BRITISH STANDARD

METHODS OF TESTING VULCANIZED RUBBER

PART A9. DETERMINATION OF ABRASION RESISTANCE

B.S. 903 : Part A9 : 1957

Incorporating amendments issued May, 1963 (PD4907) and December, 1965 (PD5698)

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BRITISH STANDARDS INSTITUTION

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THIS BRITISH STANDARD, having been approved by the Rubber Industry Standards Committee and endorsed by the Chairman of the Chemical Divisional Council, was published under the authority of the General Council on 13th March, 1957.

B.S. 903, first published June, 1940.
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First published as B.S. 903 : Part A 9, March, 1957.

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 5000, indexed and cross-indexed for reference, together with an abstract of each standard, will be found in the Institution's Yearbook.

This standard makes reference to the following British Standards:

B.S. 907. Dial guages for linear measurement.
B.S. 1814. Marking system for grinding wheels.
B.S. 1995. Di-2-ethyl hexyl phthalate.

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following B.S.I. references relate to the work on this standard:–
Committee references RUC/10, RUC/10/4
Draft for comment CW(RUC) 4394

CO-OPERATING ORGANIZATIONS

The Rubber Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and industrial organizations:—

Board of Trade
*British Rubber Producers' Research Association
*Federation of British Rubber and Allied Manufacturers' Associations
*Institution of the Rubber Industry
*Ministry of Supply
Natural Rubber Development Board
*Research Association of British Rubber Manufacturers
*Rubber Growers' Association

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:—

Admiralty
Air Ministry
Association of British Chemical Manufacturers
British Chemical Plant Manufacturers' Association
British Electrical and Allied Industries Research Association
British Railways, The British Transport Commission
British Rubber and Resin Adhesive Manufacturers' Association
Department of the Government Chemist
General Post Office
Institute of Brewing
Institution of Chemical Engineers
Institution of Gas Engineers
Institution of Mechanical Engineers
Institution of Mechanical Engineers (Automobile Division)
Institution of Municipal Engineers
Institution of Water Engineers
London Advisory Committee for Rubber Research (Ceylon and Malaya)
Ministry of Housing and Local Government
Ministry of Works
National College of Rubber Technology
National Physical Laboratory
Royal Institute of Chemistry
Rubber Trade Association of London
Society of Motor Manufacturers and Traders Ltd.

BRITISH STANDARD

METHODS OF TESTING VULCANIZED RUBBER

Part A 9. Determination of Abrasion Resistance

FOREWORD

This British Standard has been published under the authority of the Rubber Industry Standards Committee. In deciding to issue a revision of the 1950 edition, it has also been considered desirable to publish B.S. 903 in separate parts and the present part replaces Part 24 of 1950, from which it differs mainly in the inclusion of a method of testing under conditions of constant torque with the Du Pont abrasion machine. Additionally, the layout has been altered and metric equivalents have been included.

The group of parts in which the prefix letter ' A ' is used covers methods of testing the physical properties of rubber. Further parts in this group have been issued as follows:—

Part A 1. Determination of density and specific gravity.
Part A 2. Determination of tensile stress-strain.
Part A 3. Determination of tear strength.
Part A 4. Determination of compression stress-strain.
Part A 10. Determination of flex cracking.
Part A 11. Determination of resistance to crack growth.
Part A 16. Determination of swelling.
Part A 18. Determination of equilibrium water vapour absorption.
Part A 19. Accelerated ageing tests.

SECTION 1 DEFINITIONS

Abrasion loss. The volume of rubber abraded from a specified test piece when subjected to abrasive wear under specified conditions.

Abrasion resistance. The reciprocal of abrasion loss.

Abrasion resistance index. The ratio of the abrasion resistance of the rubber under test to that of a standard rubber expressed as a percentage.

SECTION 2 SUMMARY, EXPLANATORY NOTE AND STANDARD RUBBERS

In this standard, details of three machines and four methods for determining abrasion resistance are given; each method is suitable only for comparing rubber vulcanizates of a similar type, i.e. made from the same general type of polymer and having not very dissimilar hardness.

Different types of abrasion machine give both absolutely and relatively different results for different rubbers. The type of machine used must therefore be selected with reference to the intended use of the rubber, and all tests must be comparative, a standard rubber being included so that the result can be expressed as an abrasion resistance index which is the abrasion resistance relative to that of the standard rubber.

No close relation between the results of the abrasion test and service performance is implied. The test should not be used for purchasing specifications because of the difficulty of reproducing the comparison standard rubber in different laboratories. The purpose of the standardized abrasion test is for intra-laboratory comparisons.

Four methods of determining abrasion resistance have been specified as follows:—

*Method A—Du Pont machine.
Method B—Du Pont machine with constant torque modification.
Method C—Akron machine.
Method D—Dunlop machine.

Improved correlation with service performance has been obtained in certain cases with Method B.

Methods A and B are suitable for most tire-tread, sole and heel rubbers; some difficulty has been encountered with softer rubbers. Method C is suitable only for rubbers covering a hardness range of 57–80° B.S. such as tire-tread type rubbers. Method D is especially suitable for testing tire-tread rubbers; reliable results can be obtained also on sole, heel, and conveyor-belt cover rubbers, covering a hardness range of about 57–93° B.S.

Two comparison standard rubbers are specified; these are:

'*A*' *Tire-tread type rubber*

Smoked sheet	100
Zinc oxide	5
Stearic acid	3
E.P.C. black	50
Benzthiazyl disulphide	1
Sulphur	3
Phenyl-beta-naphthylamine	1
Vulcanization: 40 min at 144°C	

* This method is being considered for adoption by the appropriate committee of the International Organization for Standardization (ISO).

'B' Sole and heel type rubber

Smoked sheet	100
Zinc oxide	4
Stearic acid	3
*Di-2-ethyl hexyl phthalate	3
E.P.C. black	60
Whiting	60
Mercaptobenzthiazole	1
Sulphur	3
Phenyl-beta-naphthylamine	1
Vulcanization: 40 min at 153°C	

It is recommended that a large batch of the standard stock be prepared and stored, vulcanized or unvulcanized, under cool dark conditions, for use in any particular laboratory. Unvulcanized stocks must be protected from contamination by grit; four years' storage is suggested as the maximum period the unvulcanized stocks will maintain their abrasion resistance unchanged. When a batch is almost used up, or shortly before the termination of the maximum storage period, a further batch should be prepared and the two standards run in conjunction until continuity of standards is assured (at least five tests).

The results are expressed as abrasion resistance index.

SECTION 3 METHOD A—DU PONT MACHINE

3.1. Test piece. The test piece shall be 2 ± 0·05 cm square by approximately 1 cm thick, with parallel faces and with suitable fixing lugs. Where the rubber exhibits marked calender grain, test pieces having the grain both parallel and perpendicular to the direction of abrasion shall be tested. The test piece is shown in Fig. 1.

3.2. Apparatus (Fig. 2). A disk which carries an abrasive surface shall be mounted in a vertical plane on a hollow shaft and rotated counter-clockwise at a uniform speed within the range 34–40 rev/min. The provision of a revolution counter is desirable. Two test pieces shall be mounted with their 2 cm square faces parallel to the abrasive, on the inner surface of a bar, one placed at each end so that their centres are 2·5 in. (6·35 cm) 6·3 from the axis of the shaft.

The test pieces shall be held in contact with the abrasive by a weight attached to a cable acting over a pulley. The cable shall be attached to a rod which extends through the hollow shaft carrying the abrasive disk; this rod shall have a small vertical pin through the end, which seats into a groove on the front face of the bar carrying the test pieces, thus prevent-

* B.S. 1995, 'Di-2-ethyl hexyl phthalate'.

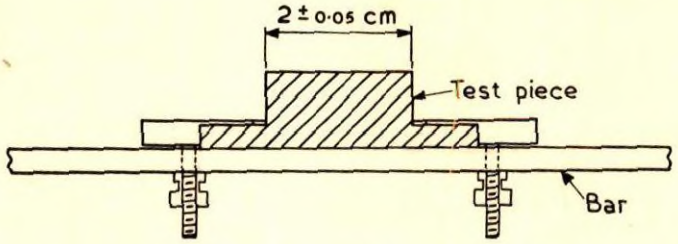

Fig. 1. Test piece for Du Pont abrasion machine

ing its slipping through the bar. A lever arm shall be attached to the end of the bar which holds the test pieces. The other end of this lever arm shall carry a bucket, the weight of which shall be adjusted with lead shot. A vernier spring balance shall be attached to the lever arm for final adjustment of the load, so as just to prevent rotation of the lever arm. A dash-pot shall be connected to the lever arm between the spring balance and the bucket to prevent excessive vibration of the end of the arm.

The abrasive shall be in the form of an annular disk 6½ in. (16·5 cm) in outside diameter with a central hole 2¾ in. (7 cm) diameter. The weight of the paper substance carrying the abrasive grains shall be at least 220 g/sq.m or 90 lb per 480 sheets of 20 in. × 30 in., both with a tolerance of ± 5 per cent. The paper and the adhesive used to bond the abrasive disk shall be waterproof so that a minimum of softening occurs under moist conditions.* The abrasive grains shall be silicon carbide, a suitable size being that known commercially as 180.†

NOTE. Special supplies of suitable paper have been made available by the Minnesota Mining and Manufacturing Co., Arlen Road, Adderley Park, Birmingham, 8. (The paper should be referred to as ' Special ISO Batch ' when ordering.)

The abrasive surface shall be continuously cleaned‡ by means of air jets (not less than 25 lb/sq.in. (1·8 kg/sq.cm) pressure) the air being filtered to remove oil, water and dirt; three jets, each 0·04 in. (1·0 mm) diameter spaced at ¼ in. (6 mm) pitch radially, shall be provided at the top and three at the bottom of the annular surface, and so arranged as to leave ¼ in. (6 mm) space between jets and abrasive.

* It is not recommended that the test should be performed in relative humidities greater than 90 per cent.

† Apertures on screening sieves are quoted in nominal micron sizes, but no correlation is at present available with commercial grain sizes.

‡ It is advantageous also to provide two stiff bristle brushes, freely rotating and set at an angle to the track, at opposite points of the track to supplement the cleaning by air jets.

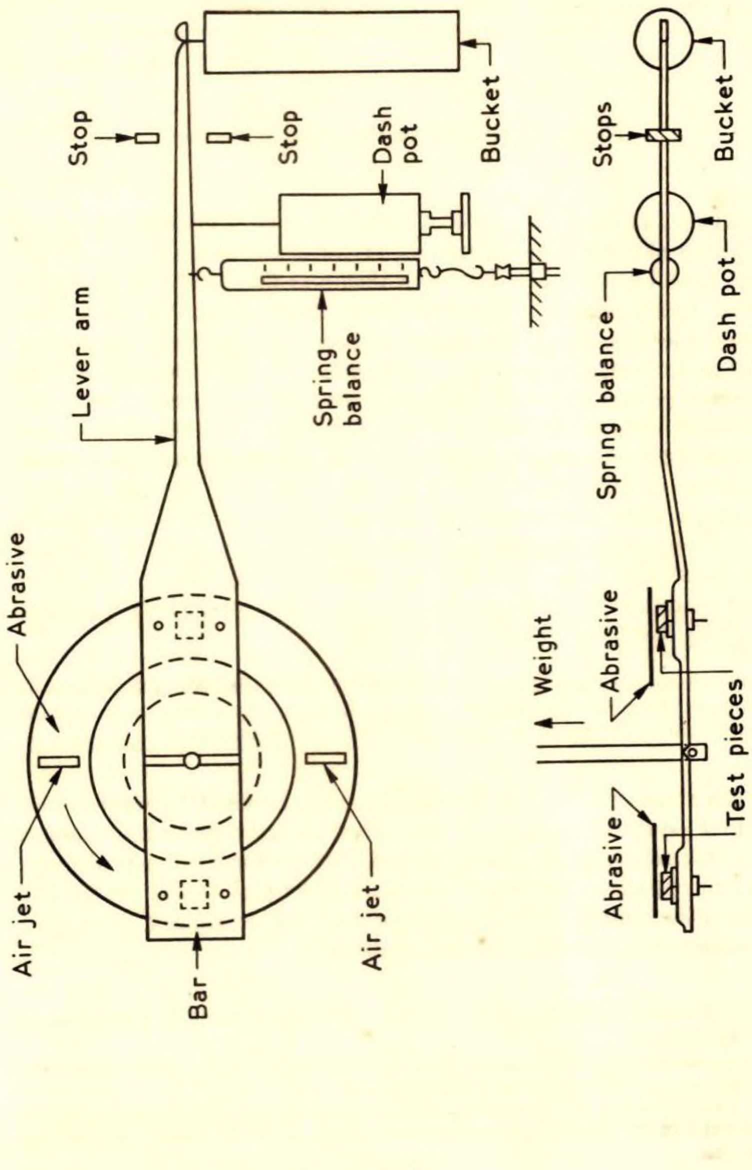

Fig. 2. Du Pont abrasion machine

3.3. Procedure.

3.3.1. *Preparation of test piece.* Test pieces shall be trimmed of any moulding flash.

3.3.2. *Conditioning of test pieces.* The properties of vulcanized rubber change continuously with time, these changes being particularly rapid during the first 24 hours after vulcanization. No tests should therefore be carried out within this period and, for accurate comparisons between different rubbers, it may be necessary to ensure that these are tested at substantially the same interval after vulcanization.

Test pieces shall be protected from light as completely as possible during the interval between vulcanizing and testing.

The test pieces shall be kept at a temperature of 20 ± 2°C for a period of not less than 12 hours immediately prior to being measured and tested.

NOTE. See Note under Clause 3.4. Temperature of test.

3.3.3. *Measurement of test pieces.* The thickness of the test pieces shall be measured.

'The determination consists of: *As amended May, 1963*

a. Weighing a pair of test pieces before and after a one-minute trial run.

b. A running-in period.

c. Weighing before and after each of two test runs in a planned order.

d. Calculating the volume loss per 1000 rev for the rubber under test.

e. Repeating the procedure *b* to *d* on two further pairs of test pieces for each rubber.

The duration of *b* and *c* will depend on the volume loss, determined from *a* by dividing the weight loss by the relative density of that rubber determined as described in B.S. 903, Part A1, according to Table 1.

The above procedure is required to ensure that the volume loss sustained is approximately the same for all rubbers tested (being usually of the same order as that given by the standard tyre-tread rubber A after 5 minutes). There is some evidence of a systematic effect on the weight loss of the amount of test piece projecting from the clamp bar. No test piece shall be used after ⅛ in (3 mm) has been abraded away. Also, to give an even seating of the test pieces a running-in period is necessary.

To compensate for the gradual change in cutting power of an abrasive paper disk when testing together for comparison more than one rubber (as will always be the case when final results are to be expressed as in Clause 3.5) the two test runs for each rubber shall be in reverse order. Thus for four rubbers including the standard

TABLE 1. RUNNING-IN AND TEST RUN TIMES

Volume loss in 1-minute trial run	Running-in time 1st pair	2nd and 3rd pair	Test run time Two runs each of
ml	min		min
Not above 0·050	11	12	12
Above 0·050 not above 0·057	10	11	11
Above 0·057 not above 0·064	9	10	10
Above 0·064 not above 0·070	8	9	9
Above 0·070 not above 0·082	7	8	8
Above 0·082 not above 0·095	6	7	7
Above 0·095 not above 0·110	5	6	6
Above 0·110 not above 0·132	4	5	5
Above 0·132 not above 0·182	3	4	4
Above 0·182 not above 0·260	2	3	3
Above 0·260 not above 0·350	1	2	2
Above 0·350	0	1	1

1st test run — A_1 B_1 C_1 D_1 A_2 B_2 C_2 D_2 A_3 B_3 C_3 D_3

2nd test run — D_3 C_3 B_3 A_3 D_2 C_2 B_2 A_2 D_1 C_1 B_1 A_1

where the suffixes indicate the three pairs of test pieces.

Experimental procedure. The surface of the abrasive disk shall first be cleaned by the air jets. Two test pieces shall be weighed and then inserted in the clamps of the bar. The clamps shall be tightened uniformly, care being taken to avoid distorting the surface to be abraded. In subsequent runs on the same pair of test pieces they shall be replaced in exactly the same position as in the first run. The bar shall be placed in position with its axis rod extending through the hollow shaft which supports the abrasive disk. The 8 lb (3·62 kg) weight shall be connected to the end of the axis rod, levelling the cable over the grooved pulley, thus holding the test pieces evenly and firmly against the abrasive disk. The balance weight (bucket) shall be attached to the end of the lever arm and the spring-balance and dash-pot connected to the lever arm; for most tests the total weight of the bucket and shot shall be 1·1 lb (500 g). The machine shall then be run; during the first minute the tension in the spring balance shall be adjusted so that the lever arm oscillates about the mid point between its two stops. After the appropriate runs (as shown in Table 1) the test pieces shall be removed and, in test runs, weighed and the volume loss calculated.

Paper life. The useful life of one abrasive paper disk is about 6 hours, of which the first hour shall be used for trial runs and running in (since the rate of change of cutting power is not linear with time during approximately the first hour of use of a paper).

The paper shall be discarded when the rate of volume loss from the standard rubber has fallen by more than 25 per cent of the rate of loss at the first measuring after the 1-hour running-in period of the paper.

3.4. Temperature of test. The test shall be carried out at a room temperature of 20 ± 2°C.

NOTE. A temperature of 20 ± 2°C for conditioning and testing is not yet practicable for all countries. In tropical climates where it is not possible to maintain this temperature, a temperature of 27 ± 2°C is permitted.

3.5. Expression of results. The results shall be expressed as follows:—

$$\text{Abrasion resistance index} = \frac{S}{T} \times 100$$

S = volume loss, in millilitres per 1000 rev, calculated from the total test runs on each of three pairs of test pieces of the standard rubber, and

T = volume loss, in millilitres per 1000 rev, calculated from the total test runs on each of three pairs of test pieces of the sample rubber.

3.6. Report. The report shall state:—

1. Abrasion resistance index as calculated in accordance with Clause 3.5.
2. Standard rubber used.
3. Temperature of test, if other than 20 ± 2°C.

3.7. Reproducibility of results.

The coefficient of variation of the abrasion resistance index is about 5 per cent. *As amended May, 1963*

SECTION 4 METHOD B—USING DU PONT MACHINE CONSTANT TORQUE METHOD

4.1. Test pieces. The test piece shall be 2 ± 0·05 cm square by approximately 1 cm thick, with parallel faces and with suitable fixing lugs. Where the rubber exhibits marked calender grain, test pieces having the grain both parallel and perpendicular to the direction of abrasion shall be tested. The test piece is shown in Fig. 1.

4.2. Apparatus (Figs. 2 and 3). A disk which carries an abrasive surface shall be mounted in a vertical plane on a hollow shaft and rotated counter-clockwise at a uniform speed within the range 34–40 rev/min. The provision of a revolution counter is desirable. Two test pieces shall be mounted with their 2 cm square faces parallel to the abrasive on the inner surface of a bar, one placed at each end so that their centres are 2·5 in. (6·35 cm) from the axis of the shaft.

The test pieces shall be held in contact with the abrasive by an adjustable spring tensioning device. The bar on which the test pieces are mounted shall have attached to it one end of a rod, placed centrally with respect to the test pieces, which passes through the hollow shaft. This rod shall have a small vertical pin through the end, which seats into a groove on the front face of the bar, thus preventing it slipping through the bar. At the other end of the rod shall be attached (but easily removable) a cable which passes round a pulley to the spring tensioning device. A lever arm shall be attached to the end of the bar which holds the test pieces. The other end of this lever arm shall carry a bucket, the weight of which can be adjusted by lead shot. A vernier spring balance shall be attached to the lever arm and between this and the bucket shall be attached a dashpot.

The abrasive shall be in the form of an annular disk 6½ in. (16·5 cm) in outside diameter with a central hole 2¾ in. (7 cm) diameter. The weight of the paper substance carrying the abrasive grains shall be at least 220 gm/sq.m or 90 lb per 480 sheets of 20 in. × 30 in. both with a tolerance of ± 5 per cent. The paper and the glue used to bond the abrasive disk shall be waterproof so that a minimum of softening occurs under moist conditions.* The abrasive grains shall be silicon carbide, a suitable size being that known commercially as 180.†

The abrasive surface shall be continuously cleaned‡ by means of air jets (not less than 25 lb/sq.in. (1·8 kg/sq.cm) pressure), the air being filtered to remove oil, water and dirt; three jets, each 0·04 in. (1·0 mm) diameter spaced at ¼ in. (6 mm) pitch radially, shall be provided at the top and three at the bottom of the annular surface, and so arranged as to leave ¼ in. (6 mm) space between jets and abrasive.

4.3. Procedure.

4.3.1. *Preparation of test pieces.* Test pieces shall be trimmed of any moulding flash.

4.3.2. *Conditioning of test pieces.* The properties of vulcanized rubber change continuously with time, these changes being particularly rapid during the first 24 hours after vulcanization. No tests should therefore be carried out within this period and, for accurate comparisons between different rubbers, it may be necessary to ensure that these are tested at substantially the same interval after vulcanization.

Test pieces shall be protected from light as completely as possible during the interval between vulcanizing and testing.

The test pieces shall be kept at a temperature of 20 ± 2°C for a period of not less than 12 hours immediately prior to being measured and tested.

NOTE. See Note under Clause 4.4. Temperature of test.

* It is not recommended that the test should be performed in relative humidities greater than 90 per cent.

† Apertures on screening sieves are quoted in nominal micron sizes, but no correlation is at present available with commercial grain sizes.

‡ It is advantageous also to provide two stiff bristle brushes, freely rotating, and set at an angle to the track, at opposite points of the track to supplement the cleaning by air jets.

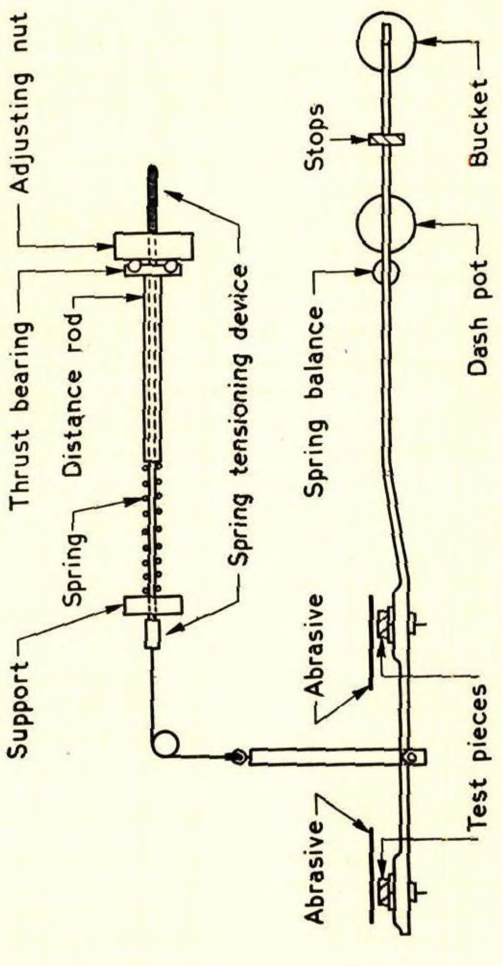

Fig. 3. Constant torque Du Pont abrasion machine

4.3.3. *Measurement of test piece.* The thickness of the test pieces shall be measured.

As amended May, 1963

The determination consists of:

a. Weighing a pair of test pieces before and after a one-minute trial run.

b. A running-in period.

c. Weighing before and after each of two test runs in a planned order.

d. Calculating the volume loss per 1000 rev for the rubber under test.

e. Repeating the procedure *b* to *d* on two further pairs of test pieces for each rubber.

The duration of *b* and *c* will depend on the volume loss, determined from *a* by dividing the weight loss by the relative density of that rubber determined as described in B.S. 903, Part A1, according to Table 2.

TABLE 2. RUNNING-IN AND TEST RUN TIMES

Volume loss in 1-minute trial run	Running-in time 1st pair	Running-in time 2nd and 3rd pair	Test run time Two runs each of
ml	min		min
Not above 0·050	11	12	12
Above 0·050 not above 0·057	10	11	11
Above 0·057 not above 0·064	9	10	10
Above 0·064 not above 0·070	8	9	9
Above 0·070 not above 0·082	7	8	8
Above 0·082 not above 0·095	6	7	7
Above 0·095 not above 0·110	5	6	6
Above 0·110 not above 0·132	4	5	5
Above 0·132 not above 0·182	3	4	4
Above 0·182 not above 0·260	2	3	3
Above 0·260 not above 0·350	1	2	2
Above 0·350	0	1	1

The above procedure is required to ensure that the volume loss sustained is approximately the same for all rubbers tested (being usually of the same order as that given by the standard tyre-tread rubber A after 5 minutes). There is some evidence of a systematic effect on the weight loss of the amount of test piece projecting from the clamp bar. No test piece shall be used after ⅛ in (3 mm) has been abraded away. Also to give an even seating of the test pieces a running-in period is necessary.

To compensate for the gradual change in cutting power of an abrasive paper disk when testing together for comparison more than one rubber (as will always be the case when final results are to be expressed as in Clause 4.5) the two test runs for each rubber shall be in reverse order.

Thus for four rubbers including the standard

1st test run —	$A_1\ B_1\ C_1\ D_1$	$A_2\ B_2\ C_2\ D_2$	$A_3\ B_3\ C_3\ D_3$
2nd test run —	$D_3\ C_3\ B_3\ A_3$	$D_2\ C_2\ B_2\ A_2$	$D_1\ C_1\ B_1\ A_1$

where the suffixes indicate the three pairs of test pieces.

Experimental procedure. The surface of the abrasive disk shall first be cleaned by the air jets. Two test pieces shall be weighed and then inserted in the clamps of the bar. The clamps shall be tightened uniformly, care being taken to avoid distorting the surface to be abraded. The bar shall be placed in position with its axis rod extending through the hollow shaft which supports the abrasive disk. The cable attached to the tensioning device shall be connected to the end of the axis rod, and levelled over the grooved pulley, thus holding the test pieces evenly and firmly against the abrasive disk. The bucket shall be attached to the end of the lever arm and the spring balance and dashpot connected to the lever arm. The weight of the bucket and the tension in the spring balance shall be adjusted to give a total torque of 30 000 g cm. The machine shall then be run; during the first minute the tension in the tensioning device shall be adjusted so that the lever arm oscillates about the mid point between its two stops. After the appropriate runs (as shown in Table 2) the test pieces shall be removed and, in test runs, weighed and the volume loss calculated.

Paper life. The useful life of one abrasive paper disk is about 6 hours, of which the first hour shall be used for trial runs and running in (since the rate of change of cutting power is not linear with time during approximately the first hour of use of a paper).

The paper shall be discarded when the rate of volume loss from the standard rubber has fallen by more than 25 per cent of the rate of loss at the first measuring after the 1-hour running-in period of the paper.

4.4. Temperature of test. The test shall be carried out at a room temperature of 20 ± 2°C.

NOTE. A temperature of 20 ± 2°C for conditioning and testing is not yet practicable for all countries. In tropical climates where it is not possible to maintain this temperature, a temperature of 27 ± 2°C is permitted.

4.5. Expression of results. The results shall be expressed as follows:—

$$\text{Abrasion resistance index} = \frac{S}{T} \times 100$$

S = volume loss, in millilitres per 1000 rev, calculated from the total test runs on each of three pairs of test pieces of the standard rubber, and

T = volume loss, in millilitres per 1000 rev, calculated from the total test runs on each of three pairs of test pieces of the sample rubber.

4.6 Report. The report shall state:—

1. Abrasion resistance index calculated in accordance with Clause 5.5.
2. Standard rubber used.
3. Temperature of test, if other than 20 ± 2°C.

4.7. Reproducibility of results.

As amended May, 1963

The coefficient of variation of the abrasion resistance index is about 5 per cent.

SECTION 5 METHOD C—AKRON MACHINE

5.1. Test piece. The test piece shall be a disk 0·50 + 0·02 − 0·00 in. (12·7 + 0·5 − 0·0 mm) thick and 2·50 + 0·02 − 0·00 in. (63·5 + 0·5 − 0·00 mm) diameter, with a central hole 0·50 + 0·0 − 0·02 in. (12·7 + 0·0 − 0·5 mm) diameter.

5.2. Apparatus. The test piece (T), see Fig. 4, shall be mounted on a 0·50 in. (12·7 mm) diameter spindle (S) and clamped between two disks, D_1 2·20 in. (56 mm) diameter with rounded edge to avoid cutting the rubber and D_2 1·73 in. (44 mm) diameter with raised peripheral rim 0·15 in. (4 mm) wide and 0·02 in. (0·5 mm) high to contact with the rubber, in such a way that it is compressed by 0·02 in. (0·5 mm). The test piece shall be rotated at 250 ± 5 rev/min with the whole width of its curved surface in contact with that of an abrasive wheel A, 6 in. (15 cm) diameter 1 in. (2·5 cm) thick, grade A36—P5—V.* The abrasive wheel shall be mounted on ball-bearings and shall be driven by the test piece; a revolution-counting device shall be connected with the wheel. The planes of the test piece and the abrasive wheel shall be inclined at an angle to one another which can be varied but is generally 15°. (A larger angle, 25°, has been used with GR-S (butadiene/styrene) and, although 15° is the recognized standard for natural rubber, the angle used shall be quoted with the results to avoid possibility of confusion.) The abrasive wheel shall be pressed against the test piece by a load of 10 lb (4·5 kg) (if the thickness of the test piece lies within the specified limits). The test piece shall be well brushed during its rotation by the freely rotatable bristle brush B.

5.2.1. *Measuring instrument.* The instrument for measuring the thickness of the test piece shall consist of a micrometer dial-gauge firmly held in a rigid stand over a flat base-plate of diameter at least 2 in. (5 cm). The gauge shall have a scale graduated in unit divisions of 0·01 mm, and shall comply where relevant with the requirements of B.S. 907† for a Type A gauge, particularly in respect of the accuracy of calibration.

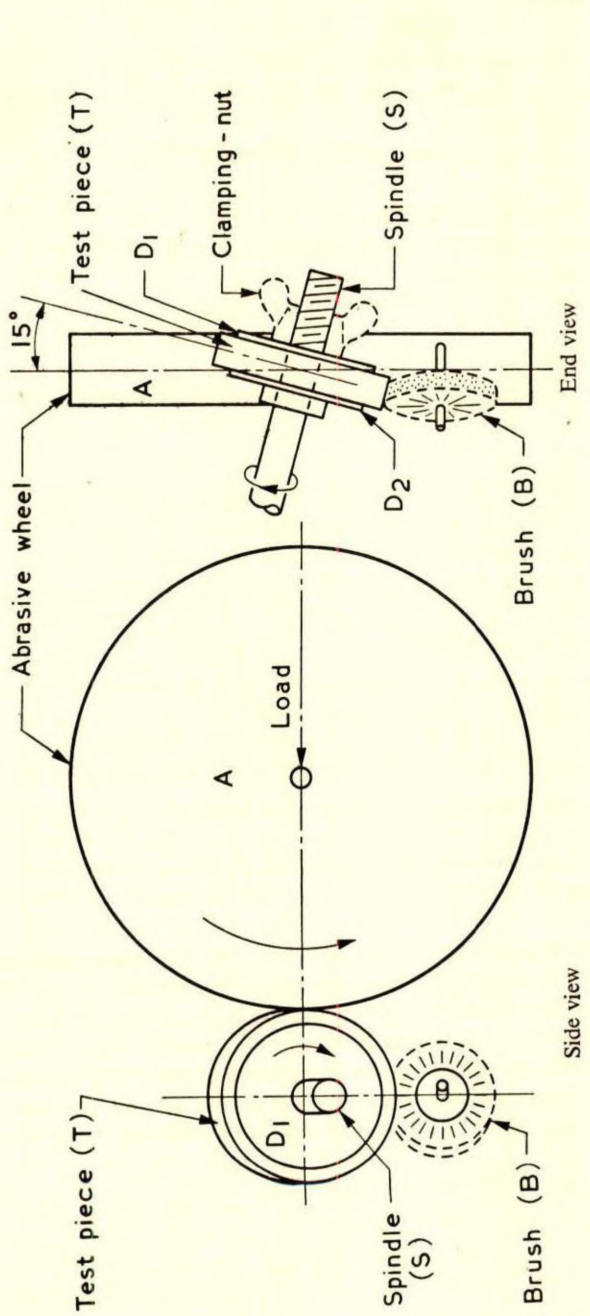

Fig. 4. Akron abrasion machine

As amended Dec., 1965 The dial gauge shall be fitted with a flat contact square to the plunger and parallel to the base plate and shall operate with a pressure of 200 ± 30 gf/cm^2.

For the most accurate results, the instrument shall be used as a comparator as recommended in B.S. 907,† which also includes notes on the care and use of dial-gauges.

NOTE. It is preferable for the gauge to have a contact of diameter about 4 mm as this may be used on almost all test pieces without any sub-part of the contact over-hanging the test piece edge which would increase the contact pressure.

5.3. Procedure.

5.3.1. *Preparation of test piece.* The test piece shall be trimmed of any moulding flash.

5.3.2. *Conditioning of test piece.* The properties of vulcanized rubber change continuously with time, these changes being particularly rapid during the first 24 hours after vulcanization. No test should therefore be carried out within this period and, for accurate comparisons between different rubbers, it may be necessary to ensure that these are tested at substantially the same interval after vulcanization.

Test pieces shall be protected from light as completely as possible during the interval between vulcanizing and testing.

The test pieces shall be kept at a temperature of 20 ± 2°C for a period of not less than 12 hours immediately prior to being measured and tested.

NOTE. See Note under Clause 54. Temperature of Test.

5.3.3. *Measurement of test pieces.* The thickness of the test piece shall be measured.

5.3.4. *Determination of abrasion loss.* The test piece shall first be weighed and then run for 500 revolutions of the abrasive wheel. The load pressing the abrasive wheel against the specimen shall be 10 lb (4·5 kg) if the thickness of the test piece lies within the specified limits. If the thickness of the test piece lies outside these limits the load shall be altered in proportion. The test piece shall then be reweighed and the volume loss calculated (the specific gravity of the rubber having been previously determined as described in B.S. 903, Part A1). From this loss the total running-in period shall be estimated, using Table 1. This ensures that the volume loss sustained during the total running-in period shall be approximately the same for all rubbers (being of the same order as that given by the standard tire-tread rubber ' A ' after 3000 revolutions of the abrasive wheel).

* See B.S. 1814, ' Marking system for grinding wheels '.
† B.S. 907, ' Dial gauges for linear measurement '.

After the completion of the running-in period, the test piece shall be weighed and then subjected to five test runs, the number of revolutions per test being also determined from Table 3 (for the standard tire-tread rubber each test run should be 500 revolutions).

TABLE 3. APPROXIMATE RUNNING-IN AND TEST RUNS

Volume loss in 500-revolution trial run	Revolutions (additional to trial run) for:	
	Running-in	Test run
ml		
Above 0·05, not above 0·10	4000	1000
„ 0·10, „ „ 0·20	2000	500
„ 0·20, „ „ 0·40	750	250
„ 0·40	125	125

The periphery of the abrasive wheel shall be cleaned with a steel-wire brush each time the test piece is removed for weighing. Care shall be taken to ensure that the test piece is not reversed, i.e. it shall always be replaced on the spindle with the same side towards the clamping nut. Should the weight loss for any of the five test runs differ by more than $\pm$ 10 per cent from the mean, a further run shall be carried out to replace it.

From the mean of the five test runs, the volume of rubber abraded per 1000 revolutions of the abrasive wheel shall be calculated.

5.4. Temperature of test. The test shall be carried out at a room temperature of 20 $\pm$ 2°C.

NOTE. A temperature of 20 $\pm$ 2°C for conditioning and testing is not yet practicable for all countries. In tropical climates where it is not possible to maintain this temperature, a temperature of 27 $\pm$ 2°C is permitted provided the temperature of conditioning and testing is stated in the test report.

5.5. Expression of results. The results shall be expressed as follows:—

$$\text{Abrasion resistance index} = \frac{S}{T} \times 100$$

S = Volume loss per 1000 revolutions of abrasive wheel, calculated from the mean of 5 runs on standard rubber.

T = Volume loss per 1000 revolutions of abrasive wheel, calculated from the mean of 5 runs on the sample rubber.

5.6. Report. The report shall state:—

1. Abrasion resistance index calculated in accordance with Clause 3.5.
2. Standard rubber used.

3. Angle between the planes of the test piece and the abrasive wheel.
4. Load on the abrasive wheel.
5. Temperature of test, if other than 20 ± 2°C.

5.7. Reproducibility of results. The coefficient of variation of a single test measurement is 3 to 4 per cent, but serious discrepancies are found between tests made in different laboratories, even when the same abrasive wheel is used. The variations between the losses on nominally identical abrasive wheels may be as large as 25 per cent, though the effect of this variation is reduced by calculating the abrasion index.

SECTION 6 METHOD D—METHOD USING DUNLOP MACHINE

6.1. Test piece. The test wheel consists of a steel centre-piece on to which the rubber under test is moulded. The outside diameter is approximately 1·7 in. (4·3 cm) and the face 0·4 in. (1 cm) wide. The 'tread' thickness is approximately 0·2 in. (0·5 cm).

6.2. Apparatus.

6.2.1. *Abrasion machine* (Fig. 5). The rubber test wheel (TW) shall be mounted securely on the front spindle of the bracket (B) by means of a washer slightly smaller than the metal centre of the test wheel, and a nut, so that there shall be no possibility of squeezing the rubber. The bracket which carries the test wheel shall be pivoted on the rear spindle (S) and shall be provided with a counter-balance weight (W) so that any desired weight can be applied to the test wheel. The test wheel shall be driven at a speed of 600 rev/min by the motor (M), the speed being indicated by the tachometer (T_1) and controlled by a rheostat (R_1) across the armature of the motor. The drive shall be transmitted through the rubber to an abrasive wheel (AW) 7 ± 0·1 in. (17·8 ± 0·25 cm) in diameter and 0·75 – 1 in. (1·8 – 2·5 cm) thick; a 36 grit silicon-carbide abrasive has been found satisfactory, with an approximate life of 320 operating hours. These wheels show a gradual decrease in abrasive action with use.

The abrasive wheel rotates at a speed recorded by the tachometer (T_2); the number of revolutions of both test wheel and abrasive wheel can be read off on the counters (C_1) and (C_2) respectively. The slip between the test wheel and abrasive wheel shall be produced by means of an eddy-current brake. Eddy currents are set up in the copper plate (P) due to its motion between the poles of the electro-magnet (E) when a current is passed through the latter. The copper-plate, being co-axial with the abrasive wheel, acts as a brake, thereby causing slip between the rubber and abrasive. By varying the electro-magnetic current by rheostat (R_2) the slip can be varied at will, and by using both tachometers in conjunction with the rheostats any desired amount of slip can be maintained. The surface of the abrasive wheel shall be kept free from particles of abraded rubber by means of a rotating wire brush (BR) preferably arranged

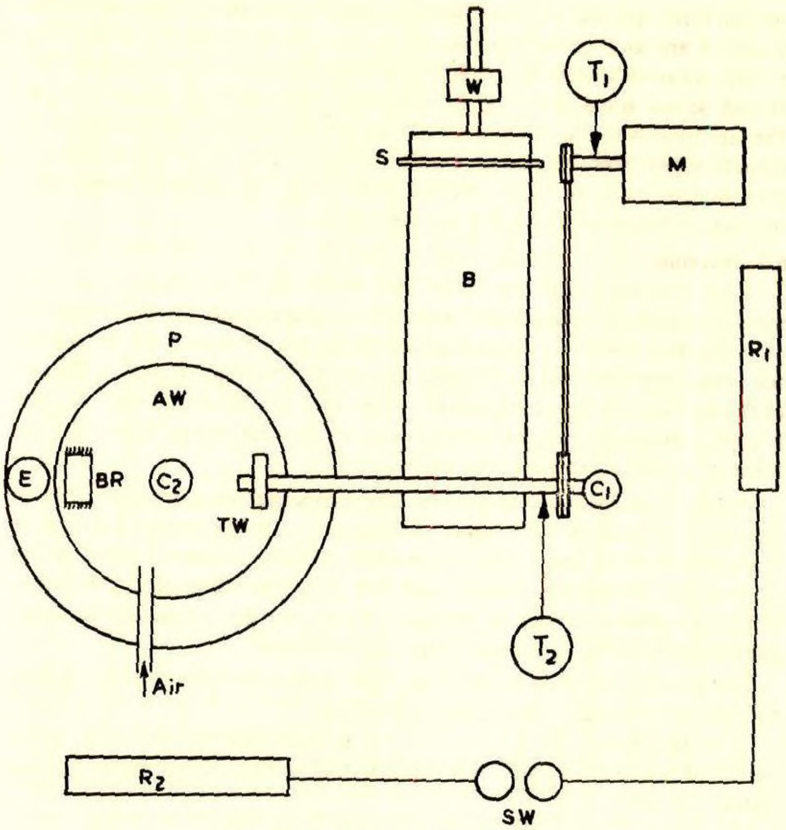

Fig. 5. Dunlop abrasion machine

obliquely to the track, and an air suction pipe. (SW) are the rheostat switches.

6.2.2 *Buffing machine*. It is necessary to provide a means of removing the outer surface of the moulded test wheel and also of making the outer periphery of the test wheel substantially concentric with the spindle hole so that there is no vibration during the actual test run or preliminary run on the abrasion machine which actually completes the alignment of the test surface.

A buffing machine is employed for the above purpose. The test piece is mounted on a spindle of suitable diameter driven by an electric motor (say 1500–1800 rev/min) and the test piece is brought into contact with the face of an abrasive wheel (of the same material as used for the abrasion machine) mounted on a second spindle so as to buff the edge of the test wheel concentrically with its central spindle hole. The two spindles, that on which the test piece is mounted, and that on which the abrasive wheel is carried are so disposed that the test piece spindle is parallel to the face of the abrasive wheel. The spindle axes need not intersect exactly but should be not more than 1½ in. (38 mm) apart at their closest point. The abrasive wheel is rotated slowly either by hand or by means of a reduction gear from the other spindle, a convenient ratio being 100 : 1. Provision is made to bring the test piece and the abrasive wheel into contact by means of a suitably located screw.

6.3 Procedure.

6.3.1 *Preparation of test piece.* Test pieces shall be trimmed of any moulding flash. They shall then be fitted one at a time to the motor spindle of the buffing machine. While they are being turned rapidly by the motor the abrasive wheel shall be brought into contact with them until sufficient of the surface has been removed to ensure that the circumferential surface is truly concentric with the spindle carrying the test pieces. Care shall be taken to avoid overheating the rubber.

6.3.2 *Conditioning of test piece.* The properties of vulcanized rubber change continuously with time, these changes being particularly rapid during the first 24 hours after vulcanization. No tests should therefore be carried out within this period and, for accurate comparisons between different rubbers, it may be necessary to ensure that these are tested at substantially the same interval after vulcanization.

Test pieces shall be protected from light as completely as possible during the interval between vulcanizing and testing.

The test pieces shall be kept at a temperature of 20 ± 2°C for a period of not less than 12 hours immediately prior to being measured and tested.

NOTE. See Note under Clause 6.4. Temperature of test.

6.3.3 *Measurement of abrasion loss.* The test wheel after preparation and conditioning shall be weighed and given a preliminary run of 1000 revolutions of the abrasive wheel. It shall then be reweighed, and the volume loss calculated (the specific gravity of the rubber having been determined previously as described in B.S. 903, Part A1). From this loss the total running in period shall be estimated using Table 1. This ensures that the volume loss sustained during the total running-in period shall be approximately the same for all rubbers (being of the same order as that given by the standard tire-tread rubber 'A' after 3000 revolutions of the abrasive wheel).

After the completion of the running-in period (taking care, both here and in the subsequent procedure, always to fit the test wheel to run in the same direction) the test wheel shall be weighed and its outside diameter measured. It shall then be run on the machine for a distance as determined by Table 4 at a slip of approximately 16 per cent. The test wheel shall be reweighed and its outside diameter again measured. The mean diameter shall thus be obtained and the percentage slip calculated. The test wheel shall be given further test runs of the same distance to give a range of four slips, two on either side of 16 per cent, and the volume loss at precisely 16 per cent obtained by interpolation (calculating the volume as before from the loss in weight in grammes and the specific gravity). From the volume loss per test run shall then be calculated the volume loss for a running distance of 1 kilometre.

TABLE 4. APPROXIMATE RUNNING-IN TIMES AND TEST RUN LENGTHS

Volume loss in 1000-revolution trial run	Revolutions (additional to trial run) for running-in	Test run
ml		km
Above 0·01, not above 0·02	5000	2
„ 0·02, „ „ 0·04	2000	1
„ 0·04, „ „ 0·08	500	0·5
„ 0·08	0	0·25

The slip shall be calculated as follows:—

D = diameter of abrasive track.
d = mean diameter of rubber test wheel.
N = revolutions of abrasive track in unit time.
n = revolutions of rubber test wheel in unit time.

$$\text{Then percentage slip} = \frac{nd - ND}{nd} \times 100.$$

In comparing several rubbers, it is preferable to run the standard test wheel once, followed by one run of all the test wheels in order. This is repeated to give the four test runs required on each test wheel. One wheel shall be tested for each rubber.

6.4 Temperature of test. The test shall be carried out at a room temperature of 20 ± 2°C.

NOTE. A temperature of 20 ± 2°C for conditioning and testing is not yet practicable for all countries. In tropical climates where it is not possible to maintain this temperature a temperature of 27 ± 2°C is permitted.

6.5 Expression of results. The results shall be as follows:—

$$\text{Abrasion resistance index} = \frac{S}{T} \times 100$$

S = Volume loss at 16 per cent slip, calculated from the four test runs on standard rubber.

T = Volume loss at 16 per cent slip, calculated from the four test runs on the sample rubber.

6.6 Report. The report shall state:—

1. Abrasion resistance index calculated in accordance with Clause 6.5.
2. Type of abrasive.
3. Standard rubber used.
4. Temperature of test if other than 20 ± 2°C.

6.7 Reproducibility of results. The logarithm of the abrasion resistance index has a standard deviation of 0·0095.

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