vibration during operation, and so disposed that the test piece is pressed against the drum with a vertical force of 10 ± 0,2 N obtained by adding weights to the top of the test piece holder. For special purposes a force of 5 ± 0,1 N may be used.

The abrasive cloth shall be attached to the drum using three evenly spaced strips of double-sided adhesive tape extending along the complete length of the cylinder. Care shall be taken to ensure that the abrasive cloth is firmly held so as to present a uniform abrasive surface over the whole area of the cylinder. One of the strips shall be placed where the ends of the abrasive cloth meet. Ideally the ends should meet exactly, but any gap left between them shall not exceed 2 mm. The adhesive tape shall be about 50 mm wide and not more than 0,2 mm thick.

Placement of the test piece on to the cloth at the beginning of a test run, and its removal after an abrasion run of 40 m (equivalent to 84 revolutions), shall be automatic. In special cases of very high volume loss of the test piece, an abrasion distance of only 20 m (equivalent to 42 revolutions) may be used. If using an abrasion distance of 20 m, a revolution counter or automatic stopping device should be connected to the drum.

To protect the abrasive cloth from damage by the test piece holder, a device for switching off the apparatus just before the lower edge of the test piece holder touches the cloth is recommended.

5.2 Abrasive cloth

Abrasive cloth made with aluminium oxide of grain size 60, at least 400 mm wide, 473 mm long and 1 mm average thickness, shall be used as the abrasive medium.

In a test using a non-rotating test piece of the standard rubber described in annex B, clause B.1, this abrasive surface shall cause a mass loss between 180 and 220 mg for an abrasion distance of 40 m.

When each new sheet of cloth is first used, the direction of motion shall be indicated on the sheet, as it is important that the same direction be used for all subsequent test runs.

Notes on a suitable paper are given in annex A.

5.3 Hollow drill (see figure 2)

The drill may be required for preparation of test pieces (see 6.1). The frequency of rotation of the drill needs to be at least 1 000 min^{-1} for most rubbers, and even higher for rubbers with a hardness of less than 50 IRHD (see ISO 48).

5.4 Balance

The balance shall be of sufficient accuracy to enable the mass loss of a test piece to be determined to ± 1 mg.

5.5 Standard rubbers

Specifications for standard rubbers are given in detail in annex B.

6 Test piece

6.1 Type and preparation

The test pieces shall be cylindrical in shape, of diameter 16 ± 0,2 mm, with a minimum height of 6 mm.

Test pieces are normally prepared using the hollow drill (5.3). During cutting, the cutting edge should be lubricated with water to which a wetting agent has been added. Punching of the test pieces is not permitted.

Alternatively, test pieces may be vulcanized in a mould.

If test pieces of the required thickness are not available, the necessary thickness may be obtained by bonding a piece of the test rubber to a base element of hardness not less than 80 IRHD. The thickness of the test rubber should be not less than 2 mm.

6.2 Number

Three test runs shall be carried out. This will normally require three test pieces, but only one test piece may be necessary if the mass loss per run is very low.

6.3 Time interval between vulcanization and testing

For all test purposes, the minimum time between vulcanization and testing shall be 16 h. For non-product tests, the maximum time between vulcanization and testing shall be 4 weeks and, for evaluations intended to be comparable, the tests, as far as possible, shall be carried out after the same time interval. For product tests, whenever possible, the time between vulcanization and testing shall not exceed 3 months. In other cases, tests shall be made within 2 months of the date of receipt of the product by the customer.

6.4 Conditioning

Condition all test pieces, at standard laboratory temperature, in accordance with ISO 471, for a minimum period of 16 h immediately before testing.

NOTE — For some rubbers which are sensitive to moisture, the humidity should also be controlled.

7 Test temperature

The test shall be carried out at standard laboratory temperature (see ISO 471).

During a test run, there may be a considerable increase in temperature at the abrading interface, which may lead to temperature rises within the test piece. For the purposes of this International Standard, such temperature rises are to be disregarded, the temperature of test being that of the ambient atmosphere and of the test piece before commencing the test.

When repeat runs are made on the same test piece, sufficient time shall be allowed between such runs for the temperature of the whole of the test piece to return to standard laboratory temperature.

8 Procedure

8.1 General test procedure

Before each test, any rubber debris left on the abrasive cloth from a previous abrasion test shall be removed with a brush. A strong brush of about 55 mm diameter and about 70 mm length is recommended for this purpose. In some cases, a blank test with a standard rubber will effectively clean the abrasive cloth.

The test run may be carried out with the test piece either rotating or stationary (non-rotating). For method A (9.1) the non-rotating test piece shall be used. For method B (9.2) the rotating test piece is preferred but the non-rotating test piece may also be used. The test piece used shall be stated in the test report, because the results obtained by these two procedures can differ. For measurements intended to be comparable, the same conditions shall be used.

Weigh the test piece to the nearest 1 mg. Fix the test piece in the test piece holder in such a way that a length of 2,0 ± 0,1 mm protrudes from the opening. This length shall be controlled by means of a gauge.

The test piece should be pressed against the drum with a vertical force of 10 ± 0,2 N. If, for special cases, the vertical force is reduced to 5 ± 0,1 N, this shall be stated in the test report because the severity of abrasion is lower.

Move the test piece holder and sledge to the starting point, place the test piece on the abrasive cloth and set the cylinder in motion. Check for vibration in the test piece holder. This test method does not yield meaningful results if there is abnormal vibration in the test piece holder. The test run is stopped automatically after an abrasion distance of 40 m. When relatively large mass losses (usually more than 400 mg in 40 m) occur, the test run may be stopped after 20 m, and the length of exposed test piece reset to 2,0 ± 0,2 mm so that the test can be restarted and completed. At no time shall the height of the test piece be less than 5 mm. If the mass loss is greater than 600 mg in 40 m, the test should only be carried out for half distance (i.e. 20 m) and this should be stated in the test report. The results should be multiplied by 2 so that the mass loss can still be given for an abrasion distance of 40 m.

Weigh the test piece to the nearest 1 mg after the test run. Sometimes a small edge hanging from the test piece has to be pulled off before weighing, especially if a non-rotating test piece is used.

Perform three test runs on each rubber under test. Normally only one run per test piece is carried out, but if the mass loss is relatively small, up to three test runs can be carried out on the same test piece. When repeat runs are made on the same test piece, sufficient time shall be allowed between such runs for the temperature of the whole of the test piece to return to standard laboratory temperature. For non-rotating test pieces, care shall be taken to ensure that the test piece is always placed in the sample holder in the same way. If a series of rubbers is being tested, all three test runs on the same rubber shall be carried out consecutively.

8.2 Density

Determine the density of the test material by the method specified in ISO 2781.

8.3 Comparison against standard rubbers

In this International Standard, the test rubbers are compared against standard rubbers. Two standard rubbers are specified in annex B for use with the two methods of expressing results (see clause 9). That specified in clause B.1 is intended for use in method A, where the abrasion resistance is expressed as relative volume loss ΔV (see 9.1). That specified in clause B.2 is intended for use in method B, where the abrasion resistance is expressed as an abrasion resistance index, ARI (see 9.2).

The mass loss of a standard rubber shall be determined by carrying out a minimum of three test runs both before and after each test series following the procedure in 8.1. There shall be a maximum of three test rubbers in each test series.

For rubbers which have a tendency to smear, the mass loss of the standard rubber shall be determined after each test run. In extreme cases of smearing, there will be a considerable reduction in mass loss of the standard rubber measured after the test run compared to that measured before the test run. This is due to the fact that in the test run, the abrasive cloth is being "cleaned" by the standard rubber, as opposed to the standard rubber being abraded by the cloth. If the reduction in mass loss of the standard rubber is greater than 10 %, then the method is not valid.

9 Expression of results

The results may be expressed either as a relative volume loss (method A — see 9.1) or as an abrasion resistance index (method B — see 9.2).

Calculate the mean value of the mass losses of the test rubber, m, and of the standard rubber, m_s, from the three and six separate determinations respectively.

Calculate the volume losses of the test rubber, V_t, and of the standard rubber, V_s (for method B only), from the respective mass losses and densities.

9.1 Method A — Relative volume loss, ΔV

In this method, the standard rubber specified in clause B.1 in annex B is used. The non-rotating test piece shall be used for both the test rubber and the standard rubber. The measured mass loss of the standard rubber using a non-rotating test piece shall be within the range 180 to 220 mg.

The relative volume loss (see 4.2) is given by the formula

$$\Delta V = V_t \times \frac{200}{m_s}$$

where

V_t is the volume loss, in cubic millimetres, of the test rubber;

m_s is the mass loss, in milligrams, of the standard rubber (clause B.1) using a non-rotating test piece.

NOTE — The non-rotating test piece is used because of the considerable experience obtained previously with this method using the non-rotating test piece.

9.2 Method B — Abrasion resistance index, ARI

In this method, the standard rubber specified in clause B.2 in annex B is used. The same type of test piece (rotating or non-rotating) shall be used for both the test rubber and the standard rubber.

The abrasion resistance index (see 4.3) is given by the formula

$$\text{ARI} = \frac{V_s}{V_t} \times 100$$

where

V_s is the volume loss, in cubic millimetres, of the standard rubber (clause B.2);

V_t is the volume loss, in cubic millimetres, of the test rubber.

NOTE — The rotating test piece is the preferred test piece because the abrasion loss is more uniform over the whole surface of the test piece in contact with the abrasive cloth.

10 Test report

The test report shall include the following particulars :

a) sample details :

1) full description and origin,

2) compound details, cure time and temperature, if available,

3) method of preparation of the test pieces from the sample, i.e. whether cut or moulded;

b) test method : reference to this International Standard;

c) test details :

1) standard laboratory temperature used,

2) whether a non-rotating or rotating test piece was used,

3) type of standard rubber used,

4) any deviations from the test procedure, especially if the test run comprised only half the abrasion distance or if half the vertical force was used;

d) test result :

1) either the relative volume loss or the abrasion resistance index,

2) standard deviation of test result,

3) density;

e) date of test.

Annex A

Notes on a suitable abrasive cloth

(Forms an integral part of the Standard.)

A suitable abrasive cloth is produced commercially[1]. It comprises corundum particles of grain size 60, i.e. passing through a 60 mesh sieve, bonded to a twill cloth with a phenolic resin. As produced, the abrasive cloth causes an abrasion loss of more than 300 mg when the standard rubber specified in annex B, clause B.1, is tested using a non-rotating test piece. It is necessary to perform one or two runs with a steel test piece to reduce the abrasive loss to about 210 to 220 mg. Experience has shown that a minimum of a few hundred runs can be carried out with this type of cloth.

Abrasive cloth produced and standardized in this manner may be obtained from the Bundesanstalt für Materialprüfung (BAM), Unter den Eichen 87, D-1000 Berlin 45, or the Laboratoire de recherches et de contrôle du caoutchouc (LRCC), 12, rue Carvès, F-92120 Montrouge, France.

1) Details may be obtained from the Secretariat of ISO/TC 45 (BSI) or from ISO Central Secretariat.

Annex B

Standard rubbers

(Forms an integral part of the Standard.)

B.0 Introduction

The use of a standard rubber is intended to minimize the variation in abrasion resistance found between laboratories and between machines operating under nominally identical conditions.

The composition and methods of manufacture of the standard rubbers described below are to be taken as a guide; other formulations may be used provided that they fulfil the requirements given in B.1.5 and B.2.4. The standard rubber described in clause B.1 shall be used for the calibration of the abrasive cloth (5.2) and for the calculation of the relative volume loss, ΔV (see 9.1). The standard rubber described in clause B.2 shall be used for the determination of the abrasion resistance index (see 9.2).

B.1 Standard rubber for the determination of relative volume loss, ΔV

B.1.1 Formulation of standard rubber

Ingredient	Parts by mass
Natural rubber (SMR 5)	100,0
Dibenzthiazyl disulfide	1,2
N-isopropyl-*N'*-phenyl-*p*-phenylenediamine	1,0
Zinc oxide (type 1; see ISO/R 275)	50,0
Oil furnace black (N330-HAF)*	36,0
Sulfur	2,5
TOTAL	190,7

* See ASTM D 1765.

B.1.2 Mixing procedure

The following procedure is recommended.

Masticate the natural rubber to a Mooney viscosity, ML (1 + 4) at 100 °C, of 80 ± 5, using a mixing mill which complies with the requirements specified in ISO 2393. Then prepare the mix in an internal mixer. Cool the internal mixer to maintain the temperature at 50 ± 5 °C.

	Time (min)
Add the rubber	0
Add the accelerator, antioxidant and zinc oxide	5
Add the carbon black and sulfur	8
Discharge	30

Sheet out the mix on an open mill to a thickness of about 10 mm and check the batch mass.

NOTE — Other mixing procedures may be used provided the quality of the standard rubber produced meets the requirements of B.1.5.

B.1.3 Vulcanization

Bring the mould to the vulcanization temperature and then insert an unvulcanized piece of mix which has been pre-heated for 20 min at 70 °C. An excess of approximately 10 % is recommended. Vulcanize in a closed press at 150 ± 2 °C for 30 ± 1 min, using a moulding pressure of 3,5 MPa.

Sheets measuring approximately 180 mm × 120 mm × 8 mm will provide about 65 test pieces.

B.1.4 Storage

Store the standard sheets in a cool, dark place and wrap them with materials which protect the sheets from attack by ozone (for example polyethylene).

B.1.5 Quality

Each batch of the standard rubber should be compared to a "reference sheet" obtainable from the Bundesanstalt für Materialprüfung (BAM), Unter den Eichen 87, D-1000 Berlin 45, or the Laboratoire de recherches et de contrôle du caoutchouc (LRCC), 12, rue Carvès, F-92120 Montrouge, France, using an abrasive cloth prepared in accordance with annex A.

The quality of the standard rubber shall be examined by determining the abrasion resistance of a test piece taken from a corner of the sheet, measured using a non-rotating test piece as described in this International Standard, and then comparing this mass loss with the mean mass loss of a "reference sheet" in immediate consecutive tests. The differences between the mass losses shall not exceed 8 mg.

A standard rubber sheet shall be considered to be a reference sheet if the mass losses measured at six different places (four at the corners and two in the middle) differ by not more than 10 mg and the mean value differs by not more than 5 mg fro the mean value of six single values of another reference sheet.

NOTE — It is permitted to carry out three test runs on the same test piece.

B.2 Standard rubber for the determination of abrasion resistance index, ARI

B.2.1 Formulation of standard rubber

Ingredient	Parts by mass
Natural rubber (SMR 5)	100,0
Stearic acid	2,0
Zinc oxide	5,0
Oil furnace black (N 330-HAF)*	50,0
N-isopropyl-*N'*-phenyl-*p*-phenylenediamine	1,0
Cyclohexyl-benzothiazole sulfenamide	0,5
Sulfur	2,5
TOTAL	161,0

* See ASTM D 1765. For referee purposes, the current Industry Reference Black should be used, but this may give slightly different results.

B.2.2 Mixing and vulcanization

The equipment and procedures used for preparation, mixing and vulcanization shall be in accordance with the relevant requirements of ISO 2393; an internal mixer may be used, however, instead of the mixing mill specified in ISO 2393. Sheets shall be vulcanized at 140 °C for 60 min.

B.2.3 Storage

Store the standard sheets in a cool, dark place and wrap them with materials which protect the sheets from attack by ozone (for example polyethylene).

B.2.4 Quality

The mass losses for two different batches of standard rubber, determined in accordance with clause 8, shall agree to within ± 10 %.

NOTE — It has been found that the standard rubber gives an abrasion loss of about 150 mg when tested in accordance with clause 8, using a rotating test piece.