

Methods of testing vulcanized rubber —

Part A9: Determination of abrasion resistance

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Foreword

This Part of BS 903 has been prepared under the direction of the Rubber Standards Committee and supersedes BS 903-A9:1957 which is withdrawn.

Four methods (A to D) are described in this Part of BS 903, because no single method has been found which will adequately simulate the various conditions to which rubber products may be subjected in service. A comparison of these methods and guidance on which method should be chosen for a particular application is given in Appendix A.

Method A is technically equivalent to ISO 4649:1985 "*Rubber — Determination of abrasion resistance using a rotating cylinder drum device*". Method B is a revised version of method C (using an Akron machine) of the 1957 edition; the main change in the revised method is the provision, as an option in the procedure, for the application of a dust during the test in order to prevent clogging of the abrasive wheel with rubber debris which would otherwise cause abnormally low losses of material due to abrasion. Method C is a revised version of method A (using a Du Pont machine) of the 1957 edition; the main change in the revised method is that the duration of a test run is now specified either as a time (as in the 1957 edition) or, alternatively, as a number of revolutions of the abrasive disc. Method D is technically similar to ISO 5470:1980 "*Rubber or plastics coated fabrics — Determination of abrasion resistance*", but it is applicable to flat rubber sheet instead of coated fabrics. Method B (using a Du Pont machine with constant torque modification) of the 1957 edition has not been included. Method D (using a Dunlop machine) of the 1957 edition was deleted by an amendment issued in 1974.

The methods for determining abrasion resistance are classified into two groups:

- a) continuous abrasion, for which the whole of the test surface is in contact with the abrading surface throughout the test; and
- b) discontinuous abrasion, for which any particular part of the test surface is only in intermittent contact with the abrading surface.

In each of the methods, rubber is abraded by cutting its surface by asperities. Depending on the method chosen, various abrasives, with different degrees of roughness, are used. The severity of the abrasive action between the rubber and the abrasive surface depends on the contact pressure, the slip velocity and the nature of the abrasive. The presence of particles in the abraded rubber in the interface between the test piece and the abrading surface can cause stickiness and variable loss of rubber; each method therefore incorporates a means of removing these particles as they are formed. The discontinuous methods are better in this respect because both the abrading surface and the test piece can be cleaned during the test.

The results obtained for various rubbers using one particular method may not be comparable (either absolutely or relatively) to those obtained using another method.

The expression of a result in the form of an abrasion resistance index, based on the abrasion loss of a standard rubber, is intended to help overcome the problem of the variability of abrasion loss found between different machines operating under essentially the same conditions.

The important parameters of each method are compared in Appendix A.

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Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 16, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

0 Introduction

Abrasion is the loss of material (the wear) resulting from frictional action upon a surface. The resistance of rubbers to abrasion is one of their most important technological properties. However, the analysis of the processes of abrasion and of its measurement under laboratory conditions and in service has proved to be a difficult problem.

In performing laboratory tests it is generally necessary to obtain a significant amount of abrasion in a short time in order to have measurable mass losses. This has led to tests based on the use of sharp abrasive surfaces of corundum, high loads, and high slip velocities, although these conditions are not characteristic of service. Wear in service, for example, can take place not only on surfaces with sharp asperities but also on mechanically smooth surfaces such as glass or polished metal.

In the case of asperities, the predominant action is that of cutting or tearing of the surface, and loss of material occurs as asperities plough through the surface. It is found that the mass loss is directly related to the sliding distance and to the applied load; it is also very dependent upon the sharpness of the edges of the asperities and upon the hardness of the rubber.

With smooth surfaces, abrasion is due to different processes and is considered to arise from stress concentrations in the surface associated with the mechanism of friction of polymers. However, abrasion by friction forces between relatively smooth surfaces is not of sufficient interest to justify the preparation of a standard method at the present time.

No close relationship between the results of an abrasion test and service performance can be inferred.

1 Scope

This Part of BS 903 describes four methods (A to D) for determining the abrasion resistance of rubber by comparing the wear of the rubber under test with that of a standard rubber under the same conditions. Methods A and D are applicable to rubbers of any degree of hardness, whilst methods B and C are restricted to rubbers with a hardness in the range 55 to 95 IRHD.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 903, the following definitions apply.

2.1

abrasion resistance

the resistance to wear of a rubber when its surface is subjected to mechanical action

the abrasion resistance can be expressed as an abrasion resistance index referred to a standard rubber, and this is applicable to all methods. For method A only, an alternative way of expressing the abrasion resistance is as a relative volume loss referred to a calibrated abrasive cloth

2.2

abrasion resistance index

the expression of abrasion resistance, being the ratio of the volume loss of a standard rubber to the volume loss of the rubber under test, determined under the same specified conditions, expressed as a percentage

2.3

relative volume loss

the volume loss in cubic millimetres of the test rubber when subjected to abrasion by an abrasive cloth which causes the appropriate standard rubber to lose a mass of 200 mg under the conditions of test for method A.1 (see 3.2 and 7.4.1)

2.4

slip velocity

the vectorial difference between travelling and circumferential velocities. It is calculated as $\Delta v = v \sin \theta$.

3 Principle of methods

3.1 Method A

The flat end of a cylindrical test piece is abraded against the surface of a rotating drum covered with an abrasive cloth, while the test piece is traversed from one end of the drum to the other to reduce contamination of the cloth.

In method A.1 the test piece is held stationary (i.e. non-rotating) in the holder during traverse along the drum.

In method A.2 the test piece is held stationary (i.e. non-rotating) or rotated in a plane tangential to the surface of the drum during its traverse.

NOTE The results of the two types of test may differ.

3.2 Method B

A rotating test piece in the form of a disc is abraded against an abrasive wheel under a specified load, the planes of the test piece and the wheel being inclined at an angle. A dust is applied, if required, during the test in order to prevent clogging of the abrasive wheel with rubber debris.

3.3 Method C

A flat test piece is abraded against a rotating abrasive disc under a specified load.

3.4 Method D

A flat test piece is subjected to rotary slip between itself and a pair of abrasive wheels. The test is carried out using one of a range of wheel loadings and abrasive surfaces, so that it is possible to choose test conditions that are relevant to conditions experienced in service.

NOTE 1 S1 is identical to the standard rubber specified in B.1 of ISO 4649:1985 and is used as the standard rubber for method A when relative volume loss measurements are required.

S2 is identical to the standard rubber specified in B.2 of ISO 4649:1985; it replaces standard rubber A (tyre-tread type) in BS 903-A9:1957.

S3 is a high abrasion resistance compound based on synthetic rubber and may be preferred when highly resistant rubbers are being evaluated.

S4 is a rubber of low abrasion resistance and may be preferred when less resistant rubbers are being evaluated; it replaces standard rubber B (sole and heel type) in BS 903-A9:1957.

NOTE 2 The choice of standard rubber will depend on the application for which the test is being carried out. The four standard rubbers are intended to cover a wide range of abrasion resistance.

NOTE 3 The variability between different batches of a standard rubber can be minimized by careful control of mixing and vulcanization. Two batches of the same standard rubber should suffer abrasion losses which agree to within $\pm 10\%$ when tested by the same method under the same conditions. To minimize variation, the quality of compounding ingredients should be in accordance with BS 4398, whenever this is appropriate.

4 Standard rubbers

The standard rubber compound to be used in a test shall be one of those listed in Table 1. The mixing and vulcanization procedures for S1 and S2, shall be in accordance with Appendix B and for S3 and S4 shall be in accordance with either Appendix B or BS 1674.

Table 1 — Standard rubber compounds

Standard rubber	S1	S2	S3	S4
Ingredients and their designations	Parts by mass	Parts by mass	Parts by mass	Parts by mass
Natural rubber (NR), SMR 5	100	100	—	100
Styrene-butadiene rubber (SBR) 1 500 (see note 1)	—	—	100	—
Stearic acid	—	2	1	2
Zinc oxide	50 (see note 2)	5	3	5
Oil furnace black (HAF), N330 (see note 3)	36	50	—	60
ISAF black, N220 (see note 4)	—	—	50	—
Whiting (see note 5)	—	—	—	60
Di-2-ethylhexylphthalate	—	—	—	3
CBS (see note 6)	—	0.5	1.0	0.6
Dibenzthiazyl disulphide	1.2	—	—	—
sulphur	2.5	2.5	2.0	2.5
Antioxidant (see note 7)	1.0	1.0	1.0	1.0
Vulcanization conditions				
Cure time, min	30	40	60	40
Cure temperature, °C	150	140	150	140
NOTE 1 In accordance with International Institute of Synthetic Rubber Producers (IISRP) No. 1500.				
NOTE 2 99.5 % ZnO of 9 m ² /g surface area (see BS 4398). The standard rubber quality is assessed by the tests described in Appendix B.				
NOTE 3 Designated in accordance with ASTM D1765 "Standard classification system for carbon blacks used in rubber products". For reference purposes, the current industry reference black should be used, but this may give slightly different results.				
NOTE 4 Designated in accordance with ASTM D1765.				
NOTE 5 Ground limestone, 79 % < 25 µm, 99.8 % < 75 µm.				
NOTE 6 N-cyclohexylbenzothiazole-2-sulphenamide.				
NOTE 7 N-isopropyl-N'-phenyl-p-phenylenediamine (IPPD).				

5 Conditioning

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 shall be carried out after the same time interval.

For product tests, the time between vulcanization and testing shall not exceed 3 months. When the date of vulcanization is unknown, products shall be tested within 2 months of receipt.

Samples and test pieces shall be conditioned, after any necessary preparation, at a temperature of 23 ± 2 °C for at least 3 h and then either measured and tested immediately, or kept at a temperature of 23 ± 2 °C until tested.

If the preparation involves buffing, the interval between buffing and testing shall be at least 16 h but shall not exceed 72 h.

If the test is to be carried out at a temperature other than 23 ± 2 °C (see clause 6), the test pieces shall be conditioned for a period sufficient to reach substantial temperature equilibrium at the test temperature, immediately prior to testing. For elevated test temperatures this period shall be kept as short as possible in order to avoid ageing the rubber.

6 Temperature of test

Unless otherwise specified in the material specification, tests shall be carried out at a temperature of 23 ± 2 °C.

NOTE During a test, there may be a considerable increase in temperature at the interface between the test piece and the abrasive, particularly when using a continuous abrasion method. This may lead to temperature rises within the test piece. For the purposes of this Part of BS 903, such temperature rises should be disregarded, the temperature of the test being defined as that of the atmosphere in the test chamber (or room) and of the test piece at the commencement of the test. If repeat runs on the same test piece are to be carried out, sufficient time should be allowed between such runs for the temperature of the entire test piece to be restored to the temperature of test.

7 Method A

7.1 Test pieces

7.1.1 Type and preparation. The test pieces shall be cylindrical in shape, of diameter 16 ± 0.2 mm, with a minimum height of 6 mm.

Prepare the test pieces either by the normal method using a hollow drill (see 7.2.3) or by vulcanization in a mould. During cutting, the cutting edge shall be lubricated with water to which a wetting agent has been added. Punching of the test pieces is not permitted.

If test pieces of the required thickness are not available, obtain the necessary thickness 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 shall be not less than 2 mm.

NOTE The preparation of test pieces by cutting should follow the recommendations of BS 903-A36.

7.1.2 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.

7.2 Apparatus and materials

7.2.1 Abrasion machine, as shown in Figure 1, consisting of a laterally movable test piece holder and a rotatable cylinder to which the abrasive cloth (7.2.2) 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 40 ± 1 r/min, the direction 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 mm 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 1 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 ± 1 mm.

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.

NOTE 2 For special purposes a force of 5 ± 1 N may be used. If so it should be stated in the test method [see 7.5 c) 4)].

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, ensuring that the 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.

NOTE If using an abrasion distance of 20 m, a revolution counter or automatic stopping device should be connected to the drum.

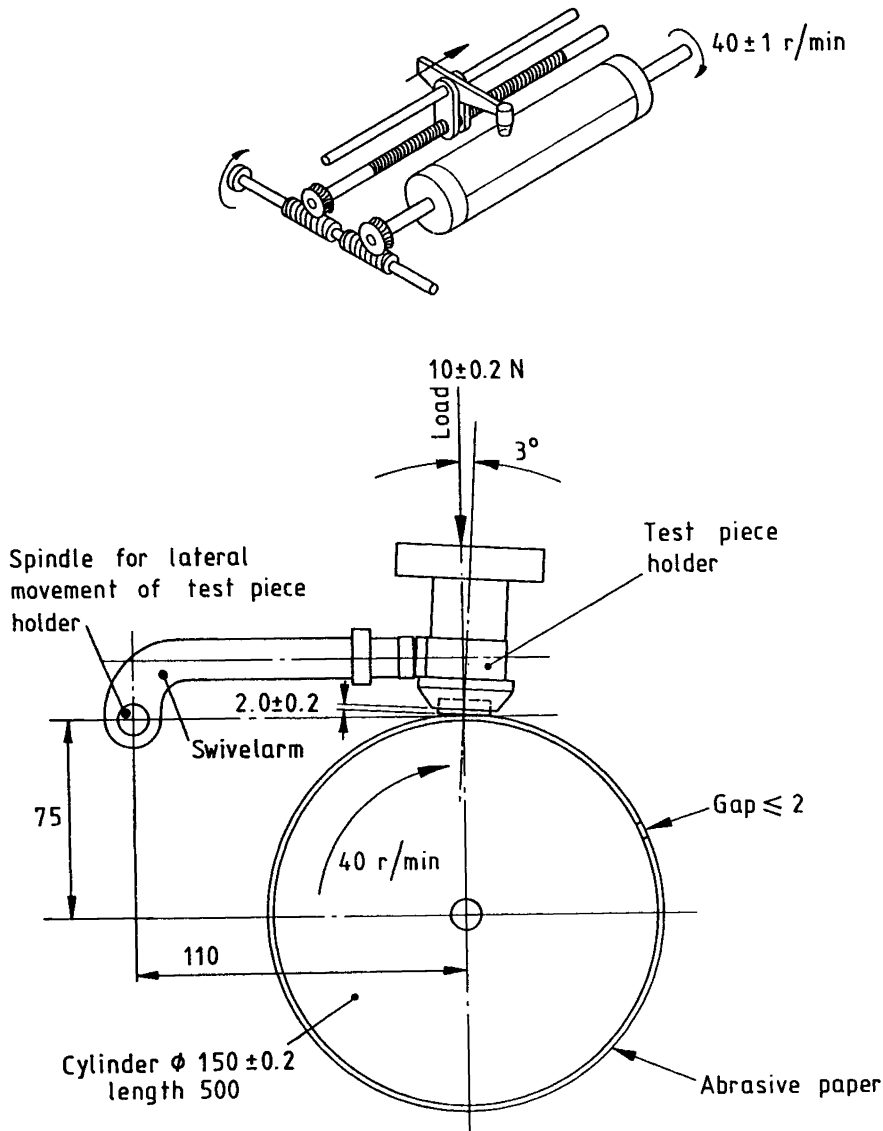
To protect the abrasive cloth from damage by the test piece holder, a device for switching off the apparatus just before the lower edge of the test piece holder touches the cloth is recommended.

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

When tested using a fixed test piece of the standard rubber S1, this abrasive surface shall cause a mass loss between 180 mg and 220 mg over 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.

Details of a suitable abrasive cloth are given in Appendix C.



All dimensions are in millimetres.

Figure 1 — Schematic illustration of apparatus for method A

7.2.3 Hollow drill, where required, for preparation of test pieces (see 7.1). The dimensions of the drill shall be in accordance with Figure 2. The frequency of rotation of the drill needs to be at least 1 000 r/min for most rubbers, and even higher for rubbers with a hardness of less than 50 IRHD.

7.2.4 Balance, of sufficient accuracy to enable the mass loss of a test piece to be determined to ± 1 mg.

7.3 Procedure

7.3.1 General test procedure. Remove by brushing any rubber debris left on the abrasive cloth from a previous abrasion test.

Weigh the test piece to the nearest milligram. Mount 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. Control this length by means of a gauge. Use a stationary (i.e. non-rotating) test piece for method A.1 and either a stationary (i.e. non-rotating) test piece or a rotating test piece for method A.2.

NOTE 1 For method A.2, use of a rotating test piece is preferred, because the abrasion loss is more uniform over the whole surface of the test piece in contact with the abrasive cloth. The stationary test piece is used for method A.1 because of the considerable experience obtained previously with this method using the stationary test piece.

Press the test piece 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, state this in the test report because the severity of abrasion is lower.

NOTE 2 A force of 10 N produces a nominal contact pressure of 50 kPa.

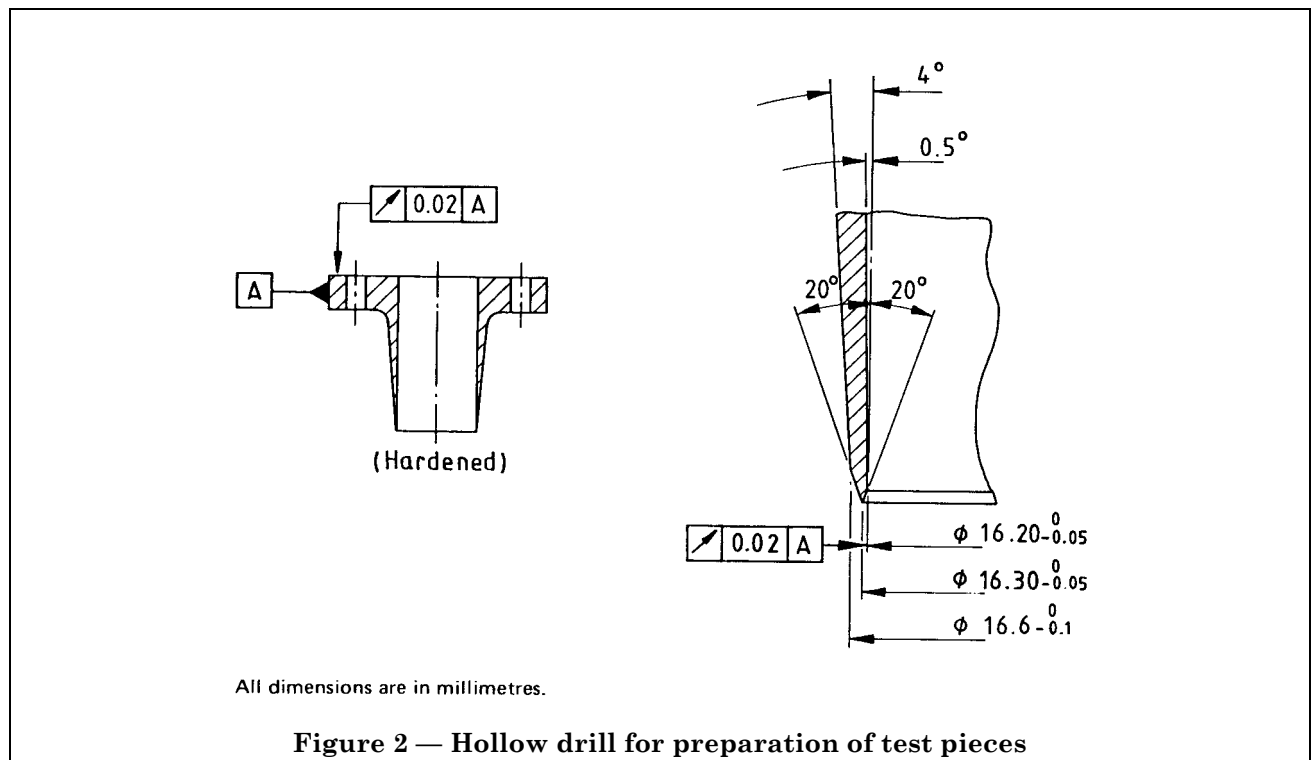
Move the test piece holder and sledge to the starting point and set the cylinder in motion. Check for vibration in the test piece holder as this method does not yield meaningful results if there is abnormal vibration in the test piece holder. Stop the test run automatically after an abrasion distance of 40 m.

NOTE 3 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 allow the height of the test piece to fall below 5 mm.

If the mass loss is greater than 600 mg in 40 m, conclude the test run at half distance (i.e. 20 m) and state so in the test report. In this case multiply the results by two to correct the mass loss for an abrasion distance of 40 m.

Weigh the test piece to the nearest milligram after the test run. Pull off any small sliver attached to the edge of the test piece before weighing, especially if a fixed test piece is used.



Perform three test runs on the 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, allow sufficient time between such runs for the temperature of the whole of the test piece to return to standard laboratory temperature. Take care to ensure that a fixed test piece is always placed in the test piece holder in the same way. If more than one rubber is to be tested, carry out all three test runs on each rubber consecutively.

7.3.2 Comparison with standard rubber

NOTE 1 The procedure given in this clause is for comparison of the performance of the test rubber with that of the appropriate standard rubber (see Table 1). Two standard rubbers are specified for use with the two methods of expressing results (see 7.4). That specified as S1 is intended for use in method A.1, where the abrasion resistance is expressed as relative volume loss Δv . That specified as S2 is intended for use in method A.2, where the abrasion resistance is expressed as an abrasion resistance index (ARI).

NOTE 2 Standard rubber S2 is specified for calculation of ARI because S3 and S4 are not included in ISO 4649. Standard rubbers S3 and S4 may, however, be used for this purpose provided it has been shown that the abrasive cloth is of an acceptable quality and provided use of one or other of these rubbers is described in the test report.

Follow the procedure described in 7.3.1 using test pieces prepared from the appropriate standard rubber. Carry out a minimum of three test runs on the standard rubber both before and after testing a "series" of test rubbers, where a "series" comprises a maximum of three test rubbers.

For test rubbers that have a tendency to smear, determine the loss in mass of the appropriate standard rubber after each test run.

NOTE 3 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 %, the method cannot be used for the test rubber concerned.

7.3.3 Density. Determine the densities of the test material and of the appropriate standard rubber by the procedures specified in BS 903-A1.

7.4 Calculation and expression of results

7.4.1 General. Express the results either as a relative volume loss (for method A.1, see 7.4.2) or as an abrasion resistance index (for method A.2, see 7.4.3).

Calculate the mean value of the mass losses (in mg) of the test rubber, m_t , and of the standard rubber, m_s , from the three and six separate determinations respectively.

Calculate the volume losses (in mm³) of the test rubber, V_t , and of the standard rubber, V_s (for method A.2 only) from the respective mass losses and densities.

7.4.2 Method A.1: relative volume loss, Δv . Calculate the relative volume loss Δv from the equation:

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

where V_t and m_s are as defined in 7.4.1.

7.4.3 Method A2: abrasion resistance index, ARI. Calculate the abrasion resistance index from the equation:

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

where V_t and V_s are as defined in 7.4.1.

7.5 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) A reference to this British Standard, i.e. method A of BS 903-A9:1988.
- c) Test details:
 - 1) temperature of test, if other than 23 ± 2 °C;
 - 2) whether a fixed or rotating test piece was used;
 - 3) type of standard rubber used;
 - 4) any deviations from the test procedure, e.g. 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) density.
- e) Date of test.

8 Method B

NOTE This method is a revised version of the Akron machine test.

8.1 Test piece

8.1.1 Type and preparation. The test piece shall be a disc $12.5^{+0.5}_0$ mm thick and $63.5^{+0.5}_0$ mm in diameter, with a central hole $12.7^{+0.5}_0$ mm in diameter, prepared by moulding.

8.1.2 Number. Only one test piece is required, with which five test runs shall be carried out.

8.2 Apparatus and materials

8.2.1 Abrasion machine, as shown in Figure 3. It consists of a spindle upon which the test piece is mounted and which is driven by an electric motor at a constant speed. A free-running abrasive wheel is pressed against the test piece by means of a mass acting through a pivoted crank, and is rotated by the test piece.

The test piece is clamped between two discs, D_1 of 56 mm in diameter with rounded edge to avoid cutting the rubber and D_2 of 44 mm in diameter with raised peripheral rim 4 mm wide and 0.5 mm high to contact with the rubber, in such a way that when the clamping nut is fully tightened the test piece is compressed by 0.5 mm.

The abrasive wheel shall be 150 mm diameter and 25 mm thick and mounted so that the whole width of the test piece is in contact with the wheel. A revolution counter shall be connected to the wheel. The planes of the test piece and the abrasive wheel shall be inclined at an angle to each other and can be set at either 15° or 25° . A 15° angle is the recognized standard for natural rubber vulcanizates and shall be used for all rubbers except those whose abrasion resistance is large, when the angle shall be 25° . The angle shall be accurate to $\pm 0.5^\circ$.

To remove debris, a freely rotating bristle brush may be used, mounted as shown in Figure 3, or alternatively a dust may be applied to the interface between test piece and wheel. When using dust, a suction nozzle shall be fitted at approximately 1 mm from the surface of the abrasive wheel. A dust dispenser shall be provided to deliver 20 mg of dust every 25 ± 5 revolutions of the abrasive wheel.

NOTE 1 A suitable dust consists of a mixture of two parts by volume of silicon carbide grit No. 180 and one part of fuller's earth (absorption grade). The ingredients, previously oven dried, should be kept in closed containers and a fresh batch made up each day since the fuller's earth absorbs moisture. The mixture should be well stirred before use.

NOTE 2 The use of dust is recommended for soft rubbers and particularly for oil-extended rubbers, but different results may be obtained when the dust is used, compared to a test in which dust is not used, even for rubbers which do not clog the abrasive wheel.

The test piece shall be rotated at 250 ± 5 r/min. The slip velocity is dependent upon the slip angle; for 15° it is 210 mm/s and for 25° it is 350 mm/s.

The abrasive wheel shall be pressed against the test piece with a force of 45 N, providing a nominal contact pressure of 300 kPa.

8.2.2 Abrasive wheel, of designation A36-P5-V complying with BS 4481-1.

When the rate of mass loss due to abrasion of the standard rubber S2 has fallen systematically to below 75 % of that determined on a new or redressed wheel, the wheel shall be redressed or replaced by a new one.

NOTE The surface sharpness of the abrasive wheel will fall with use, thereby causing a reduction in mass loss due to abrasion. The effect of wheel age is less evident when the abrasion resistance index is calculated but is not necessarily eliminated completely.

8.2.3 Balance, of sufficient accuracy to enable the loss in mass of a test piece to be determined to ± 1 mg.

8.3 Procedure

8.3.1 General test procedure. The procedure consists of a trial run, a running-in period and five test runs.

Weigh the test piece, clamp it to the spindle and make a trial run of 500 revolutions of the abrasive wheel.

If dust is used, deliver it at the specified rate (see 8.2.1) into the nip between the test piece and the abrasive wheel and uniformly over the width of the test piece.

After brushing off loose debris, reweigh the test piece.

After the trial run, abrade the test piece for a running-in period of duration as given in Table 2 according to the mass loss measured after the trial run.

NOTE 1 Running-in is intended to produce an even test piece abraded surface in the minimum possible time so that subsequent test runs are conducted under comparable conditions of abrasion. The procedure described ensures that the mass loss sustained during the running-in period is approximately the same for all rubbers. Experience has shown that with some rubbers the running-in period may be omitted without discernible effect on the final test results. This shorter alternative procedure is permissible provided sufficient test runs are carried out after the trial run to ensure that there are no systematic changes in the rate of abrasion that could be attributed to continuing changes in the area of contact between the test piece and abrasive wheel surfaces.

After running-in, reweigh the test piece and then carry out five test runs, each for the number of revolutions per run given in Table 2. Brush and reweigh after each of the five test runs.

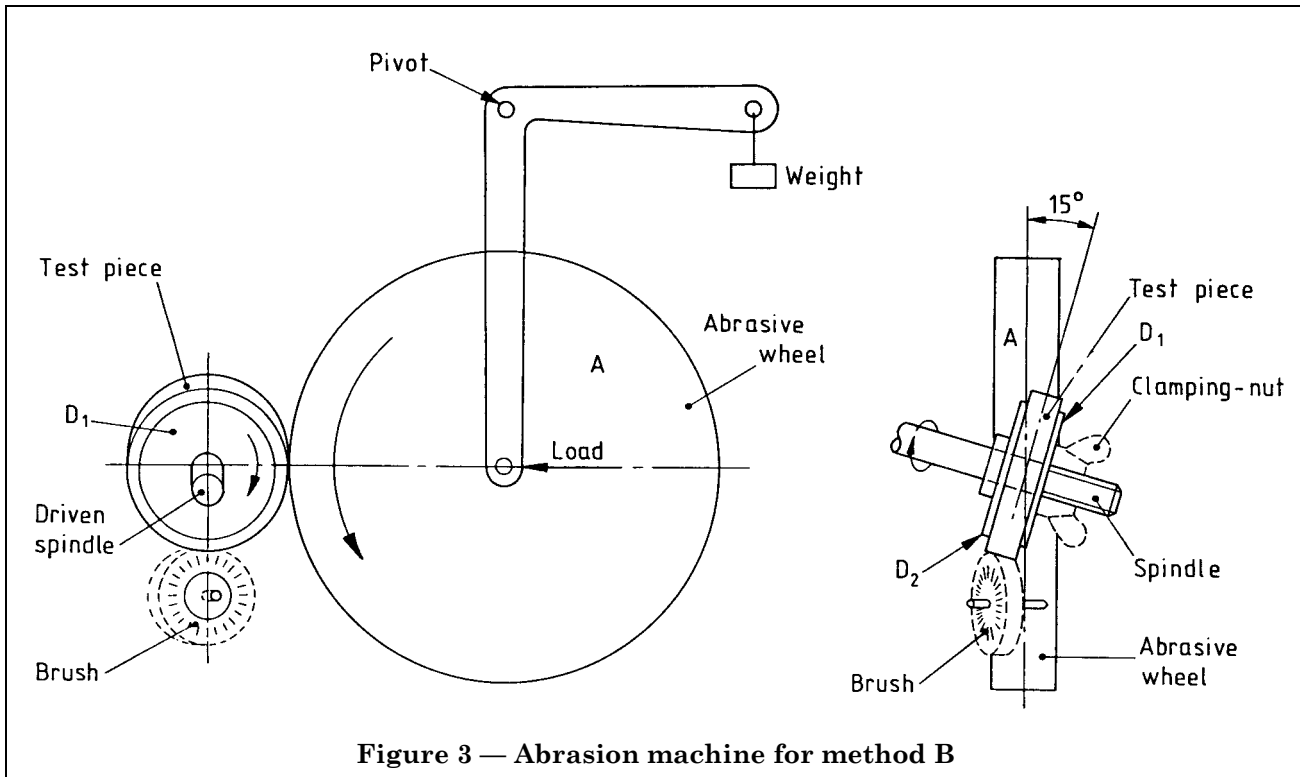


Figure 3 — Abrasion machine for method B

Table 2 — Running-in and test run revolutions

Mess loss in trial run mg	Revolutions of abrasive wheel	
	Running-in	Per test run
Not above 100	4 000	1 000
Above 100, not above 200	2 000	500
Above 200, not above 400	750	250
Above 400	125	125

For each test run, replace the test piece on the spindle with the same side towards the clamping nut.

NOTE 2 It is recommended that an appropriate distinguishing mark is added on one side of the test piece before starting the test.

Between each run, clean the periphery of the abrasive wheel either with a steel wire brush, or, if dust is being used, with a stiff bristle brush and rotate it slowly past the suction nozzle.

8.3.2 Comparison with standard rubber. Follow the procedure described in 8.3.1 using a test piece prepared from the appropriate standard rubber (see Table 1), both before and after making the test runs.

8.3.3 Density. Determine the densities of the test material and standard rubber by the procedures described in BS 903-A1.

8.4 Calculation and expression of results

8.4.1 Mass loss. The mass loss for the calculation of the abrasion resistance index shall be the mean value determined from the five test runs, expressed as milligrams per 1 000 revolutions of the abrasive wheel.

For the standard rubber, the mass loss shall be the mean of the values determined on that rubber both before and after making the test runs.

8.4.2 Calculation of abrasion resistance index. Calculate the abrasion, as the loss of volume of the test piece due to abrasion, from the density and mass loss as determined in 8.3.3 or 8.4.1 respectively.

Calculate the abrasion resistance index ARI from the equation:

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

where

V_t is the volume loss (in mm³) of the test rubber;

V_s is the volume loss (in mm³) of the standard rubber determined under the same test conditions.

8.5 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.
- b) A reference to this British Standard, i.e. method B of BS 903-A9:1988.
- c) Test details:
 - 1) temperature of test, if other than 23 ± 2 °C;
 - 2) angle between the planes of the test piece and the abrasive wheel;
 - 3) whether dust is used;
 - 4) type of standard rubber used;
 - 5) any non-standard procedure used.
- d) Test results:
 - 1) abrasion resistance index;
 - 2) absolute values of abrasion loss;
 - 3) density.
- e) Date of test.

9 Method C

9.1 Test piece

9.1.1 Type and preparation. The test piece (see Figure 4) shall be 20.0 ± 0.5 mm square by approximately 10 mm thick, with parallel faces and with suitable fixing lugs. Prepare the test pieces by moulding or by cutting as described in BS 903-A36 from sheet of the correct thickness. Where the rubber exhibits marked calendar grain, prepare test pieces having the grain both parallel and perpendicular to the direction of abrasion.

9.1.2 Number. Three pairs of test pieces shall be used for each determination.

9.2 Apparatus and materials

9.2.1 Abrasion machine, as shown diagrammatically in Figure 5. An annular abrasive surface, of 165 mm outer diameter with a central hole of 70 mm diameter, is attached centrally to a disc which is mounted in a vertical plane. The disc is carried on a hollow shaft and rotated counter-clockwise at a uniform speed.

NOTE 1 The provision of a revolution counter is desirable.

Two test pieces are mounted on the inner surface of a bar with their 20 mm square faces parallel to the abrasive, one placed at each end so that their centres are each 63.5 mm from the axis of the shaft.

The test pieces are held in contact with the abrasive by a weight-piece attached to a cable acting over a pulley. The cable is attached to a rod which extends through the hollow shaft carrying the abrasive disc; this rod has a small vertical pin through the end, which seats into a groove on the front face of the bar carrying the test pieces, thus preventing its slipping through the bar. A lever arm is attached to the end of the bar which holds the test pieces. The other end of this lever arm carries a bucket, the mass of which can be adjusted with lead shot. A vernier spring balance is attached to the lever arm for final adjustment of the load. Upper and lower stops are provided to prevent rotation of the lever arm. A dash-pot is connected to the lever arm between the spring balance and the bucket to prevent excessive vibration of the end of the arm.

The abrasive surface shall be continuously cleaned by means of air jets (using an air line pressure of not less than 180 kPa), the air being filtered to remove oil, water and dirt; three jets, each of 1.0 mm diameter spaced at 6 mm pitch radially, shall be provided at the top and three at the bottom of the annular surface, so arranged as to leave 6 mm space between jets and abrasive.

NOTE 2 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. The disc shall be rotated within the speed range 34 r/min to 40 r/min, to an accuracy of ± 1 r/min. The corresponding slip velocity at the surface of the rubber is between 190 mm/s and 310 mm/s.

The mass at the end of the cable shall be 3.62 kg. This gives a test piece to abrasive contact pressure of 45 kPa.

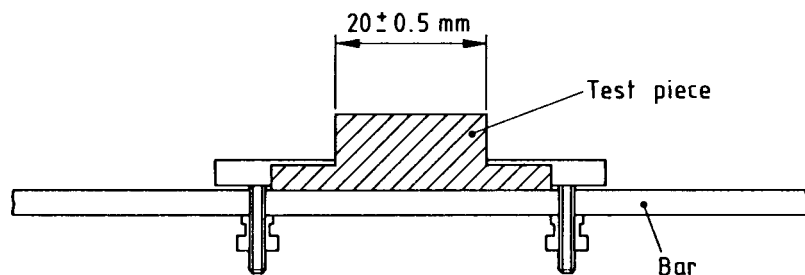
9.2.2 Abrasive discs, consisting of silicon carbide cloth of J weight, grade P180 complying with BS 871. Discs of the correct dimensions shall be cut from flat sheet.

The useful life of one abrasive disc is about 6 h, 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 the time during approximately the first hour of use as a disc).

The disc shall be discarded when the mass loss from the standard rubber S2 has fallen systematically to below 75 % of the loss determined at the first measuring after the 1 h running in period of the disc.

NOTE It is not recommended that the test should be performed in relative humidities greater than 90 %, to avoid excessive shortening of the life of the abrasive cloth.

9.2.3 Balance, of sufficient accuracy to enable the mass loss of a test piece to be determined to ± 1 mg.



Dimension is in millimetres.

Figure 4 — Test piece for abrasion machine for method C

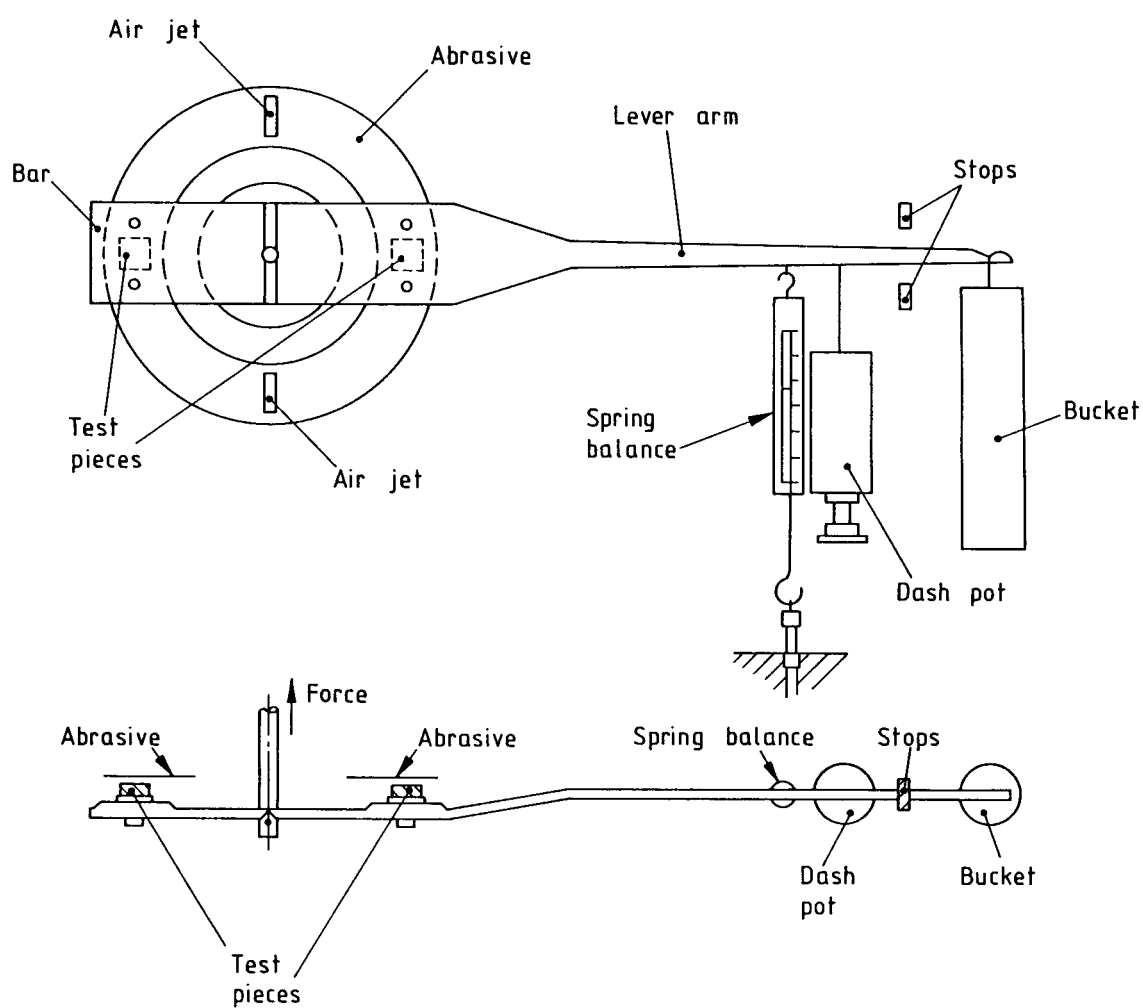


Figure 5 — Abrasion machine for method C

9.3 Procedure

9.3.1 General test procedure

9.3.1.1 The procedure consists of a running-in period, a trial run, and two test runs for each pair of test pieces.

Weigh and run-in a pair of test pieces, using the procedure given in **9.3.1.2**, for the minimum possible time consistent with producing evenly abraded test piece surfaces and an even seating of the test pieces against the abrasive surface.

After the running-in period reweigh the test pieces, remount them and conduct a trial run using the procedure given in **9.3.1.2** of either 1.5 min duration or 50 revolutions of the disc. Reweigh the test pieces.

Conduct the test run using the procedure given in **9.3.1.2** for the appropriate length of time or appropriate number of revolutions as indicated in Table 3. Discard any test piece after 3 mm of thickness has been abraded away. Repeat the procedure on two further pairs of test pieces for each test rubber, omitting the trial run.

Table 3 — Test run times and revolutions

Mass loss in trial run	Test run	
	Time	Number of revolutions
mg	min	
Not above 50	12	400
Above 50, not above 150	6	200
Above 150, not above 250	3	100
Above 250	1.5	50

NOTE The above procedure is required to ensure that the mass loss sustained is approximately the same for all rubbers tested. There is some evidence of a systematic effect on the mass loss of the amount of test piece projecting from the clamp bar.

To compensate for the gradual change in cutting power of an abrasive disc, when testing several rubbers together for comparison, make the two test runs for each rubber in reverse order. Thus for four rubbers, including the standard rubber, test runs are made as follows:

1st test A₁ B₁ C₁ D₁ A₂ B₂ C₂ D₂ A₃ B₃ C₃ D₃
run:

2nd test D₃ C₃ B₃ A₃ D₂ C₂ B₂ A₂ D₁ C₁ B₁ A₁
run:

where the suffixes indicate the three pairs of test pieces.

9.3.1.2 Weigh the two test pieces and insert them into the test piece holders in the horizontal bar. If the run is a test run, ensure the test pieces are replaced in the holder in exactly the same way as for the trial run. Do not distort the surface to be abraded when tightening the clamps. Place the bar in position against the abrasive disc with its axis rod extending through the hollow shaft. Attach the weight to the end of the cable and set the cable over the pulley, thus holding the test pieces evenly and firmly against the abrasive disc.

Attach the balance weight (bucket) to the end of the lever arm and connect the spring balance and dash-pot, the total mass of the bucket and shot being 500 g. Run the machine and during the first minute adjust the tension in the spring balance so that the lever arm oscillates about the mid-point between its two stops. After the appropriate run duration given in Table 3, stop the machine, remove the test pieces, and reweigh.

9.3.2 Comparison with standard rubber. Follow the procedure described in **9.3.1** using test pieces prepared from the appropriate standard rubber (see Table 1).

9.3.3 Density. Determine the densities of the material and standard rubber by the procedure described in BS 903-A1.

9.4 Calculation and expression of results

9.4.1 Mass loss. Sum the total mass loss of all the six test pieces used in the three pairs run, w .

Sum also the number of revolutions made in the three test runs, N .

Calculate the average mass loss for 1 000 revolutions W , assuming a uniform rate of abrasion, from the equation:

$$W = \frac{1000w}{2N}$$

9.4.2 Calculation of abrasion resistance index. Calculate the abrasion loss, as the loss of volume of the test pieces due to abrasion, from the density and mass loss as determined in **9.3.3** and **9.4.1** respectively.

Calculate the abrasion resistance index ARI from the equation:

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

where

V_t is the volume loss (in mm³) of the test rubber;

V_s is the volume loss (in mm^3) of the standard rubber determined under the same test conditions.

9.5 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) A reference to this British Standard, i.e. method C of BS 903-A9:1988.
- c) Test details:
 - 1) temperature of test, if other than 23 ± 2 °C;
 - 2) type of standard rubber used;
 - 3) any non-standard procedures used.
- d) Test results:
 - 1) abrasion resistance index;
 - 2) absolute values of abrasion loss;
 - 3) density.
- e) Date of test.

10 Method D

10.1 Test piece

10.1.1 Type and preparation. The test piece shall be a disc of outer diameter $100 \begin{smallmatrix} +5 \\ 0 \end{smallmatrix}$ mm with a central hole of diameter 6.4 mm and a minimum thickness of 2.0 mm. It shall be of uniform thickness value between 2 mm and 10 mm.

Prepare test pieces by moulding or by cutting from sheet of the correct thickness as described in BS 903-A36.

10.1.2 Number. Three test pieces are required.

10.2 Apparatus and materials

10.2.1 Abrasion machine¹⁾, rotary platform double head type (see Figure 6), consisting of a housing of compact design, a flat circular specimen table, a pair of pivoted arms to which abrasive wheels are attached, a motor for rotating the table in the plane of its surface, a counter for indicating the revolutions of the specimen table and a vacuum attachment for removing debris.

The abrasive wheels, which are attached to the free end of the pivoted arms, are free to rotate and have, when resting on the test piece, a peripheral engagement with the surface of the test piece, the direction of travel of the periphery of the wheels and of the test piece at the contacting portions being at acute angles, and the angle of travel of one wheel periphery being opposite to that of the other. Motion of the abrasive wheels, in opposite directions, is provided by the friction between them and the rotating test piece. The position of the abrasive wheels relative to the centre of the specimen table is shown in Figure 7.

The test piece is clamped to the table by means of a central threaded rod with nut and washer. The vertical distance from the centre of the pivot point of the abraser arms to the top surface of the specimen table is approximately 25 mm.

The speed of rotation of the platform shall be 60 ± 2 r/min. This corresponds to a slip velocity of 45 mm/s.

NOTE 1 This angular velocity of the platform is based on an electrical supply of 240 V 50 Hz.

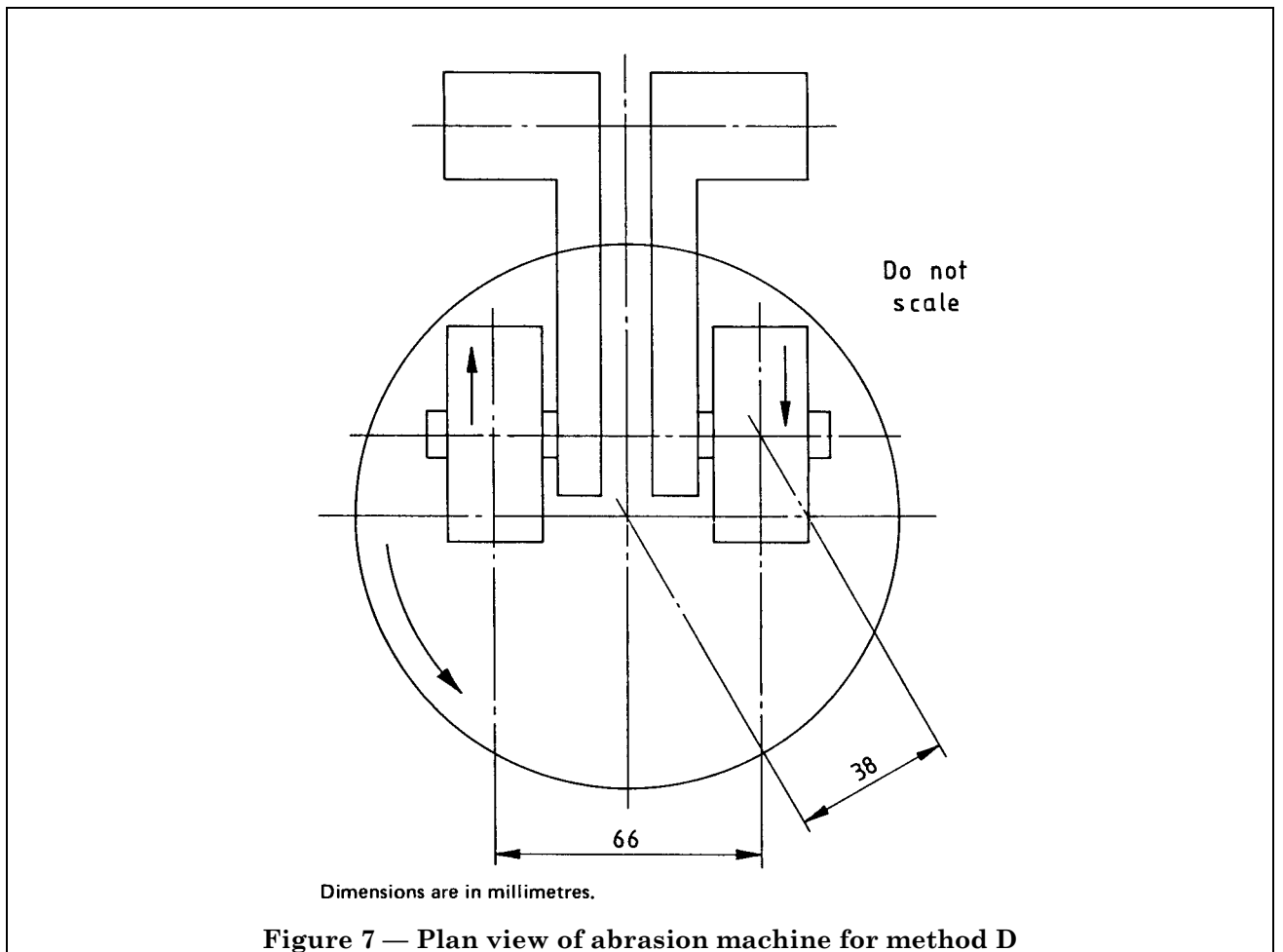
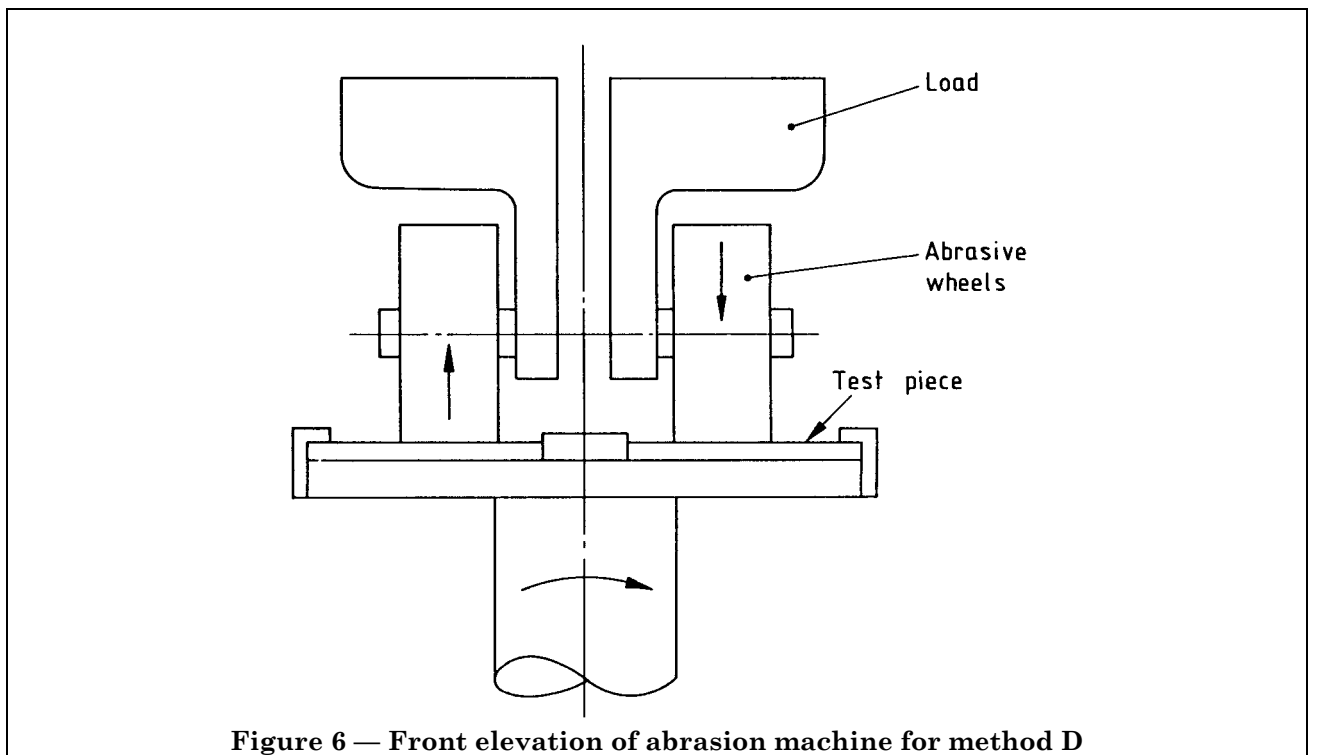
The abrasion machine shall be provided with a mass adjustment for varying the contact pressure between the abrasive wheels and the test piece.

NOTE 2 The pivoted arms without auxiliary masses or counter masses should be designed to apply a force against the test piece of 2.5 N per wheel. Additional masses should increase the force to 5.0 N and to 10.0 N. A counter mass attachment may be added to permit a reduction of force against the test piece to 1.25 N per wheel. The preferred force is 10.0 N.

10.2.2 Abrasive surfaces, in which the quality and grit size of the abrasive particles, and the type of binder can be altered, e.g. abrasive wheels. For general purpose testing a non-resilient vitrified type with medium abrasive properties is recommended. Abrasive wheels of designation A36-P5-V complying with BS 4481-1 are suitable. Alternatively, abrasive paper wrapped around the circumference of a suitable plain solid wheel may be used. When using either wheels or paper, any systematic change in the mass loss of the standard rubbers over a period of time should be noted and in instances where a significant departure from normal occurs it is recommended that wheels be redressed or replaced, and paper replaced.

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

¹⁾ For information on the availability of suitable apparatus, apply to Enquiry Section, BSI, Linford Wood, Milton Keynes MK14 6 LE, enclosing a stamped addressed envelope for reply.



10.3 Procedure

10.3.1 General procedure. Before testing each new material lightly reface the wheels with a diamond tool.

Weigh each test piece and mount it on the specimen table. Lower the abrasive wheels on to the test piece and adjust the vacuum extraction head to be just clear of the test piece surface. Run the abrasion machine either

- a) for 1 000 revolutions of the specimen table after which the test piece shall be removed, loose particles carefully brushed away and the test piece reweighed; or
- b) for a series of measurements each of 1 000 revolutions and a graph of mass loss against number of revolutions prepared.

NOTE 1 Procedure b) is preferred if test runs in excess of 1 000 revolutions are required and will show any departure from a linear relationship between mass loss and number of revolutions.

NOTE 2 The test severity can be varied to suit the type of product being tested. If very little abrasion occurs, consideration should be given to increasing the severity of the test conditions either by increasing the contact pressure or by changing the grade of the abrasive surface. Similar considerations apply to excessive abrasion, except that the contact pressure would be reduced in this instance. As a general guide, the test severity should be reduced if the mass loss per 1 000 revolutions exceeds 2 g for the standard rubber used for comparison. A change in test severity should also be considered should smearing of the test piece or abrasive surface occur.

NOTE 3 A change in test conditions can affect the relative performance of one rubber to another.

10.3.2 Comparison against standard rubber. Follow the procedure described in **10.3.1** using a test piece prepared from the appropriate standard rubber (see Table 1), both before and after each test series.

10.3.3 Density. Determine the densities of the test material and standard rubber by the procedures specified in BS 903-A1.

10.4 Calculation and expression of results

10.4.1 Mass loss. The mass loss for the determination of the abrasion resistance index shall be the mean of the three individual mass losses for 1 000 revolutions.

If procedure b) of **10.3.1** has been used, the mass loss for 1 000 revolutions shall be taken from the graph if the plot of mass loss against number of revolutions is linear. If non-linearity is found this shall be reported together with individual mass losses for all test runs.

NOTE A convenient measure of non-linearity suitable for reporting purposes is the ratio of mass loss between the first test run and a specified additional test run.

10.4.2 Calculation of abrasion resistance index.

Calculate the abrasion loss, as the loss of volume of the test piece due to abrasion, from the density and mass loss as determined in **10.3.3** and **10.4.1** respectively.

Calculate the abrasion resistance index ARI from the equation:

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

where

V_t is the volume loss (in mm³) of the test rubber;

V_s is the volume loss (in mm³) of the standard rubber determined under the same test conditions.

10.5 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) A reference to this British Standard, i.e. method D of BS 903-A9:1988.
- c) Test details:
 - 1) temperature of test, if other than 23 ± 2 °C;
 - 2) grade of abrasive wheel used;
 - 3) contact force used;
 - 4) type of standard rubber used;
 - 5) any non-standard procedures used.
- d) Test results:
 - 1) abrasion resistance index;
 - 2) absolute values of abrasion loss;
 - 3) density.
- e) Date of test.

Appendix A Comparison of methods

A comparison of the methods described in this standard is given in Table 4.

Table 4 — Comparison of methods

Method	A	B	C	D
Type of abrasion Abrasive	Continuous Aluminium oxide paper	Discontinuous Abrasive wheel	Continuous Silicon carbide paper	Discontinuous Abrasive wheels
Test piece shape	Cylinder	Disc	Sheet	Sheet
Test piece thickness, mm	6 (min.)	12.5 ^{+0.5} ₀	Approximately 10	2.0 (min.)
Force, N	10 ^a	45	18	1.25 to 10.0
Nominal loaded area, mm ²	200	Approximately 150	400	Approximately 150
Nominal contact pressure, kpa	50	300	45	Not applicable
Slip velocity, mm/s	314	210 to 350	190 to 310	45
Means of removing debris	Suction or brush	Dust or brush	Air jets	Suction

^a May be reduced to 5 N. See note 2 to 7.2.1.

Appendix B Standard rubbers for method A

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.

B.1.2 to **B.1.4** and **B.2.2** to **B.2.4** describe the procedures for mixing, vulcanization and storage. **B.1.5** and **B.2.5** describe tests for assessing the quality of the prepared material. The standard rubber described in **B.1** is used for the calibration of the abrasive cloth (see 7.2.2) and for the calculation of the relative volume loss, Δv (see 7.4.2). The standard rubber described in **B.2** is required to be used for the determination of the abrasion resistance index (see 7.4.3).

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

B.1.1 Formulation

See Table 1, standard rubber S1.

B.1.2 Mixing

Masticate the natural rubber to a Mooney viscosity, ML (1 + 4) at 100 °C, of 80 ± 5, using a mixing mill which complies with BS 1674. Then prepare the mix in an internal mixer according to the following schedule. Cool the internal mixer to maintain the temperature at 50 ± 5 °C.

Stage of preparation	Time min
Add the rubber	0
Add the accelerator, antioxidant and zinc oxide	5
Add the carbon black and sulphur	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 that 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 insert an unvulcanized piece of mix which has been preheated for 20 min at a temperature of 70 °C. An excess of approximately 10 % is recommended. Vulcanize in a closed press at a temperature of 150 ± 2 °C for 30 ± 1 min, using a moulding pressure of 3.5 MPa.

Sheets measuring approximately 180 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 Assessment of quality

Assess the quality of each batch of the prepared rubber as follows.

Determine the abrasion resistance of a test piece taken from a corner of a sheet from the batch using a stationary test piece (see clause 7) and an abrasive cloth prepared as described in Appendix C. Compare this mass loss with the mean mass loss of a "reference sheet"²⁾ in immediate consecutive tests. Reject the batch if the differences between the mass losses exceed 8 mg.

Measure the mass losses of six test pieces taken from an intended reference sheet. Take one test piece from each corner of the sheet and two from the middle. Carry out similar tests on a reference sheet²⁾. Reject the sheet if the results for the test sheet differ by more than 10 mg and the mean value differs by more than 5 mg from the mean value of the six tests on the "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

B.2.1 Formulation

See Table 1, standard rubber S2.

B.2.2 Mixing and vulcanization

Prepare, mix and vulcanize the rubber using the equipment and procedures described in BS 1674. An internal mixer may be used instead of the mixing mill specified in BS 1674. Vulcanize the sheets at a temperature of 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 Assessment of quality

Determine the mass losses for two different batches of the prepared standard rubber in accordance with clause 8. Reject the batches if the mass losses do not agree within $\pm 10\%$.

NOTE It has been found that the standard rubber gives an abrasion loss of about 150 mg when tested in accordance with 7.3, using a rotating test piece.

Appendix C Details on a suitable abrasive cloth for method A

A suitable abrasive cloth is produced commercially.²⁾ It comprises corundum (i.e. Al_2O_3) 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 a mass loss due to abrasion of more than 300 mg when the standard rubber S1 is tested using a fixed test piece. It is necessary to perform one or two runs with a steel test piece to reduce the mass loss due to abrasion to about 210 mg to 220 mg. Experience has shown that a minimum of a few hundred runs can be carried out with this type of cloth.

²⁾ For information on the availability of reference sheets, apply to Enquiries Section, BSI, Linford Wood, Milton Keynes MK14 6LE, enclosing a stamped addressed envelope for reply.

Publications referred to

BS 871, *Specification for abrasive papers and cloths.*

BS 903, *Methods of testing vulcanized rubber.*

BS 903-A1, *Determination of density.*

BS 903-A36, *Preparation of test pieces.*

BS 1674, *Specification for equipment and general procedure for mixing and vulcanizing rubber test mixes.*

BS 4398, *Compounding ingredients for rubber test mixes.*

BS 4481, *Bonded abrasive products.*

BS 4481-1, *Specification for general features of types of abrasive wheels, blocks, honing stones, segments and profiles.*

ISO 1382, *Rubber — Vocabulary.*

ISO 4649, *Rubber — Determination of abrasion resistance using a rotating cylindrical drum device.*

ISO 5470, *Rubber or plastics coated fabrics — Determination of abrasion resistance³⁾.*

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

³⁾ Referred to in the foreword only.

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