BRITISH STANDARD

BS 903 :
Part 1 : 1995

Physical testing of rubber

Part 1. Guide to the selection and use of methods of test for rubber

STANDARDS

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee PRI/22, Physical testing of rubber, upon which the following bodies were represented:

BP Chemicals Limited
British Railways Board
British Rubber Manufacturers' Association Ltd.
GAMBICA (BEAMA Ltd.)
Institution of Mechanical Engineers
Malaysian Rubber Producers' Research Association
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RAPRA Technology Ltd.
SATRA Footwear Technology Centre

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Foreword

This Part of BS 903 has been prepared by Technical Committee PRI/22.

In preparing the guide, the aim has been to draw together in a coherent form the various British Standards relevant to the design of rubber compounds, components and products, the laboratory estimation of service performance and the use of standard methods for quality control and quality assurance purposes.

In addition, it is hoped that this guide will assist in the preparation of specifications and help to minimize the unnecessary variation in requirements through the adoption of preferred property gradations. For this purpose a technically equivalent version of ISO 1433 has been incorporated as annex A.

It was orginally intended to limit the scope of the guide to the selection and use of methods of test in the BS 903 : Part A series, but because of the need to consider such subjects as component design, quality assurance and the testing of thermoplastic rubbers, it became necessary to make reference to additional sources of information outside the scope of BS 903, for example BS 6716, and to some test methods from other industries, for example BS 2782 for plastics, considered suitable for rubbers.

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

Guide

Introduction

Methods of test describe equipment and procedures for measuring, with varying degrees of accuracy and precision, a physical or chemical property of a material or product. They do not predetermine the limits of the physical or chemical property being investigated, except to the extent of the degree of resolution of the method of test itself.

A particular method of test may be designed for process quality control or for verification of specific design parameters. It may also be used as a pre-production design tool. Usually, because of the type of data which is obtained from the method of test, the results can be analysed statistically, but the results from some methods merely provide a pass/fail criteria, which is not always amenable to simple statistical analysis (see BS 5324).

It is also important to recognize other limitations of test methods. For example, they are often used for purposes for which they were not intended. This can arise because of a failure to draw a clear distinction between tests, even test conditions, intended for quality control purposes and those chosen to provide information relevant to the design or performance of the application. A test may also be specified in the mistaken belief it will give the same information as another but in, say, a much shorter time and without the need for more elaborate apparatus.

The results obtained from test methods tend to become regarded, erroneously, as properties of the material or product rather than a limited assessment of that property. This is exemplified by the misguided assumption made about the performance of a product, based on the required test result of a median or mean value, when a simple statistical estimate of the confidence intervals of the mean of the population might indicate that the true mean could be much lower, or higher, than the estimate given by the method of test. It is then necessary to assess the risks associated with failure caused by such a potentially mistaken assumption, before committing oneself to either acceptance or rejection or changes in design.

Changes or variations in one property may have effects on others and in assessing service performance there is a need to obtain multi-point measurements of the material or product characteristics.

If, therefore, the BS 903 series and associated standards are to continue to serve the industry, it is essential that the users of the test methods recognize these unavoidable limitations. It is equally important that product designers make their needs known, especially where data are required about a parameter for which there is no test available.

Since it was first introduced in 1940, BS 903 has become one of the best-known series of standards in the rubber industry both in the United Kingdom and abroad, finding extensive use in process control, material characterization and British Standard specifications. Many of the original parts of BS 903 were the basis for international standardization of test methods. However, few of the standards offer guidance on the selection of methods, procedures and test conditions where a choice exists.

It is hoped that this guide will draw together and inter-relate the various Parts of BS 903 and associated standard laboratory test methods, as well as highlighting the merits and shortcomings of small-scale tests generally. It is also hoped that the guide will provide what is perceived as essential assistance in the interpretation of test results in terms of precision and statistical variation (in conjunction with BS 5324) and in the intended usage of the test methods.

To facilitate its use, this British Standard contains some repetition and variation in presentation of the same information, especially with regard to the applications of test methods and selection of test pieces. Guidance is given in tabular form as far as possible.

The guide is intended to complement, not to replace, information published in books on rubber testing and related subjects. Attention is drawn to the publications listed in annex B.

1 Scope

This Part of BS 903 provides guidance to designers, manufacturers and users of rubber products and components, on the selection and use of appropriate standard laboratory methods of test, for the design, performance, quality control and quality assurance of rubber products and for the evaluation and specification of rubber materials. It applies to solid rubber in raw, compounded or fabricated form, test pieces prepared from solid rubber products and solid test samples prepared from latex or liquid rubber. It does not apply to coated fabrics, ebonite, and cellular rubber, although a number of the tests described are applied to expanded and sponge rubbers. This Part of BS 903 is not concerned with the needs of particular end uses or polymers, except by way of examples in the text.

NOTE. The international equivalents (where they exist) of the publications referred to in this Part are listed in annex C.

2 References

2.1 Normative references

This Part of BS 903 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this Part of BS 903 only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This Part of BS 903 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this Part of BS 903 the definitions given in BS 3558 : 1980 and in individual parts of BS 903 apply.

Symbols for types of rubber are taken from BS 3502 : Part 2 : 1991.

4 General information for test laboratories

4.1 General

It is recommended that testing is undertaken in a laboratory conforming to BS 7501.

Particular attention should be paid to the following:

- the laboratory environment (see **4.2**);
- the calibration and maintenance of testing equipment (see **4.3**);
- the level of training of staff;
- the storage and handling of samples and test pieces (see **6.3** and **7.4**);
- the use of up-to-date test methods.

4.2 Laboratory environment

The standard laboratory temperature for rubber testing in the United Kingdom is 23 °C ± 2 °C, the same as that in most other temperate countries.

For most physical tests, humidity control need not be specified, but when it is required, for example for electrical testing, the standard laboratory humidity should be 50 % ± 5 % relative humidity at 23 °C ± 2 °C.

As far as possible, tests should not be made in a room which contains apparatus that generates ozone, such as a fluorescent lamp, or which for any other reason has an atmospheric ozone concentration above that in normal indoor air. Periodic checks are advised to ensure the ambient concentration is preferably less than 1 part by volume per 100 million parts (pphm) of air. Ozone attack is a cause of surface cracking in unsaturated rubbers held under, or cycled through, a tensile strain and thus higher than normal concentrations may influence the results of tests for tension fatigue (BS 903 : Part A51), tension set (BS 903 : Part A5) and ageing in tension (BS 903 : Part A52) undertaken at or near ambient temperature.

Care should also be taken to avoid direct sunlight or strong light in order to minimize the risk of photo-oxidation or discoloration.

4.3 Testing equipment

The testing equipment required is specified in individual test methods. It includes, for measurements of force, the testing machines specified in BS 5214 : Parts 1 and 2.

All equipment should be properly maintained and calibrated as appropriate. Any item that has been subjected to overloading or mishandling, or that gives suspect results, should be withdrawn from service for repair and revalidation.

Guidance on calibration of testing equipment is given in BS 5781 : Part 1.

4.4 Health and safety

Attention is drawn to the Health and Safety at Work etc. Act. Particular care should be taken when handling cutters and knives used for the preparation of test pieces (see BS 903 : Part A36).

Protective gloves should be worn when test pieces and equipment are handled at elevated and sub-normal temperatures.

Attention is drawn to the highly toxic nature of ozone (BS 903 : Parts A43 and A44) and some fluids used for swelling measurements (BS 903 : Part A16).

5 Tests available

5.1 General

Many standard laboratory test methods are now available for the measurement of the properties and performance of rubbers in their raw state, during processing and manufacture, and in the finished product. A property guide to existing test methods is given in annex D. The list will continue to grow as new methods are introduced to meet the demands of new materials, manufacturing processes and products, and as further information on the behaviour of rubber, for example during processing, becomes available.

Although tests serve a wide variety of purposes it is important that they should not be treated in isolation. There is need for an interface between test methods and standards concerned with sampling, statistical analysis, quality assurance, preparative and evaluation procedures for rubber, and even existing material specifications. An example of the inter-relationship is depicted in figure 1.

5.2 Types of test

5.2.1 *BS 903 A series*

The title of BS 903 is *Physical testing of rubber* and the A series consists of separately published methods of test for raw, compounded, vulcanized and thermoplastic rubbers, and some adhesion tests for composite materials containing rubbers.

Some Parts of BS 903 have been withdrawn over the years. A7, A20 and A22 have been incorporated in A26 (Determination of hardness). A28 has been incorporated in A14 (Shear modulus and adhesion using quadruple test piece). A34 has been incorporated in A42 (Determination of stress relaxation in compression). A39 has been incorporated in A6 (Determination of compression set). A23 has been superseded by A43 (Determination of static ozone resistance). No test method exists for BS 903 : Part A41.

NOTE. Some Parts of BS 903 remain under the previous title of *Methods of testing vulcanized rubber* but this will be changed when they are revised.

5.2.2 *International standards*

A few ISO test methods have not been adopted as, or used as a basis for, British Standards, because of lack of sufficient interest in the United Kingdom or because a preferred alternative method of test is already given in an existing Part of BS 903. These test methods may have been implemented by other countries and so may feature in some national specifications as well as in certain international specifications. Their suitability for adoption as British Standards is reviewed from time to time.

5.2.3 *Test methods for plastics materials*

Several of the test methods given in BS 2782 and the procedures given in BS 4618 may be suitable for certain rubbers, although intended for plastics materials. Some are particularly appropriate for the testing of thermoplastic rubbers (see clause **16**).

NOTE. The testing of ebonite (or hard rubber) is already provided for in BS 2782.

5.2.4 *Test methods for electrical properties*

Attention is drawn to the BS 903 : C series of test methods and to BS 2044.

5.2.5 *Tests for materials in general*

Several British Standards exist for the measurement of specific properties irrespective of the type of material. Examples are BS 476 (for fire tests on building materials and structures), BS 874 (for measurement of thermal conductivity) and BS 6920 : Parts 1 and 2, (for suitability of non-metallic products for use in contact with potable waters).

5.2.6 *Tests in product specifications*

Specifications for rubber products (see clause **14**) sometimes include BS 903 test methods modified to suit the particular product, as well as other tests designed to measure specific properties not yet covered by BS 903. Some of the latter tests are occasionally found suitable for wider application but it is suggested that they are confined to development work in the absence of an agreed alternative. For general purposes, BS 903 should always be used if an appropriate test exists.

5.3 Guidance

Information on specific properties and the types of rubbers for which BS 903 test methods are intended is given in BS 6716. For information on the application of statistics to rubber testing see BS 5324, and for guidance on preparation of precision statements for test methods see ISO/TR 9272 and BS 5497.

6 Samples for testing

6.1 General

In most BS 903 test methods, the use of specially moulded test sheets, and in some instances moulded test pieces, is preferred, but there is provision for the preparation of test pieces cut from finished products.

Whatever the source, samples for tests should be provided in adequate quantity and should be representative of the material or item being tested. The sampling procedure specified in the relevant material or product specification should be followed. The direction of any grain or any orientation should be clearly identified on test samples.

Sampling and further preparation of raw rubber should be carried out in accordance with BS 6315.

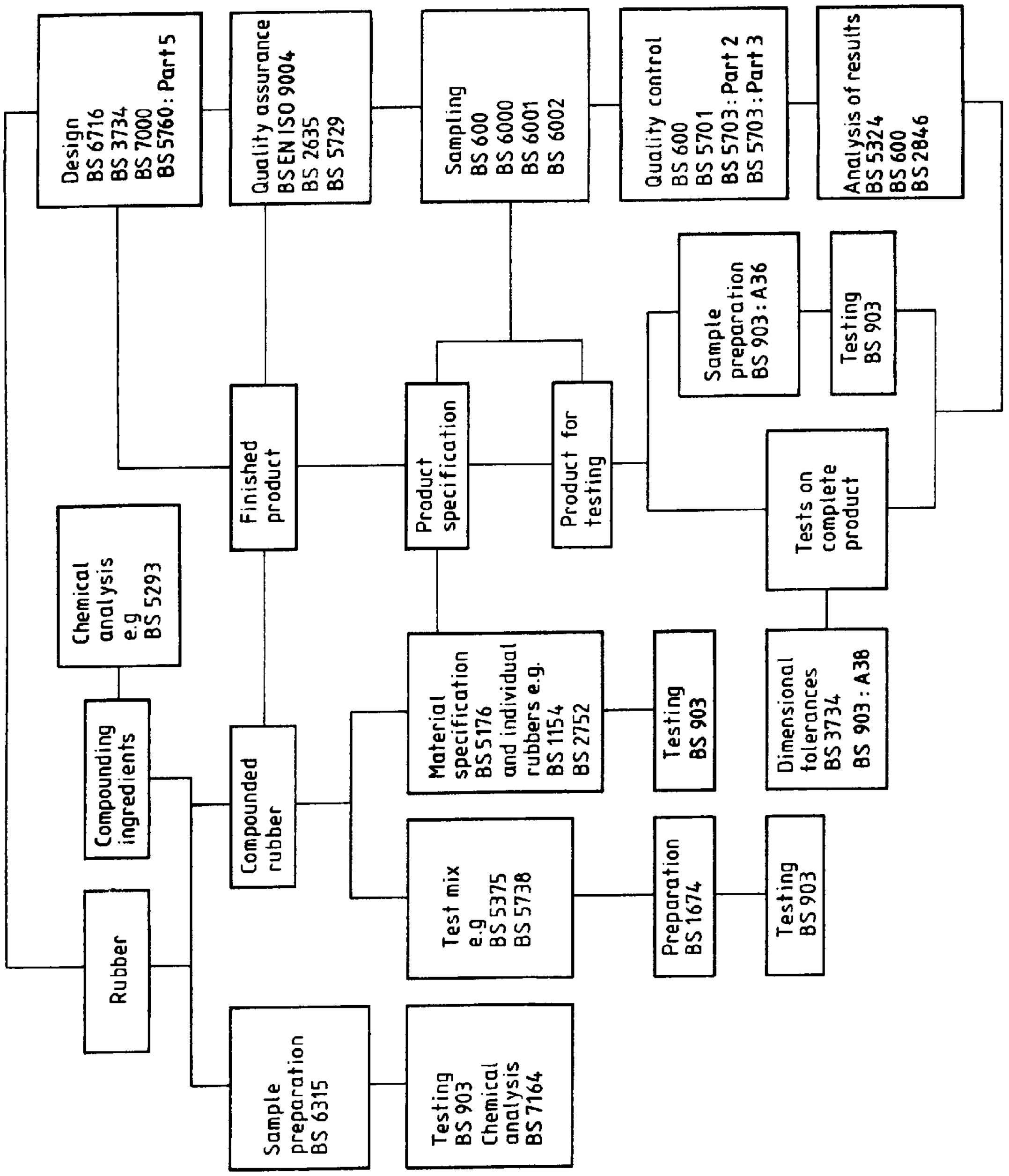

Figure 1. Inter-relationship of methods of test

6.2 Thickness

To assist laboratories when setting up test facilities, including the acquisition of moulds for test sheets and test pieces, table 1 lists the standard thicknesses and thickness ranges for the BS 903 test methods.

As far as possible, thicknesses should be those either specified or preferred in the individual test method, but there may be instances where alternatives are required, for example because of shortages of suitable moulds or because of special features of the material or product being tested. When considering the use of alternative thicknesses, including any permitted in the test method, it should be noted that the results obtained may differ with different thicknesses because of possible differences in the state of cure and the thickness dependence of diffusion-controlled effects such as thermal oxidative ageing, absorption of fluids and surface migration of protective agents for ozone resistance. An increase in thickness introduces a higher risk of non-uniformity in thermal ageing tests, whereas a decrease in thickness reduces the reservoir of anti-degradants (should any be present) and increases the risk of rapid exhaustion of ozone protective waxes during storage before testing.

It should be understood that in many instances the stated test piece thickness of the test method is not compatible with the thickness of a product to which the test method may apply, and it is especially in these cases that moulded test sheets or test pieces are used to give meaningful data about the material. An alternative procedure, confined to a relatively small number of test methods, is to build up the standard test piece thickness from thinner sheet.

Comparisons of results should only be made for tests conducted on the same thicknesses of test sheets and test pieces. If the thickness is achieved by plying together other thicknesses, this should be recorded.

Recommended thicknesses in BS 903 : Part A36 are 1, 2, 4, 6.3 and 12.5 mm because of their applicability to a number of test methods. Especially suitable for general purposes is a two-thickness test sheet of the type described in BS 1674. Part of the sheet should have a thickness of 6.3 mm ± 0.3 mm, and the remainder a thickness of 2.0 mm ± 0.2 mm. If required the thicker part may be replaced by moulded cylindrical discs suitable for use as test pieces without further preparation.

Test sheets of 2.0 mm ± 0.2 mm thickness are also suitable for electrical testing (BS 903 : C series).

6.3 Storage

For specially moulded test sheets and test pieces the minimum time between vulcanization and testing is 16 h; this period is necessary to establish equilibrium because the properties of vulcanized rubber change most rapidly immediately after vulcanization, in the absence of ageing. The maximum time between vulcanization and testing is 4 weeks in order to minimize any contribution of ageing or depletion in level of protective agents. For evaluations intended to be comparable, the tests, as far as possible, should be carried out after the same time interval.

Longer storage times are permitted for products (see clause **14**).

Most BS 903 test methods state that samples should be protected from light, and in a few instances from heat, during storage. These should be regarded as minimum requirements and every effort should be made to protect samples from any potential cause of degradation or damage and any change in storage. It is recommended that the conditions of storage meet the requirements of BS 3574.

In some test methods it is a requirement that samples and, where appropriate, test pieces do not, at any time, come into contact with those of a different composition. This is to prevent ingredients which may affect resistance to various forms of degradation from migrating from one rubber to another, for example from a protected vulcanizate to an unprotected vulcanizate intended as a control.

Samples and test pieces should be handled as little as possible during storage and unnecessary deformation should be avoided.

Samples taken out of store for testing should not be cleaned or otherwise treated unless it is a requirement. Cleaning may remove protective agents present on or near the surface.

It is recommended that raw rubber and unvulcanized compounded rubbers are stored in accordance with BS 6882.

6.4 Pre-test history

Variation in properties from one batch to another or from one laboratory to another can often be traced to differences introduced some time before testing, therefore it is recommended that as full a record as possible is kept of the method of preparation, post-cure treatments, and conditions of storage. The following may be relevant:

a) sources of rubber and ingredients;
b) mixing procedures;
c) method of preparing blanks for moulding;
d) times between mixing, blanking and vulcanization;
e) vulcanization conditions (i.e. time and temperature);
f) moulding method (i.e. whether compression, transfer or injection);
g) after-moulding treatment (e.g. post-cure, quenching);
h) method of packaging;
i) time and conditions of storage;
j) any special treatment (e.g. surface chlorination, dusting, buffing, cutting).

7 Test pieces

7.1 Size and shape

As far as possible, the size and shape of the test piece should be those either specified or preferred in the relevant test method.

The shape of the test piece is determined by the requirements of the test, including achievement of reproducibility and speed of throughput in the event of a high intensity of testing. In the preparation of BS 903 an effort has been made to avoid a proliferation of test piece geometries because of the additional cost of keeping and maintaining more cutters, dies and even test piece grips than are really necessary.

Table 2 lists test pieces that can be used for more than one purpose.

The choice of test piece, and even of test method, where alternatives exist, is also governed by the size and shape of the sample. This is especially relevant to tests undertaken on rubber taken from products (see clause 14).

Comparisons of results should only be made for tests in which the same type of test piece has been used.

7.2 Preparation

Test pieces cut from sheet, slabs or products should be prepared in accordance with the methods described in BS 903 : A36.

7.3 Number of test pieces

The number of test pieces specified in BS 903 test methods is often described as a minimum. Depending on the material or product being tested, this number may not be sufficient to establish reliably the central tendency and the intrinsic variability of the sample. There is a distinction between testing errors and the variability within a product or material. For example, the intrinsic variation in tension fatigue life of SBR, or any other non-strain crystallizing rubber, is known to be significantly higher than that of NR and is as important for design purposes as the median or mean.

Guidance on statistical analysis of results and the significance of test piece population is given in BS 5324.

Sufficient material should be available to allow investigation of any grain or orientation effects where these are known to exist.

In conducting ageing tests over a comparatively long period it may be prudent to increase the number of test pieces, in case of loss or damage during ageing or testing and the possibility of having to discard some test results. Note that the variability of a material may change as a result of ageing or any other treatment.

7.4 Conditioning

7.4.1 *Environmental conditioning*

For tests at 23 °C ± 2 °C, the period for conditioning immediately before testing should be not less than 3 h, and during this period the test piece should be positioned in such a manner that as far as possible the whole rubber surface is exposed (BS 903 : Part A35). If test pieces are cut from conditioned test samples, and provided there is no additional or special treatment, they need not be conditioned for this period and so may be tested straight away.

For tests at sub-normal or elevated temperatures, the time for conditioning needs to be sufficiently long to ensure temperature equilibration. This period is sometimes specified in the test method, but if guidance is required, attention is drawn to BS 903 : Part A32 and to Brown [1].

Some tests require special environmental conditioning. Test pieces which are to be exposed to ozone under a constant tensile strain (see BS 903 : Part A43) are conditioned in the stretched state for a period between 48 h and 96 h in an essentially ozone-free atmosphere in the dark. This procedure is an option for test pieces exposed outdoors (see BS 903 : Part A53).

Test pieces used for some low temperature tests (see annex E) need to be heated for 30 min to 45 min at 70 °C to remove any residual crystallization which may have occurred during storage. The purpose of this decrystallization is to eliminate any memory effect (e.g. crystallinity within built-in stresses) which might lead to variations in results.

7.4.2 *Mechanical conditioning*

For some tests it is recommended that test pieces are mechanically conditioned before testing.

NOTE. This process of mechanical conditioning is often referred to as scragging.

The procedure involves cycling of the test pieces through a number of deformations, typically five, for the purposes of:

a) improving test reproducibility through the removal of any differences in strain history; and

b) reflecting the behaviour of some products in service.

The effect of mechanical conditioning is most evident in filler-reinforced rubber where it causes a partial breakdown in filler structure and leads, for example, to a reduced modulus or a reduced creep rate. Changes can also be observed in lightly filled rubbers.

The time between mechanical conditioning and testing should be specified because some recovery of filler structure can occur and thus influence the test result.

8 Applications of the BS 903 test methods

8.1 General

The test methods in the BS 903 series are used for a variety of purposes; the principal ones being:

a) an estimation of performance, for example, aspects of processability (see clause **9**) and durability (see clause **11**);

b) generation of data suitable for product design (see clause **10**);

c) material characterization, compound development and evaluation of compounding ingredients (see clause **12**);

d) specification of materials and products (see clause **13**);

e) the testing of finished products (see clause **14**);

f) quality control (see clause **15**).

Several test methods are also used to assist product failure diagnosis (see examples in **8.2**).

8.2 Uses of specific test methods

NOTE 1. The following list is not intended to be an exhaustive one, nor is it intended to imply any order of preference in the use of test methods. It simply reflects current practices and applications of tests reflected in material and product specifications, other test methods, technical literature and product manufacture.

Particular end-uses are mentioned only by way of example.

NOTE 2. Brief descriptions are used, full titles are given in the list of publications on the inside back cover.

For more detailed information on the processability tests in BS 903 : Parts A58, A59 and A60, see clause **9**.

8.2.1 *BS 903 : Part A1 (Density)*

This method is used as:

a) a control measure for polymer content and bulk ingredients (although it should not be used alone for this purpose);

b) a measure of cellular expansion and porosity, with the advantage of requiring only small test piece size, suited to, say, O-rings;

c) a means of converting mass changes into volume changes in combination with BS 903 : Part A9 (abrasion resistance) and BS 903 : Part A16 (resistance to liquids).

8.2.2 *BS 903 : Part A2 (Tensile stress-strain properties)*

This method is used as:

a) a control measure for ingredient dispersion, state of cure and freedom from adulterants;

b) a measure of filler reinforcement;

c) a measure of grain effects and anisotropy, say of fibrous fillers;

d) a means of assessing and specifying the effects of accelerated ageing (BS 903 : Part A19), with tensile strength retention often favoured for NR and other rubbers undergoing chain scission, and elongation at break favoured for SBR and rubbers undergoing oxidative crosslinking (hardening);

e) a means of measuring resistance to liquids (with BS 903 : Part A16) and weathering (with BS 903 : Parts A53, A54 and A55);

f) a means of setting a quality level in a material specification, for characterizing rubbers and for undertaking quality control.

8.2.3 *BS 903 : Part A3 (Tear strength)*

This method is used as:

a) a measure of filler reinforcement;

b) a measure of the effect of state of cure on tendency to tear, a property often adversely affected by overcure and post cure;

c) a measure of anisotropy and grain effects, e.g. in calendered sheet;

d) a means to characterize high strength silicone rubbers;

e) a measure of part of the fundamental dependence of crack growth rate on tearing energy when Method A (Trouser test piece) is used.

8.2.4 *BS 903 : Part A4 (Compression stress-strain characteristics)*

This method is used as:

a) a design tool measuring compression modulus under lubricated or bonded conditions and, for products, compression stiffness, with provision for assessing the effect of shape factor in bonded components;

b) a means of estimating Young's modulus;

c) a control measure for porosity in some products.

8.2.5 *BS 903 : Part A5 (Tension set)*

This method can be used as:

a) a measure of the state of cure, and is suitable for the quality control of thin products, such as sheeting and latex films;

b) a means of providing relevant information to some products used in tension.

8.2.6 *BS 903 : Part A6 (Compression set)*

This method is:

a) a control measure for state of cure;

b) used to evaluate vulcanizing systems, because of the dependence of compression set on crosslink stability at elevated temperatures;

c) used to measure the increase in hysteresis at temperatures approaching the glass transition temperature;

d) a strain-accelerated measure of low-temperature crystallization resistance of rubbers such as NR and CR;

e) used for sealing applications where recovery of shape after distortion or release of pressure is needed to prevent leakages;

f) widely used in material and product specifications.

8.2.7 *BS 903 : Part A8 (Rebound resilience)*

This method is:

a) a rapid, easy-to-understand, measure of elasticity and hysteresis, although it is generally less informative than the dynamic tests described in BS 903 : Part A24;

b) used as a guide to energy absorption on impact;

c) a measure of the state of cure;

d) used to provide information relevant to some sports applications of rubber (i.e. coefficient of restitution).

8.2.8 *BS 903 : Part A9 (Abrasion resistance)*

This method may be used to:

a) provide comparative data for evaluation of materials, e.g. reinforcing fillers;

b) provide information relevant to a wide range of applications of products and components which undergo abrasive wear, e.g. footwear, belting and sports surfaces, although correlation with actual wear experience varies from product to product.

8.2.9 *BS 903 : Part A10 (De Mattia flex cracking)*

This method is commonly used for comparative testing and evaluation of rubbers and ingredients, e.g. anti-flex cracking agents, although the results are less informative than the tension fatigue tests described in BS 903 : Part A51.

8.2.10 *BS 903 : Part A11 (De Mattia crack growth)*

This method is used to assess crack propagation, whereas Parts A10 and A51 relate to crack initiation. It is also used for comparative testing and evaluation of rubbers and ingredients.

8.2.11 *BS 903 : Part A12 (Ply adhesion to fabric)*

This method is used as:

a) a control measure for fabric-reinforced products such as belting, hose and textile-reinforced sheeting;

b) a means of evaluating bonding agents and promotors.

8.2.12 *BS 903 : Part A13 (Low temperature stiffness)*

This method is used as:

a) a measure of change in torsional modulus at low temperatures and to determine the minimum temperature at which the component will remain serviceable;

b) a means of evaluating plasticizers added to depress the glass transition temperature (T_g) of rubbers;

c) a measure of low temperature resistance, often used in material specifications, especially for rubbers having a comparatively high T_g.

8.2.13 *BS 903 : Part A14 (Shear modulus and adhesion using quadruple test piece)*

This method is used as:

a) a design tool, measuring the shear modulus under static conditions in order to provide data on the force/deflection characteristics of rubber springs, such as shear mountings and structural bearings;

b) a means of estimating Young's modulus;

c) a measure of rubber-to-metal and rubber-to-reinforcement layer strength in shear, suitable for both design and control purposes;

d) a means of evaluating bonding agents and cements.

8.2.14 *BS 903 : Part A15 (Creep)*

This method is used as:

a) a design tool relevant to products operating under a static load, e.g. structural bearings, mountings and suspensions;

b) a measure of state of cure.

8.2.15 *BS 903 : Part A16 (Resistance to liquids)*

This method is used:

a) as a classification criterion for oil and non-oil resistant rubbers (as, for example, in BS 5176);

b) to evaluate oil-resistant rubbers;

c) to assess and specify compatibility of rubber with service liquids;

d) as a measure of swelling and chemical resistance;

e) as a control measure for polymer and state of cure and is especially useful for small components, e.g. O-rings;

f) to estimate crosslink density in vulcanized rubber, if appropriate solvents and conditions are specified;

g) as a diagnostic tool to assist polymer identification.

8.2.16 ***BS 903 : Part A17 (Permeability to gases: constant volume method)***

This method is used:

a) to measure the permeability coefficient of any rubber and gas combination;

b) to provide information relevant to thin walled products such as diaphragms, inner tubes, balloons and other gas containers, often associated with the use of butyl, halobutyl and nitrile rubbers.

8.2.17 ***BS 903 : Part A18 (Equilibrium water vapour absorption)***

This method is used to measure water absorption using very small samples that permit equilibrium to be achieved quickly.

8.2.18 ***BS 903 : Part A19 (Heat resistance and accelerated ageing tests)***

This method is:

a) a control measure for composition, state of cure and antioxidant protection, usually in combination with BS 903 : Part A2;

b) a classification criterion for heat resistance of rubbers (as, for example, in BS 5176);

c) the principal means of assessing rubbers intended for high temperature applications;

d) the principal means of estimating long term resistance to ageing at normal temperatures from accelerated tests undertaken at elevated temperatures;

e) used to evaluate antidegradants and vulcanizing systems;

f) widely used in material and product specifications.

8.2.19 ***BS 903 : Part A21 (Rubber to metal bond strength)***

This method is:

a) a control measure for the quality of bonding;

b) used to evaluate bonding agents and cements, to measure the effect of compounding on adhesion strength and establish bonding procedures;

c) adaptable to suit finished products.

8.2.20 ***BS 903 : Part A24 (Dynamic properties)***

This Part of BS 903:

a) establishes principles for the determination of the dynamic moduli and damping properties of rubber in various modes of deformation over a range of temperatures and frequencies and using both free and forced vibration methods;

b) is used for material characterization, the generation of design data and the prediction of the performance of rubbers intended for vibration isolation and shock absorption applications.

8.2.21 ***BS 903 : Part A25 (Brittleness temperature)***

This method provides:

a) a classification criterion for low temperature resistance of rubbers (as in ISO 4632/1);

b) a measure of impact resistance of rubber in the vicinity of the glass transition temperatures and may be so used to determine the minimum serviceable temperatures;

c) a means to evaluate plasticizers added to depress the glass transition temperature of rubbers.

8.2.22 ***BS 903 : Part A26 (Hardness)***

This method is:

a) used as a classification criterion for rubbers varying in stiffness (as, for example, in BS 5176);

b) widely used as a control measure for state of cure and ageing resistance;

c) used to measure stiffness change after accelerated ageing (BS 903 : Part A19), or after exposure to liquids (BS 903 : Part A16) or weathering (BS 903 : Parts A53, A54 and A55);

d) useful as a means of estimating the elastic modulus and can be undertaken on very small samples, especially with the use of the micro test;

e) a non-destructive test applicable to finished products as well as test pieces;

f) a diagnostic tool assisting identification of cause of surface changes.

It is widely used in material and product specifications.

8.2.23 ***BS 903 : Part A27 (Rubber to fabric adhesion: tension method)***

This method is used to measure the adhesion strength of materials having a very thin rubber coating which is difficult to test by the stripping or peeling method of BS 903 : Part A12, (but see also BS 3424 : Part 7).

8.2.24 ***BS 903 : Part A29 (Low temperature characteristics by temperature-retraction)***

This method is used:

a) as a measure of recovery from deformation at low temperatures;

b) to evaluate plasticizers added to depress the glass transition temperature of rubbers;

c) as a measure of crystallization resistance when exposure times are extended.

8.2.25 ***BS 903 : Part A30***
(Permeability to gases: constant pressure method)

This method is used:

a) to measure the permeability coefficient of any combination of rubber and gas;

b) to provide information relevant to products such as diaphragms, inner tubes, balloons and other gas containers, often associated with the use of butyl, halobutyl and nitrile rubbers.

8.2.26 ***BS 903 : Part 31***
(Low-frequency dynamic properties)

This method is:

a) used to determine the dynamic shear modulus and damping of rubber in free torsional vibration in the frequency range 0.1 Hz to 10 Hz;

b) suitable for rubber from sheets or thin products, as it uses 1 mm to 3 mm thick test pieces.

8.2.27 ***BS 903 : Part A32 (Directions for achieving elevated or sub-normal temperatures)***

This Part of BS 903:

a) specifies the requirements for the construction and operation of temperature-controlled chambers for the conditioning and/or testing of rubber;

b) is used to achieve the uniformity and equilibrium of both high and low temperatures for testing.

8.2.28 ***BS 903 : Part A33 (Staining in contact with organic materials)***

This method is used as:

a) a control measure for non-staining antidegradants, vulcanization residues and discolouring process oils and other ingredients;

b) a means to evaluate antioxidants and antiozonants, especially when these are intended for applications coming into contact with light coloured surfaces;

c) a means of providing information relevant to such products as typewriter pads (contact stain), tyre sidewalls (migration stain), windscreen wiper blades (extraction stain) and painted rubber surfaces (penetration stain).

8.2.29 ***BS 903 : Part A35***
(Temperatures, humidities and times for conditioning and testing)

This Part of BS 903:

a) specifies the standard laboratory temperature and humidity for the conduct of BS 903 test methods;

b) specifies the minimum and maximum periods between vulcanization or forming and testing to assist in obtaining reproducible test results;

c) is used to avoid unnecessary proliferation of test conditions in specifications and other Parts of BS 903, through the adoption of standard time intervals, temperatures and their tolerances.

8.2.30 ***BS 903 : Part A36***
(Preparation of test pieces)

This Part of BS 903:

a) specifies the design, use and maintenance of cutters for the preparation of test pieces;

b) is used to specify the cutting and buffing techniques to reduce sample thicknesses to those needed for BS 903 and other tests and so is applicable to finished products as well as specially prepared samples.

8.2.31 ***BS 903 : Part A37***
(Adhesion to and corrosion of metals)

This method is used:

a) to screen rubbers, e.g. those containing reactive halogen, in contact with metal or exposed under conditions which give rise to corrosive volatile products;

b) for batch control to ensure the presence and effectiveness of acid acceptors.

8.2.32 ***BS 903 : Part A38 (Dimensions of test pieces and products for test purposes)***

This method is of critical importance because:

a) it is adopted in other test methods for measurement of test piece dimensions, e.g. thickness;

b) it is used for creep and compression set measurements;

c) it is used to measure shrinkage or swelling after exposure to heat or fluids;

d) it is used to measure the dimensions of some finished products and to determine the tolerances in specifications.

8.2.33 ***BS 903 : Part A40 (Adhesion to rigid materials using conical test piece)***

This method is used:

a) as a control measure for bonding systems, with the geometry encouraging failure at the bond;

b) to evaluate bonding systems and the effect of compounding on adhesion strength.

8.2.34 ***BS 903 : Part A42***
(Stress relaxation in compression)

This method is used as:

a) a design tool relevant to products operating under a constant deformation, e.g. seals;

b) a means of testing O-rings in a liquid medium;

c) an occasional control measure for state of cure and freedom from diluents or adulterants.

8.2.35 ***BS 903 : Part A43 (Static ozone resistance)***

This method is used:

a) as a control measure for level of protection and selection of rubber type;

b) to evaluate antiozonants, waxes and blends containing ozone-resistant rubbers;

c) to predict long-term ozone resistance from accelerated tests undertaken at higher-than-normal ozone concentrations;

d) widely in material and product specifications.

8.2.36 ***BS 903 : Part A44 (Dynamic ozone resistance)***

This method is used as Part A43, but for products undergoing a dynamic tensile strain, either continuously or intermittently. It is also used to evaluate antiozonants able to reduce the rate of growth under dynamic conditions.

8.2.37 ***BS 903 : Part A45 (Determination of test ozone concentration)***

This Part of BS 903 is a reference method for measurement of ozone concentrations over the range 25 pphm to 200 pphm in test chambers, used primarily in conjunction with Parts A43 and A44.

8.2.38 ***BS 903 : Part A46 (Vapour transmission rate)***

This method is used to measure the permeability of thin sheets of rubber (0.2 mm to 3.0 mm thick) or coated fabrics to volatile liquids.

8.2.39 ***BS 903 : Part A47 (Analysis of multi-peak traces)***

This Part of BS 903 provides techniques for analysing autographic traces obtained from tear strength or adhesion strength tests for determining median values.

NOTE. Other techniques for analysing autographic traces are given in BS 3424 : Part 5 and BS 3424 : Part 10.

8.2.40 ***BS 903 : Part A48 (Static adhesion to textile cord)***

This method is used:

a) as a control measure for effectiveness of bond between rubber and tyre cord (natural and synthetic fibres);

b) to evaluate bond promotors and pre-treatment processes.

8.2.41 ***BS 903 : Part A49 (Basic principles of flexometer testing)***

This Part of BS 903:

a) establishes general principles for flexometer tests used to measure temperature rise, creep, set and fatigue breakdown resulting from heat generation under cyclic deformation;

b) provides information relevant to such products as tyres, V-belts, engine mountings, and tank pads.

8.2.42 ***BS 903 : Part A50 (Compression flexometer)***

This method is used:

a) to measure resistance to heat build-up, creep, set and fatigue;

b) to screen rubbers differing in thermal stability or reversion resistance.

8.2.43 ***BS 903 : Part A51 (Resistance to tension fatigue)***

This method:

a) measures resistance to fatigue resulting from crack growth under cyclic tensile deformation. The test yields quantitative results not requiring operator interpretation and is conducted at clearly defined strains which can be varied to suit the application;

b) provides for the measurement of fatigue life as a function of strain, stress or strain energy density, as required by the application;

c) is used to evaluate anti-flex cracking agents;

d) is a sensitive measure of stress-raising flaws caused by maldispersion of ingredients and crosslinking, coarse adulterants and tears.

8.2.44 ***BS 903 : Part A52 (Ageing characteristics by stress measurements)***

This method is used:

a) to evaluate thermal-oxidative stability and the activity of antioxidants under continuous or intermittent tensile strain;

b) to measure ageing resistance as a function of time using the same test pieces (unlike Part A2) and, in the case of the intermittent strain test, without the need for special equipment other than the occasional use of a conventional tensile testing machine;

c) to provide information on the mechanism of oxidative ageing, the decay in stress in continuous strain exposure reflecting degradative scission reactions, and the change in stress under intermittent strain exposure reflecting the net effect of both degradative scission and crosslinking reactions.

8.2.45 ***BS 903 : Part A53 (Natural weathering)***

This method is used:

a) to measure the resistance to weathering outdoors, in the open or under glass, and thus is relevant to products used outdoors or indoors near windows, (e.g. glazing seals);

b) as a measure of resistance to photo-oxidation or change under natural conditions, with provision for expressing the exposure stage in terms of solar radiation dosage instead of time;

c) as a measure of resistance to ozone cracking outdoors, when stretched test pieces are used;

d) to evaluate antioxidants, antiozonants, ultraviolet absorbers and colouring agents.

8.2.46 *BS 903 : Part A54 (Artificial weathering)*

This method is used:

a) as a control measure for rubbers designed for light resistance;

b) as an accelerated measure of resistance to light ageing, light fastness and discoloration under controlled conditions, using a Xenon arc or other suitable light source and with or without a water spray;

c) to evaluate antioxidants, ultraviolet absorbers and colouring agents.

8.2.47 *BS 903 : Part A55* *(Methods for assessing changes in properties after weathering)*

This Part of BS 903 describes methods for the determination of changes in colour or appearance and changes in physical properties after exposure to natural weathering (see 8.2.45) or artificial light (see 8.2.46).

8.2.48 *BS 903 : Part A56 (Wire cord adhesion)*

This method is used:

a) as a control measure for effectiveness of bond between rubber and wire cord;

b) to evaluate bond promotors and pre-treatment processes.

8.2.49 *BS 903 : Part A57* *(Pocket hardness meters)*

This Part of BS 903:

a) is a widely used control measure for state of cure and composition;

b) is a non-destructive test suitable for finished products, including those already installed in service;

c) includes Shore A hardness, used as classification criterion for rubbers varying in stiffness (as for example in the USA) and in material and product specifications;

d) provides a classification criterion for thermoplastic rubbers, with use of both the Shore A and D scales;

e) may be used as a diagnostic tool assisting identification of causes of surface changes.

8.2.50 *BS 903 : Part A58* *(Methods using the Mooney viscometer)*

These methods are used:

a) as a control measure for raw rubber and mix viscosity, degree of mastication and quality of mixing;

b) to provide a measure of the influence of mastication and peptizers and other processing aids upon viscosity;

c) for the classification, grading and specification of raw rubbers;

d) to evaluate the processing behaviour of oil-extended SBR (Delta Mooney test);

e) to provide data as a control measure for the processing safety of fully compounded vulcanizable rubbers;

f) to evaluate the effect of vulcanizing systems and ingredients upon pre-vulcanization characteristics.

8.2.51 *BS 903 : Part A59* *(Methods using plastimeters)*

These methods:

a) provide a control measure for raw rubber and mix viscosity, degree of mastication and quality of mixing, and have the advantage of requiring only small size test pieces;

b) provide a measure of the influence of mastication and peptizers and processing aids upon viscosity;

c) are used in national and international systems for technically specified NR.

8.2.52 *BS 903 : Part A60 (Curemetering)*

This Part of BS 903 provides a guide to curemetering and the selection of curemeters. Although varying in detail and operation, curemeters are used:

a) as a control measure for state of cure, mix viscosity and ingredients influencing vulcanization kinetics and vulcanizate stiffness;

b) widely to determine the optimum time for vulcanization, eliminating or reducing the need for tests undertaken on a series of test sheets varying in state of cure;

c) to evaluate vulcanizing systems and ingredients affecting vulcanization.

8.2.53 *BS 903 : Part A61 (Friction)*

This Part of BS 903:

a) establishes principles for the determination of the coefficient of friction of rubber against standard comparators, against itself or any surface relevant to service over a range of temperatures, velocities and normal loads under lubricated or non-lubricated conditions;

b) is a design tool relevant to products where grip (or freedom from grip) is important, such as tyres, belting, seals, unbonded bearings and windscreen wiper blades;

c) can be used as a control measure for the surface characteristics or treatment of mass-produced goods requiring high or low friction (e.g. latex gloves).

8.2.54 ***BS 903 : Part A62 (Green strength)***

This method:

a) provides information relevant to processing operations where the raw or unvulcanized compounded rubber has to resist tensile distortion, as for example in strip feed operations, some extrusion plants and certain tyre-building operations;

b) can be used to evaluate rubbers, compounding ingredients and process aids.

8.2.55 ***BS 903 : Part A63 (Crystallization effects by hardness measurements)***

This method is used:

a) to provide a measure of the progressive stiffening of rubbers caused by crystallization during storage, usually at low temperatures;

b) as a non-destructive test, so that the same test pieces may be used to measure the effects of crystallization as a function of storage time;

c) to characterize raw and unvulcanized rubber, as well as vulcanized rubber.

NOTE. BS 903 : Part A63 supersedes BS 5294.

9 Testing for processability

9.1 General

No single test method can define the ease with which a raw rubber or rubber compound will process in a manufacturing plant. Several properties are involved, not all of them related, and their relative importance will vary from one processing operation to another. The requirements for injection moulding, for example, will not be the same as those for continuous vulcanization following extrusion.

There are fewer standard tests for measuring processability than there are for vulcanizate properties, a reflection of the complexity of the subject and the still-incomplete understanding of the rheology of elastomeric materials. The tests currently available or under consideration are shown in table 3. The most widely used are viscosity tests (see **9.2** and **9.3**) and tests for measuring vulcanizing characteristics (see **9.4**). The first of these are of limited value for prediction of flow behaviour during processing and although correlations between tests and with the processing of specific rubbers have been established, the principal value of these tests is their ability to measure consistency.

The results of tests undertaken on raw and unvulcanized rubber are strongly influenced by the way in which test pieces or test portions are prepared on processing equipment. Such equipment is often housed in an environment which is not as closely controlled as a normal test laboratory and therefore care should be taken to minimize sources of variation. Procedures for the homogenization of raw rubber and preparation of test portions are described in BS 6315.

Processing tests for thermoplastic rubbers are considered in clause **15**.

9.2 Mooney viscometer tests (BS 903 : Part A58)

9.2.1 ***Mooney viscosity***

Mooney viscosity is one of the most common measurements made in the rubber manufacturing industry. It is used to measure the progress of the polymerization reaction for synthetic rubbers and to specify the finished raw product. It also features in specifications for some grades of NR. The Mooney viscosity value is widely interpreted as an indicator of molecular weight, although the relationship is in fact rather complex, and rubbers with quite different molecular weight distributions can have similar Mooney viscosities. However, it may be assumed that rubber with a Mooney viscosity of 40 will have a lower molecular weight than one of the same type with a viscosity of 50. The lower viscosity rubber will usually mix and extrude more easily.

It should be remembered that the flow behaviour of rubbers and their compounds is non-Newtonian and that a Mooney viscosity measurement is made at a single, low shear rate (i.e. 1.6 s^{-1}). Caution should be exercised in extrapolating to the higher shear rates usually typical of processing operations, e.g. 10 s^{-1} to 100 s^{-1} for mixing, 10 s^{-1} to 1000 s^{-1} for extrusion and as high as 10 000 s^{-1} for injection moulding.

The Mooney viscosity of compounded rubber is used to specify compounds produced for sale and for in-house use, often for batch control. Carbon black masterbatches are specified by the Mooney viscosity of standard compounds.

9.2.2 ***Delta Mooney value of oil-extended emulsion polymerized SBR***

This test is used as a guide to the performance of oil-extended SBR in an internal mixing process. The more negative the value (delta Mooney 'A') or the lower the value (delta Mooney 'B') the easier the rubber will mix, reflected in shorter times, lower temperatures, and less power consumed. Milling behaviour of the mixed compound will be better and extrusion will be more consistent. On the basis of factory-scale experience, such a rubber is said to have good processability.

The delta Mooney test may also be applied to other rubbers such as non-oil extended SBR and BR, but the significance is not well known or understood.

The delta Mooney test should not be applied too widely. Values known to give good processability for a particular type of oil-extended SBR, for example 1712 (extended with aromatic oil) will not apply to another type such as 1778 (extended with naphthenic oil) or indeed to aromatic oil-extended SBRs with higher-than-normal styrene contents (> 23.5 % to 40 %). Even samples of 1712 from different manufacturers can have different ranges of values which still indicate good processability.

9.2.3 *Pre-vulcanization characteristics*

Scorch time is used as an indication of how long a rubber compound containing a vulcanizing system (or capable of self-vulcanization) will remain processable at an elevated temperature. Ideally the test should be carried out at the same temperature as, or as close as possible to, the process being studied.

Compounds with a long scorch time are referred to as safe. The length of the scorch time is determined fundamentally by the choice of vulcanizing system, but is subsequently reduced by the heat input during mixing, calendering, extruding etc. The scorch time can also decrease in storage. Therefore it is advisable to measure the scorch time at the start of each operation.

9.3 Plastimeter tests (BS 903 : Part A59)

9.3.1 *Rapid plasticity number*

This test is easy to carry out, requires a small test piece size, and the result is available within a very short time. It is not often used to specify raw rubber, an exception being technically specified NR, but is widely used as a control check on the degree of mastication and mixing.

9.3.2 *Plasticity retention index*

This test is exclusive to raw NR and is used as a measure of its resistance to oxidative degradation. In principle, the test can be applied to other types of rubber as an illustration of their resistance to hot air degradation which can be used to control levels of, say, stabilizers and pro-oxidants. The time and temperature of ageing may need to be adjusted to suit the material.

9.4 Curemeter testing (BS 903 : Part A60)

The oscillating disc curemeter is widely used by both rubber producers and rubber goods' manufacturers, and has now been joined by the more recently developed rotorless curemeter. The producers use the various parameters from the cure curve of standard compounds as specification data, indicating to their customers that the rubber has the required rate of cure or can be regarded as slow, medium or fast vulcanizing.

Curemeters are used within factories principally to check batch-to-batch consistency (see clause **15**). They are also used as indicators of processability. The minimum torque is a measure of the viscosity of the compound and can sometimes replace a Mooney viscosity or rapid plasticity measurement. One advantage is that the test is usually conducted at or near to the actual process temperature for, say, transfer or injection moulding. One shortcoming of the Mooney viscometer, for both scorch and viscosity measurements at high temperatures, is thermal lag because of the size of test piece.

Maximum torque, or more correctly the difference between maximum and minimum torques, is a measure of crosslink density and for control purposes can replace the more traditional 300 % modulus measurement undertaken on a vulcanizate. Reversion can be detected and studied by allowing the test to run for longer times.

Resistance to scorch is assessed by measuring the time for the torque to rise by a small amount; 1 unit in the case of the oscillating disc curemeter. The speed of the cure is given by the times to 50 % and 90 % of the torque rise, among other measurements.

All these parameters are available from one test.

NOTE. BS 903 : A60 : Section 60.1, a guide to the general principles of curemetering, is in the course of preparation.

10 Testing for design purposes

10.1 General

There are at least three ways in which laboratory tests may be used to assist the design of a rubber component:

a) to generate data suitable for use in design calculations (see **10.2**);

b) to define the limits of the materials, for example with respect to the upper and lower temperatures reached in service, and any fluids coming into contact with the component;

c) to provide information on the quality of the rubber being used.

The choice of test methods and test conditions will depend on the nature of the application and its mechanical and environmental requirements. Some guidance on the type of information required when designing a component is given in BS 6716.

To assist in the selection of materials of established quality, attention is drawn to the classification system for vulcanized rubber compounds described in BS 5176 and to the material specifications for individual types of rubber. These are BS 1154 (NR compounds), BS 1155 (NR extrusions), BS 2751 (NBR compounds), BS 2752 (CR compounds), BS 3227 (butyl compounds), BS 6014 (EPM and EPDM compounds) and BS 6996 (mineral oil resistant NBR compounds). Each of these specifications makes extensive use of the BS 903 methods of test.

10.2 Engineering design

Few of the existing BS 903 test methods provide results which can be incorporated in design equations or which are in a form recognized by design engineers. Those suitable for this purpose concern force-deflection characteristics under short-term and long-term loading, damping parameters, crack-growth fatigue behaviour and a number of physical constants (see table 4). Tests of this type have been used in the design and specification of pipe seals (BS 2494), elastomeric bridge bearings (BS 5400 : Section 9.2) and anti-vibration bearings for the isolation of buildings (BS 6177). Some adhesion tests (see **14.5**) can also be used to establish design limits.

Correlations or relationships established between properties, for example between Young's modulus and shear modulus, depend not only on the test conditions but also on the nature of the rubber involved and the presence of reinforcing fillers. In particular, care should be taken when establishing and using correlations between indentation hardness and a modulus because of their dependence on composition. Hardness measurements, although of great value for classification purposes, are also less precise than those for, say, shear modulus, and differences may also emerge as a result of differences in the state of cure, should test piece thicknesses not be the same.

Note also that the tensile modulus, often used in the rubber industry as a measure of reinforcement or state of cure, is a stress at a specified elongation, calculated on the unstrained cross-section of the test piece (BS 903 : Part A2).

11 Testing for durability

11.1 General

Tests are always required to assess how well a rubber resists various types of deterioration, both physical and chemical, and the rubber's ability to withstand even short-term exposure to environmental extremes, for example high and sub-normal temperatures. Over twenty BS 903 test methods are designed to measure some aspect of durability and in figure 2 they are arranged in a way to facilitate their selection.

The first task is to identify and, as far as possible, quantify, the mechanical and environmental conditions in which the rubber is to be used. It is also important to identify the most likely causes of deterioration and determine how they influence the properties upon which the performance of the product depends. Selection of the most appropriate test method is sometimes relatively straightforward. If a rubber is to spend much of its life at elevated temperature, BS 903 : Part A19 will need to be specified, although the way in which it is used will require some thought. Similar considerations apply to the use of BS 903 : Part A16 to assess a rubber intended for a product coming into repeated contact with a fluid.

In other cases, the choice of test method, and the importance attached to it, is less obvious. A bulky component undergoing repeated deformation may be susceptible to heat build-up, fatigue failure, dynamic ozone cracking and creep, and if there are periods at sub-normal temperatures, certain rubbers may undergo crystallization. A windscreen wiper blade is another example where several forms of deterioration may take place; they will include heat ageing under sunlight, compression and tension set, fatigue cracking, static as well as dynamic ozone cracking, and even abrasion. For selection of materials each of these may need examination.

Even when the overall requirements have been identified, a decision will still need to be reached on the selection of test procedure and test conditions, where options exist. It is not possible in this Guide to discuss all the relevant test methods but in annexes F and E some guidance is given for ozone resistance and for low temperature resistance. Annex F illustrates the importance of properly selecting the test conditions available even in one test method, and annex E illustrates how important it is to select the correct test method. Some guidance on other properties is provided in individual test methods.

11.2 Correlation with service behaviour

When information on long-term performance is required from tests, the following should be considered.

a) As far as possible, the test conditions should match those anticipated in service, certainly in respect of all those conditions that are not used to accelerate deterioration. In the case of the test conditions responsible for acceleration (e.g. temperature for thermal-oxidative ageing and ozone concentration for ozone resistance testing) the option in the test method closest to service requirements should be specified. Increasing the test severity to shorten a test can influence the mechanism of degradation, the efficacy of protective agent and the ranking order of rubbers.

b) For convenience of testing and to ensure uniformity of degradation, test pieces used in the laboratory are usually thin, whereas the product involved may be comparatively thick. The difference is of particular importance to thermal ageing because in a thick product the effects of oxidation may be confined at or near the surfaces, whereas the bulk undergoes (the usually milder) anaerobic degradation. Thickness also influences the activity and persistence of protective agents.

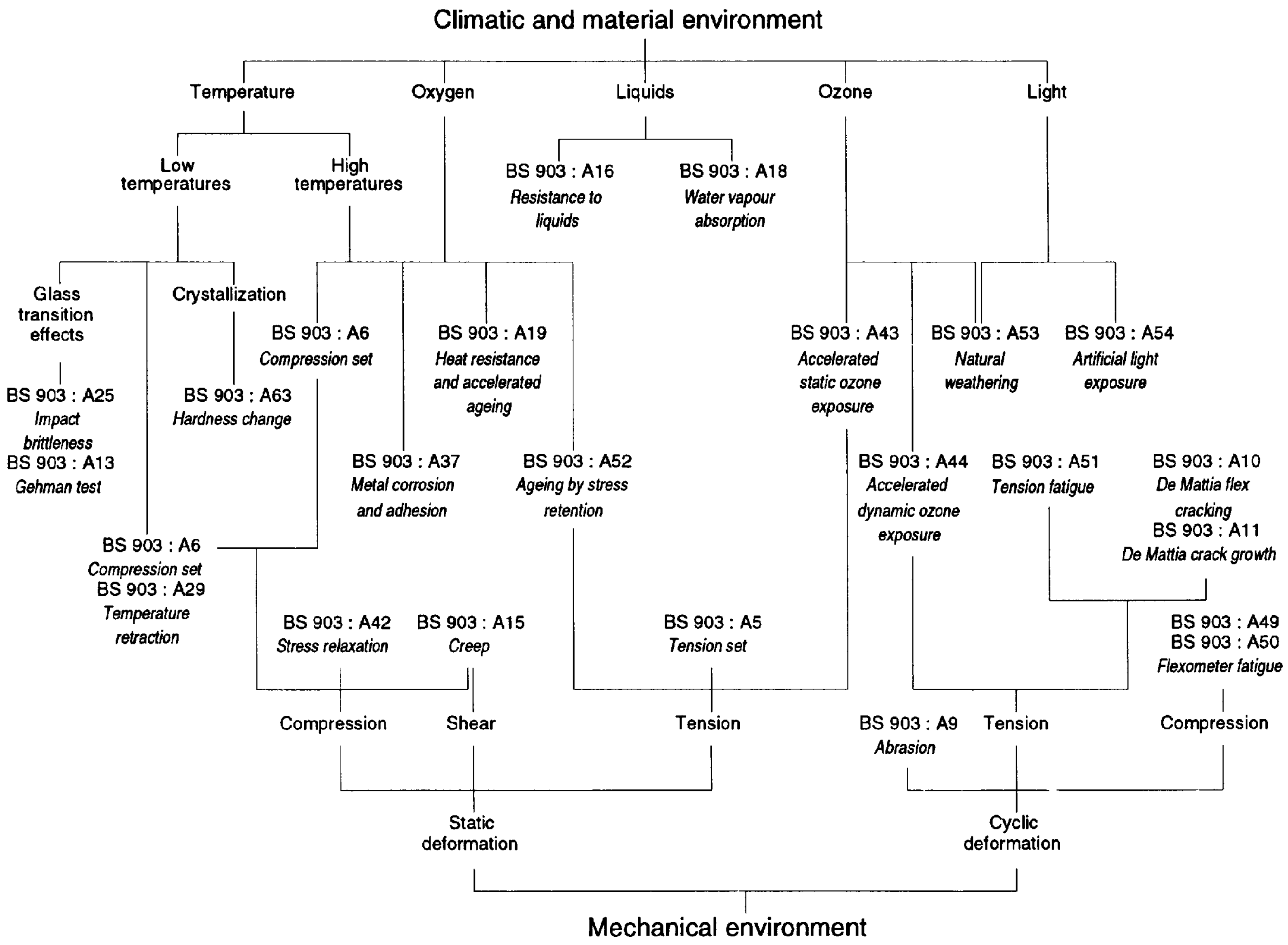

Figure 2. Durability testing

Diffusion control is also operative in fluid immersion tests. Equilibrium swelling is reached in a comparatively short period in a thin test piece, often accelerated by the use of a higher-than-normal temperature, whereas penetration of liquid into a bulky component at a lower service temperature may be very much slower and again largely confined to the surface. Differences among liquids can emerge because equilibrium absorption is influenced by the chemical composition of the liquid, whereas the rate of penetration is much more a function of the viscosity of the liquid.

c) Not all properties deteriorate at the same rate and correlations between them may be poor. As far as possible the property measured should relate to product performance. Heat resistance or accelerated ageing resistance is commonly assessed in terms of changes in tensile stress-strain behaviour measured at the standard laboratory temperature, and whilst this is convenient for initial compound screening (see clause **12**) and quality control purposes (see clause **15**), it may have little relevance to the performance of the product.

BS 903 : Part A19 may be used with *any* test method.

d) Single point measurements (e.g. one period of thermal ageing or one period of fluid immersion) offer limited information because there is no indication of how quickly a rubber will deteriorate and whether a period of protection is followed by rapid degradation. Multi-point measurements are recommended for many purposes and are required if extrapolations are to be made from Arrhenius plots of thermal ageing.

NOTE. ISO/TC45 is preparing a guide on the use of Arrhenius plots to predict long-term ageing resistance.

e) The influence of ageing on composition should be considered. Exposure to a heat ageing test may have no obvious effect on the physical properties of rubber, yet the test conditions may have been severe enough to cause a depletion in antiozonant levels caused by direct oxidation of the additive or even volatilization.

12 Evaluation and characterization of materials

12.1 General

Standard test methods are widely used to evaluate and characterize new rubbers and compounding ingredients. The work may involve the evaluation of a newly discovered additive to determine its strengths and weaknesses, tests undertaken to check the claims made for a material and to screen how suitable the material might be for another application, and the generation of test results for inclusion in a data base or in promotional literature. Even if a specification is not involved, it is desirable to use standard procedures as far as possible because these offer the best chance of recognition by anyone receiving the test results and of reducing variations between one laboratory and another.

Materials should be characterized in such a way that anyone can undertake the same test in another laboratory and be able to compare the results with those already available for other materials, perhaps from a different source. For this purpose it is recommended that for those test methods where more than one procedure or option is permitted, use should be made of any preferences given in the standard. Preferences for the BS 903 test methods are listed in annex G.

12.2 Rubbers and compounding ingredients

Choice of test method will be governed by the rubber or compounding ingredient being examined but there is a core of tests in common use, whether in technical literature or in material specifications, and these are summarized in table 5. The test methods most appropriate for the evaluation of different types of compounding ingredient are listed in table 6.

It is important that tests should not be confined to those measuring the outstanding attributes of the material. The influence of the material on other properties should also be examined to ensure there are no shortcomings and to provide sufficient information to justify the claims being made. Some of this information will be obtained other than by means of standard methods and may take the form of simple observation, for example, whether an additive causes discoloration or blooms to the surface.

Some basic evaluation procedures are described in British Standards for specific materials. These are BS 4470 (butyl rubber), BS 5047 (solution-polymerized BR), BS 5375 (CR), BS 5474 (solution-polymerized IR), BS 5563 (SBR masterbatches with carbon black or carbon black and oil), BS 5738 (NR), BS 6063 (EPDM), BS 6064 (NBR), BS 6449: Part 2 (for precipitated silica fillers), BS 6845 (halobutyl rubber) and BS 6995 (emulsion and solution polymerized SBR).

Laboratory-scale evaluations should, as far as possible, be carried out in accordance with the mixing and vulcanization methods described in BS 1674 so that variations caused by differences in the method of preparation can be minimized.

12.3 Reporting of results

It is essential that all test conditions are reported with the results. This also applies to the type of data gathered for design (see clause **9**) and durability (see clause **10**). The conditions will include choice of test piece, the direction in which test pieces are cut from sheet in the case of tensile and tear testing, and even any preferred option in the test method. Attention is drawn to the type of information requested in the test reports given at the end of each Part of BS 903.

12.4 Interpretation of results

Care should always be taken when attempting to draw conclusions from test results obtained in the laboratory, usually under limited test conditions, about any particular property of a material. This applies in particular to any claim for improvements in resistance to degradation or cause of failure. The following questions should be posed.

a) *Is the improvement in performance a generally applicable one or is it confined to one test or one set of test conditions?* For example, it would be imprudent to claim a material enhances abrasion resistance, without any qualification, simply on the basis of its performance in one of the four test methods specified in BS 903 : Part A9, and especially so if a subsequent test using one of the other methods gave no improvement. Similarly the ability of an additive to prevent ozone cracking will be of limited value if it is only shown under test conditions which have little in common with a service environment. Again, a rubber which is found to have a low glass transition temperature cannot be said to be exceptionally resistant to low temperatures if it undergoes rapid crystallization. For further information on ozone resistance and low temperature resistance see annexes F and E respectively.

b) *Is the improvement a true one or just a reflection of change in another property?* For example, concluding that a material has outstanding resistance to tension fatigue will be misleading, and likely to be incorrect, if it can be shown that the enhancement of fatigue life in a test conducted under constant deformation is simply the result of a lower initial modulus, stress softening or development of a set during the test. Any of these means that fatigue resistance is being measured under milder conditions than intended because they reduce the strain energy density available in the rubber, one of the parameters determining the fundamental crack growth characteristics of the rubber. For a given compound, the fatigue life increases rapidly as the strain energy density is lowered towards that at the mechanical fatigue limit.

c) *Does the claim depend on the way in which the result is expressed?* For example, a material may be concluded to be abrasion-resistant because it has a lower volume loss than one tested some time previously or, indeed, in another laboratory. Yet no improvement at all may be evident when the result is expressed as a ratio to the loss of a standard rubber, as is specified in BS 903 : Part A9. The standard rubber is tested alongside the test material to correct for any variations in volume loss from one abrasion machine to another and from any wear of the abrasive surface over a period of time.

d) *Is the result a statistically significant one?* The difference between materials is often quite small and so it is important to ensure that the test results are a true measure of the properties of the material and not simply chance. Little will be gained, and much may be lost, if it is later demonstrated that the claims made for a material are traceable to variability in the test sheet or to testing errors. Test data should be scrutinized to ensure that the difference is greater than the least significant difference or any other measure of significance. Relevant information is the variability of the results and the repeatability and reproducibility of the test method where this is reported. Guidance is given in BS 5324 and is the precision statement presented at the end of several Parts of BS 903.

13 Designing a specification

13.1 General

For many users, their first and often only experience of test methods is with standard evaluation procedures and with material and product specifications. Some guidance on the selection of test methods and test conditions for these purposes is given in **13.2**. However, it is outside the scope of this Guide to describe how specifications should be drafted because this will depend on several factors other than just selection of test methods. Some basic guidance on the preparation of specifications is given in BS 7373 and in BS 0 : Part 3.

13.2 Selecting tests for rubber

For the adoption of test methods for rubber the following sequence is recommended.

a) Draw up a list of properties needing to be specified and, in the case of a product, define the mechanical and environmental conditions in which it is to operate. Some useful information is given in BS 6716.

NOTE. BS 7373 defines several categories of specification and draws attention to the need to consider elements of performance (i.e. function, appearance and reliability) and location (e.g. the effect of the environment and compatibility).

b) Select what appear to be the most appropriate test methods (see clause **7** and annex D) and consider how suitable they are for, say, test pieces taken from a finished product if the end-user insists on this approach. Other considerations will be the frequency of testing and the test methods called up in related material or product specifications.

c) Decide if existing tests need modification to suit the product and if any new ones are required. If a BS 903 test method is not available, first consider whether any unadopted ISO method or a BS 2782 test method for plastics is acceptable for the purpose. Also consider any procedures already specified in related product specifications. Any modification or new test should be fully described in the specification.

d) Consider whether the specification should be open to any material or should be confined to one or more specified types of rubber. The decision will depend on experience and how successful test methods are in defining product performance regardless of the type of material being used. As a general rule, a well-established material will need fewer test requirements than an untried one because not all its attributes have to be tested, and other properties, sometimes more easily measured, will ensure the rubber is of sufficient overall quality. If a specification is an unrestricted one it will certainly need to include tests that relate closely to product performance to ensure an unsatisfactory material is not used.

e) If the specification is based on particular types of rubber, decide whether different requirements need to apply to the rubbers to ensure quality, for example an adequate state of cure and freedom from adulterants. In BS 5400 : Section 9.2 some of the requirements for NR and CR differ even though the rubbers are intended for the same application.

f) Consider whether use can be made of well-established material specifications, such as BS 5176 (a classification of vulcanized rubbers based on wide experience), and the specifications for individual rubbers, such as BS 1154 for NR. This step not only ensures a measure of quality but can reduce the number of compounds needed in a factory. It also avoids the risk of specifying impractical combinations of properties and ones that might only be achieved at the expense of others.

g) When setting test limits, consider the gradations given in annex A. The list is designed to discourage unnecessary variation in requirements and to avoid small differences which may be, statistically, insignificant.

h) Draw a clear distinction between those tests intended for type approval and those intended for more routine quality control testing, and establish a sampling protocol.

14 Product testing

14.1 General

Specifications often require test pieces cut from a finished product, so that the properties of the rubber in its final state can be measured. In specially moulded test samples and test pieces it is not always possible to match the conditions of vulcanization for a product, especially if very high temperatures are used as, for example, in continuous curing. It may also be important to take account of differences in flow behaviour between moulded sheets and the product and the effect of any material (say a fabric) in the product other than the rubber.

When establishing test limits for test pieces prepared from a product and when making comparisons with specially prepared test pieces, the following should be considered.

a) The state of cure in a product may differ from that of a test sheet and vary within the product if there are differences in thickness.

b) It is sometimes difficult to locate the grain in a product, especially in a complex shape.

c) Differences may be caused by the way in which test pieces are prepared from the product, a process that may involve separation from other materials and buffing of surfaces.

14.2 Preparatory procedures

14.2.1 *Storage of samples*

Products from which test pieces are to be prepared should be stored for no more than 3 months between vulcanization and testing. If the time of vulcanization is unknown, the tests should be made within 2 months of the date of receipt.

It is recommended that products for testing purposes should be stored under the same conditions as those suggested for specially moulded samples (see **6.3**).

14.2.2 *Preparation of test pieces*

Test pieces should be prepared by the methods described in BS 903 : Part A36.

14.3 Selection of test method

Most BS 903 test methods provide for the use of test pieces cut from products or can be adapted for this purpose. Exceptions include BS 903 : Parts A10 and A11 (De Mattia tests) and BS 903 : Part A40 (Adhesion to rigid materials using conical test piece).

The shape and size of the product may influence the choice of test method and of test piece. Size will often be a restriction and thus the smallest possible test piece is often sought. For guidance table 7 may be used.

14.4 Testing special shapes

There will be occasions when even the smallest test piece permitted in the test method will prove unsuitable and it will be necessary to seek an alternative test. Some options for difficult shapes are as follows.

a) Sheeting less than 1 mm thick

Tensile stress-strain characteristics (BS 903 : Part A2).

Tension set (BS 903 : Part A5).

Accelerated ageing (BS 903 : Part A19).

Volume, mass or dimensional change in liquids (BS 903 : Part A16).

Ozone resistance (BS 903 : Parts A43 and A44).

b) Small surface area

Micro-hardness (BS 903 : Part A26).

Volume or mass change in liquids (BS 903 : Part A16).

Compression set, if thickness allows (BS 903 : Part A6).

c) Extruded profile (e.g. windscreen wiper blade) Micro-hardness (BS 903 : Part A26).

Tension set (BS 903 : Part A5).

Volume, mass or dimensional change in liquids (BS 903 : Part A16).

Ozone resistance (BS 903 : Part A43)

14.5 Testing composites

Many products will be made of composites of rubber and a reinforcing textile fabric, metal plate, cord or wire. Examples are tyre carcasses, conveyor belting and laminated bearings. Most require satisfactory adhesion between rubber and the other material and it is usually appropriate to measure this in the product or on test pieces cut from the product.

The adhesion tests covered by BS 903 are classified in figure 3. Not all are suitable for finished products but the peel or stripping tests specified in BS 903 : Part A12 and A21 can be adapted for this purpose and feature in some product specifications.

For the adhesion testing of rubber-coated fabrics, reference should be made to BS 3424 : Part 7.

BS 903 : Part A4 and BS 903 : Part A14 can be used to measure the compression modulus and shear modulus respectively of rubber to metal bonded laminates (see also B.6).

14.6 Special requirements

Several British Standard specifications and test methods for individual rubber products contain test procedures based on BS 903 test methods. They include the following.

BS 3424 *Methods of test for coated fabrics*

BS 5173 *Methods of test for rubber and plastics hoses and hose assemblies*

BS 7442 *Rubber or plastics covered rollers*

In BS 7442 : Section 3.1 the hardness test of BS 903 : Part A26 is adapted for the curved surfaces of rollers, as is the shore hardness test of BS 903 : A57 in BS 7442 : Section 3.2.

15 Quality

15.1 Quality testing

For the purposes of this Guide, quality testing includes any testing carried out on rubber taken from a product or at any stage during product manufacture to ensure that properties remain within specified limits. In the rubber industry this may involve anything from the quality control of incoming raw materials, to process control during mixing, fabrication and vulcanization, and control of the finished product.

Whatever the precise purpose of quality testing, there will be a need for test methods which:

a) are convenient and not time consuming;

b) have acceptable levels of repeatability and reproducibility;

c) can be adapted to the needs of particular products.

Many of the BS 903 test methods meet these objectives and are in widespread use for quality control purposes.

15.2 Process control and batch consistency

15.2.1 *General*

Table 8 lists the BS 903 test methods most commonly used for control purposes and offers some of the reasons for their adoption. Table 9 shows the same information in terms of the needs of individual compounding ingredients and processing operations.

The choice of which test methods and how many are required will depend on formulation, processing operation, method of vulcanization and the type of product. (For product testing see clause **14**.)

The test method and test conditions should be capable of distinguishing between batches, and should provide sufficient data to enable a decision to be made about those that are acceptable and those that are not. These will usually be determined through experience, although existing specifications can sometimes be adopted for the purpose. The test conditions, say for accelerated ageing resistance testing, are often arbitrary for control purposes and need not relate to the requirements of service, because the prime concern is that the rubber is properly compounded and the product has been properly vulcanized.

Consistency is not an easily defined characteristic; a rubber mix or product that is consistent in one respect may vary in others. For example, batch-to-batch consistency of compound viscosity does not mean that one batch has the same vulcanizing characteristics as another. It is therefore essential that a sufficient range of testing is always undertaken; there are few short cuts for maintenance of quality.

Although this Guide is limited to those aspects of process control specifically related to rubber and cannot extend to engineering and process monitoring, attention is drawn to BS 2846 : Parts 1 to 7, BS 5703 : Part 2, BS 5703 : Part 3, BS EN ISO 9001, BS EN ISO 9004 and BS 5781 .

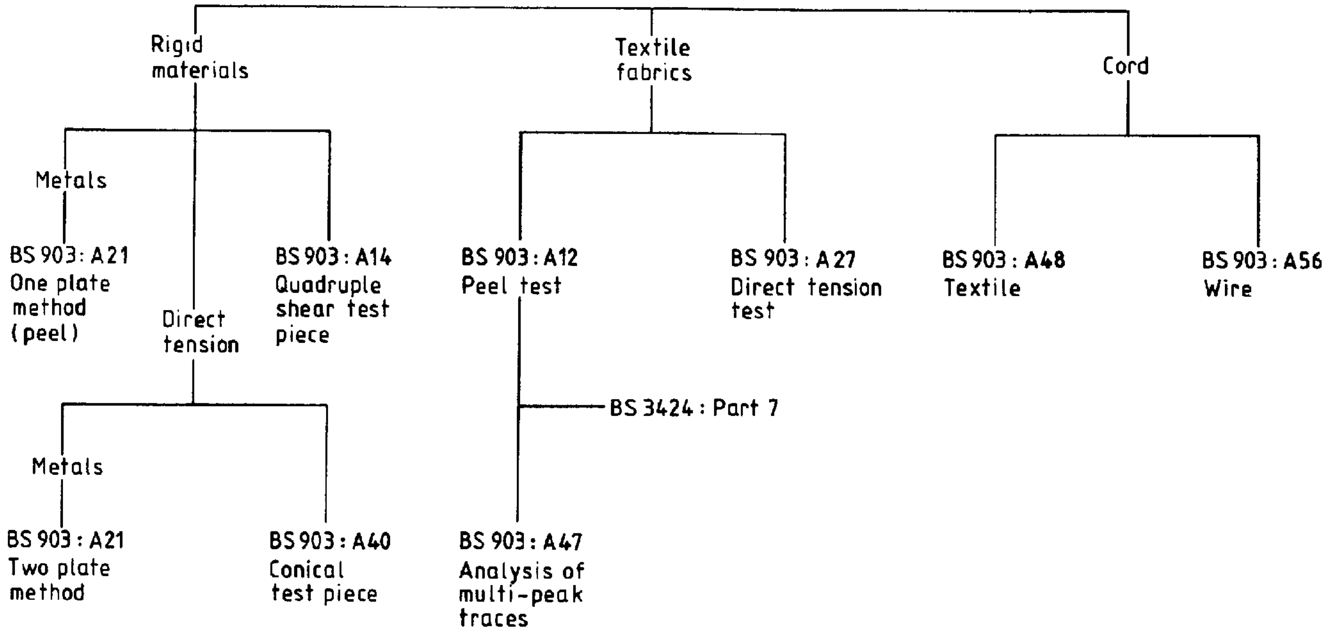

Figure 3. Adhesion testing

15.2.2 ***Sampling***

The batch or lot size needs to be identified and the risk of process control run-out within that batch size assessed. This will provide an indication of the frequency of sampling required. The size or number of units selected per sample will depend upon whether the process is effectively continuous, semi-continuous or discrete batches and whether individual components within that batch can be identified. In the latter case sampling may be carried out to BS 6001 : Parts 1 to 4 or BS 6002. Otherwise, depending upon the foreseen risk or hazard caused by failure, a sample size of sufficient quantity to enable duplicate repeats of all tests assessed through BS 2846 provides sufficient confidence in most critical cases. Guidance in sampling is provided in BS 5324.

15.3 Quality assurance

15.3.1 ***General***

Quality testing should be considered as an integral part of quality assurance. Decisions need to be taken on the optimum placement of testing in the quality management system and measures which will have the benefit of reducing the intensity, and hence cost, of testing. Testing is a measurement of quality, and should assist in identifying the causes of any inconsistency. It does not replace the need to introduce techniques or make changes which will enable the material to more easily meet the quality requirements.

Guidance on quality assurance and on quality systems is given in BS EN ISO 9000.

15.3.2 ***Design***

Rubber is, of course, no exception to the rule that quality assurance begins with design.

An early reference to BS 6716, BS 7000 and BS 7229 is therefore advisable.

Once the design performance criteria are established and the rubber type selected, the other compounding ingredients need to be selected and specified with equal care. Reference to one or more of the various British Standards for evaluation of rubbers and on specifications for individual vulcanized rubbers would be useful (see figure 1).

Service performance of the prototype design will depend upon the physical and chemical environment in which the component or product is to perform. The laboratory assessment of service performance by selection of the most appropriate methods may be aided by reference to clauses **8** to **14**. Some methods are essential in order to ensure production process control and production quality control and attention is again drawn to figure 1.

15.3.3 ***Quality assurance tests***

It should not be assumed that the function of final inspection and testing for verification of compliance with the design performance is itself the entire function of quality assurance. It is one of the functions which hopefully confirms the expectation.

The analysis of test results to estimate the confidence limits which can be placed on the test results is absolutely essential, especially where the number of results is extremely limited, as is commonly the case with most rubber tests, and in this respect, again, reference to BS 600, BS 2846 or BS 5324 is recommended.

16 Testing thermoplastic rubbers

16.1 General

An increasing number of BS 903 test methods, although based on the properties of vulcanized (thermoset) rubber, are being extended to thermoplastic rubbers, usually with little technical amendment. The suitability of other test methods will be considered when they are reviewed. The testing of thermoplastic rubbers is still in its infancy and wider experience is needed to establish the strengths and weaknesses of existing test methods. The following tests in particular should be treated with caution.

a) *Those tests involving heat.* BS 903 : Part A19 can be used to test the heat resistance and accelerated ageing characteristics of thermoplastic rubbers, but care should be taken when selecting test temperatures in view of the thermoplasticity of the materials. A similar consideration applies to BS 903 : Part A6 (Compression set) and in this case it should be understood that the reasons for undertaking a test at elevated temperatures may not be the same as with vulcanized rubber, for which compression set is often specified as a measure of state of cure. (Note, however, that some commercially available thermoplastic rubbers contain crosslinked phases which influence resistance to set at high temperatures.)
BS 903 : Parts A49 and A50 (Flexometer tests) are not considered suitable for most thermoplastics rubbers because of high heat generation.

b) *Those tests involving the development of set.* Some thermoplastic rubbers have been found to have exceptionally long lives in flex cracking and in tension fatigue tests conducted under constant deformation (BS 903 : Parts A10 and A11 and BS 903 : Part A51 respectively). This is due to stress-softening and development of set during cycling. It is essential that care is also exercised when using, and interpreting the results of, dynamic stress/strain testing (BS 903 : Part A24).

16.2 Preparatory procedures

Storage of samples, preparation of test pieces and conditioning operations should as far as possible be the same as those specified for vulcanized rubber (see clauses **6** and **7**). The time of vulcanization will be replaced by the time of fabrication.

The physical properties of thermoplastic rubbers have been shown to be dependent on the conditions of moulding (and other methods of shaping) and are also affected by the design of the mould for the test sheet. Anisotropy is much more evident in thermoplastic rubbers than in vulcanized rubber and in some injection mouldings the properties measured at the surface may not be typical of the bulk because of differences in composition and morphology.

NOTE. For thermoplastic rubber, the term plaque is often used to describe the test sheet or slab.

16.3 Test methods for plastics

The processing of thermoplastic rubbers is usually more akin to that of conventional thermoplastics materials than to vulcanized rubber, and the harder grades of thermoplastic rubbers will have many properties which are reminiscent of plastics. For these reasons, methods in the BS 2782 series are often appropriate.

Melt flow index (BS 2782 : Part 7 : Method 720A) has become an established test parameter for the processability of thermoplastic rubbers because it is much better able to describe and define the viscosity-temperature dependence of these materials than conventional rubber viscosity and plasticity tests.

Many types of thermoplastic rubbers are now classified in terms of their Shore hardness, which for harder materials extends to the Shore D scale. BS 903 : Part A57 can be used for this purpose.

BS 2782 test methods suitable for thermoplastic rubbers include Vicat softening point (Part 1 : Methods 120A, 120B, 120D and 120E), flexural properties (Part 3 : Method 335A) and, for more rigid materials, Izod impact strength (Part 3 : Method 350).

Table 1. Test piece thickness for physical testing

Standard test piece thickness mm	Method	Comments
See comments Comminuted 0.25 to 2 0.25 to 3 1 to 3	BS 903 : Part A1 BS 903 : Part A18 BS 903 : Part A17 BS 903 : Part A30 BS 903 : Part A31	No strict requirement of test piece thickness, but detailed comments on test piece dimensions are given in each standard. The limits of test piece thickness for gas permeability (BS 903 : Part A17 and A30) depend on the capacity to produce thin membranes without imperfections or pinholes.
1 to 8	BS 903 : Part A61	Other thicknesses may be used to suit finished products, but thinner test pieces may need to be supported.
Not more than 12	BS 903 : Part A24	Varies with mode of deformation.
1.0 ± 0.05	BS 903 : Part A52	
1.0 ± 0.1	BS 903 : Part A2	Type 4 dumb-bell and type B ring test piece.
1.5 ± 0.2	BS 903 : Part A51	
2.0 ± 0.2	BS 903 : Part A2, A3, A5, A9 (Methods A & D), A13, A16, A19, A24, A25, A26 (micro-test) A29, A33, A37, A43, A44, A46	Suitable for BS 903 : Part A24 tests in tension, bending and torsion, and also for A31, A51 and A61.
3.0 ± 0.1	BS 903 : Part A21 (Method A)	When used for post-vulcanization bonding studies.
4.0	BS 903 : Part A14	When used for post- vulcanization bonding studies.
4.0	BS 903 : Part A26	The test piece is usually two plies of 2.0 mm test sheets for apparent hardness.
6.0 ± 0.1	BS 903 : Part A21 (Method B)	When used for post-vulcanization bonding studies.
6.0 or 3 × 2.0	BS 903 : Part A57	Minimum thickness
6.3 ± 0.15	BS 903 : Part A10 and A11	Needs moulded groove if cut from sheet
6.3 ± 0.3	BS 903 : Part A6, A9 (Method A) A15, A24 (in compression) A42, A57	A test sheet 250 mm square with a thick section 6.3 mm ± 0.15 mm × 50 mm wide, the remainder of the sheet being 2.0 mm ± 0.15 mm thick. (See 2.0 mm thick test pieces.)
7.0 ± 1.0	BS 903 : Part A8 (Method A)	Where the quantity of material is limited, a test piece 4.0 mm thick may be used with caution using the Dunlop Tripsometer.
8 to 10	BS 903 : Part A26 (Methods N & H), A63	Plied test pieces are commonly used for measuring hardness, providing one of the test pieces is not less than 6.0 mm thick.
12.5 ± 0.5	BS 903 : Part A4, A6, A8 (Method B) A9 (Method B) A15, A24 (in compression), A42	Test pieces of this thickness are usually directly moulded to shape.
25 ± 0.25	BS 903 : Part A50	Test pieces of this thickness are usually directly moulded to shape.

Table 2. Multi-purpose test pieces

Test piece	Properties measured		Notes
	Standard uses	Other recognized uses	
Cut from sheet			
Types 1 and 2 dumb-bells (BS 903 : Part A2)	Tensile stress-strain, tension fatigue resistance	Tension set, static ozone resistance, green strength	1
Ring test pieces (BS 903 : Part A2)	Tensile stress-strain, tension fatigue resistance	Tension set	2
T50 dumb-bell	Tension set, low temperature resistance by temperature retraction	Static and dynamic ozone resistance, tensile modulus	3
Normally moulded			
Disc 13.0 mm diameter × 6.3 mm thick	Compression set, resistance to creep, resistance to stress relaxation, dynamic properties (in compression)	Apparent microhardness	4
Disc 29.0 mm diameter × 12.5 mm thick	Compression stress-strain, compression set, resistance to creep, resistance to stress relaxation, rebound resilience (BS 903 : Part A8 Method B), dynamic properties (in compression)	Hardness, rubber-to-metal bond strength (using already vulcanized rubber)	
Disc 44.6 mm diameter × 7.0 mm thick	Rebound resilience (BS 903 : Part A8 Method A), crystallization resistance by hardness change	Hardness	
Rubber-to-metal bonded			
Quadruple shear test piece	Shear modulus, rubber-to-metal bond strength, resistance to creep, dynamic properties		5
Double shear test piece	Resistance to creep, dynamic properties		5

NOTE 1. Dumb-bells are also used for the determination of ageing resistance, (BS 903 : Part A19), and resistance to liquids, (BS 903 : Part A16), as expressed by change in tensile stress-strain properties. Another common use is determination of apparent hardness on piled tab ends so that the change in hardness during ageing can be monitored.

Dumb-bells have also been used to measure stress retention in tension, although strip test pieces are generally preferred for this purpose (BS 903 : Part A52).

NOTE 2. Ring test pieces are also suitable for the determination of tension fatigue resistance under non-relaxing conditions, which is outside the scope of BS 903 : Part A51.

NOTE 3. The standard tests involved use test pieces having a reference length of 50 mm or 100 mm. A length of 50 mm is advised in the notes in BS 903 : Parts A43 and A44 which allow the use of T50 dumb-bell, for ozone resistance testing.

NOTE 4. The small compression set test piece (sometimes known as the type B or type 1 test piece) also meets the requirements for the type 2 test piece of ISO 6471 (Determination of crystallization effects under compression). ISO 6471 has not been adopted as a British Standard.

NOTE 5. The quadruple shear test piece described in BS 903 : Part A14 and the double shear test piece described in BS 903 : Part A15 can be made of rigid plates other than metal, but steel is usually specified.

Table 3. Test methods for measuring processability

Characteristic or process	Property being measured	Tests available
Storage stability	Resistance to crystallization	BS 903 : Part A63
	Scorch safety	BS 903 : Part A58
Ease of mixing	Degree of mastication and viscosity control	BS 903 : Part A58 and Part A59
	Dispersion of ingredients	See note 1
Flow behaviour	Viscosity	BS 903 : Part A58 and Part A59
Nerve	Recovery	ISO 7323
Building operations	Green strength	BS 903 : Part A62
Optimum cure	Vulcanization characteristics	BS 903 : Part A60

NOTE. An ISO test method for measurement of carbon black dispersion is being prepared. An alternative approach is to determine vulcanizate properties known to be sensitive to the level of dispersion, such as tensile stress-strain characteristics (BS 903 : Part A2), tear strength (BS 903 : Part A3) and tension fatigue resistance (BS 903 : Part A51).

Table 4. Test methods suitable for design data

Characteristic	Property measured	Test	Notes
Static deformation			
Force-deflection characteristics	Stress-strain properties		1
	– in compression	BS 903 : Part A4	
	– in shear	BS 903 : Part A14	
Retention of stress or strain	Creep in compression or shear	BS 903 : Part A15	2
	Stress relaxation in compression	BS 903 : Part A42	
Cyclic deformation			
Force-deflection characteristics	Dynamic stress-strain properties	BS 903 : Part A24, A31	3
Damping, transmissibility	Loss properties (e.g. phase angle)	BS 903 : Part A24, A31	3
Fatigue	Tension fatigue life	BS 903 : Part A51	4
Physical constants			
Density	Density	BS 903 : Part A1	
Friction	Coefficient of friction	BS 903 : Part A61	
Permeability to fluids	Permeability	BS 903 : Part A17, A30	
Thermal properties	Thermal conductivity	BS 874 : Part 2	
	Thermal expansion; heat content	BS 4618 : Section 3	

NOTE 1. Compression modulus and stress-strain behaviour can be measured under both lubricated (i.e. with slip) and bonded (i.e. without slip) test conditions. For bonded, the stiffness is shape-dependent, increasing with the ratio of the area to which the force is applied to the total force-free area (shape factor). An equation relating compression modulus, shape factor and Young's modulus is given in BS 903 : Part A4 for non-standard test pieces and use with products.

NOTE 2. Physical creep or stress relaxation directly proportional to logarithmic time can sometimes be extrapolated to give a minimum estimate of long term behaviour. The long term contribution of creep or stress relaxation caused by oxidation and network changes in the rubber is less easily predicted because of the need to estimate rates from tests undertaken at elevated temperatures and to take account of the effect of thickness on thermal oxidation. Some agreement has been reported between long term creep measurements and predictions made from an equation combining physical and chemical creep (see P. B. Lindley [2]).

NOTE 3. Guidance on selection of mode and amplitude of deformation and frequency is given in BS 903 : Part A24 (see also B.3).

NOTE 4. The fatigue test described in BS 903 : Part A51 is related to the more fundamental crack growth behaviour of rubber and its dependence on maximum deformation, stress or strain energy density during the cycle. The test can be used to estimate the mechanical fatigue limit of the rubber, the strain below which fatigue life becomes very long (typically more than 2 million cycles) in the absence of chemically induced crack growth such as ozone attack.

BS 903 : Part A51 does not provide for measurements of fatigue life under the non-relaxing conditions typical of many rubber springs, but the test can be modified for this purpose.

Table 5. Evaluation of rubbers

Method	Test property	Usual conditions	Notes
Processability tests			
BS 903 : Part A58	Mooney viscosity	ML1 + 4, 100 °C	1
BS 903 : Part A58	Mooney scorch time	t_5 at 120 °C	2
BS 903 : Part A60	Vulcanizing characteristics by curemetering	M_L, M_H (M_{HR}), t_{s1}, $t'_c(90)$ or $t'_c(95)$	3
Vulcanizate properties			
BS 903 : Part A26	Hardness	IRHD	4
BS 903 : Part A2	Tensile stress-strain characteristics	Tensile strength, elongation at break, M100, M300	5
BS 903 : Part A6	Compression set	22 h or 70 h at a standard temperature	6
BS 903 : Part A19	Heat resistance: accelerated ageing	Air oven ageing at specified combinations of time and temperature	7
BS 903 : Part A43	Ozone resistance	50 pphm ozone, 40 °C, 20 % strain	8
BS 903 : Part A16	Resistance to liquids	As specified	9
BS 903 : Part A25	Low temperature brittleness	Brittleness temperature	10

NOTE 1. An 8 min running time (ML1 + 8) is sometimes specified for IIR (BS 4470), BIIR and CIIR, and a test temperature of 125 °C is usually required for EPDM and EPM (BS 6063).

NOTE 2. A test temperature of 120 °C is now in widespread use for determination of scorch resistance but other temperatures may be specified.

NOTE 3. $t'_c(50)$ is sometimes also specified. The choice of $t'_c(90)$ or $t'_c(95)$ for cure time varies with rubber type and properties being measured.

NOTE 4. In British Standard specifications the International Rubber Hardness Degree (IRHD) scale is generally used. The Shore A hardness scale (BS 903 : Part A57) is not recommended except for quality control measurements, but it does appear in place of IRHD in many foreign specifications, especially in US standards.

In material specifications hardness is often used as a classification criterion expressed in multiples of 10 degrees between 30 IRHD and 90 IRHD.

NOTE 5. Tensile stress-strain properties are usually determined on type 1 or type 2 dumb-bells. M100 and M300 are the stresses at 100 % and 300 % elongations respectively.

NOTE 6. When conducted at an elevated temperature, the compression set test is usually a measure of the state of cure of vulcanized rubber, although it can be affected by compounding ingredients other than the vulcanizing system.

Commonly used test temperatures are 70 °C for NR, IR, BR, SBR and other sulfur-vulcanized rubbers, 100 °C for CR, NBR, IIR, EPM, and EPDM, 125 °C for EPM, EPDM and CSM, 150 °C for polyacrylates and 175 °C and higher temperatures for silicone and fluorocarbon rubbers.

NOTE 7. BS 903 : Part A19 is normally used in conjunction with BS 903 : Part A2 and A26 so that resistance to heat or to ageing is measured by change in hardness (the difference in IRHD) and in tensile strength, elongation at break and modulus (where the percentage difference is recorded).

Commonly used ageing times are 3 days, 7 days and 14 days at temperatures determined by the thermal-oxidative stability of the rubber. Of the standard test temperatures, 70 °C is popular with NR, SBR and other general-purpose rubbers, 100 °C with CR, NBR, EPM, EPDM and IIR, 125 °C with EPM, EPDM, IIR and CSM, 150 °C with polyacrylates and 175 °C and above with silicone and fluorocarbon rubbers. Examples are given in BS 5176.

NOTE 8. The test conditions shown for ozone testing have become the most popular in general-purpose specifications but BS 903 : Part A43 allows for a number of combinations of ozone concentration, chamber temperature and test strain (see annex F).

NOTE 9. For classification purposes, oil resistance is commonly measured in terms of the degree of swell after immersion in standard oil No. 3 (ASTM Reference Oil No. 3) at an elevated temperature. Attention is again drawn to BS 5176. Other liquids may be used and some are described in the annex to BS 903 : Part A16.

NOTE 10. Brittleness temperature is among the most popular of the low temperature resistance tests and is one of the three classification criteria in ISO 4632, the international equivalent to BS 5176 Other tests such as BS 903 : Part A13 are also used (see annex E).

Table 6. Evaluation of compounding ingredients and ancillary materials

Ingredient or material	Method
Antidegradants	BS 903 : Part A10, A11, A19, A33, A43, A44, A51, A52, A53, A54, A55
Antioxidants	BS 903 : Part A19, A33, A52, A53, A54, A55
Antiozonants	BS 903 : Part A33, A43, A44, A53, A54, A55
Anti-flex cracking agents	BS 903 : Part A10, A11, A33, A51
Light stabilizers	BS 903 : Part A33, A53, A54, A55
Fillers	BS 903 : Part A1, A2, A3, A9, A26
Plasticizers	BS 903 : Part A2, A6, A13, A25, A26, A29
Vulcanizing systems	BS 903 : Part A58 (Mooney scorch), A60 (curemetering), A2, A6, A19, A26
Bonding agent for rubber-to-metal adhesion	BS 903 : Part A14, A21, A40
Bonding agent for rubber-to-textile adhesion	BS 903 : Part A12, A27, A47

Table 7. Small test pieces suitable for product testing

Relevant Part of BS 903	Type of test piece or procedure, where choice exists	Smallest test piece, length × width × thickness (× number required)1)2)	Comments
A1	Method A	2.5 g (× 2)	Specified by mass
A2	Dumb-bell	35 × 6 × 1 (×3)	Type 4 dumb-bell, see note 1
	Ring	10 ext diameter × 1 (× 3)	Type B ring
A3	Method A	100 × 15 × 2 (×5)	Trouser test piece, see note 2
A4		29 diameter × 12.5 (× 3)	
A5	Strip	> 25 × 2 × 2 (× 3)	25 refers to reference length
A6	Type B	13 diameter × 6.3 (× 3)	Can be laminated from thinner sheets, see note 3
A8	Method A	8 × 8 × 4 (× 2)	Dunlop Tripsometer, see note 4
A9	Method A	16 diameter × 2 (× 1 or 3)	Bond to base element, see note 5
A12	Strip	> 100 × 25 (× 2)	Thickness to be sufficient to resist breaking during separation
A13		40 × 3 × 2 (× 3)	
A14		4 × 25 × 20 × 4 (× 3)	Test piece needs four identical parallelepipedic elements
A15	Compression	13 diameter × 6.3 (× 3)	
	Shear	25 diameter × 6.3 (× 3)	Preferred dimensions
A16	Volumetric	1 cm^3 to 3 cm^3 (× 3)	Specified by volume
	Surface area	8 × 8 × 2 (× 3)	Rhomboid in shape
	Other tests	As required	e.g. BS 903 : Part A2, A26
A17		50 diameter (× 1)	800 mm^3 min. surface area
A18		1 g (× 2)	Finely-divided form, specified by mass

Table 7. Small test pieces suitable for product testing (*continued*)

Relevant Part of BS 903	Type of test piece or procedure, where choice exists	Smallest test piece, length × width × thickness (× number required)1)2)	Comments
A19		As required by other tests	e.g. BS 903 : Part A2
A21	Method A	35 diameter × 3 (× 4)	Normally moulded test pieces
	Method B	125 × 25 × 6 (× 4)	
A24	Compression	13 diameter × 6.3 (× 3)	See note 6.
	Other modes of deformation except shear	1 mm thick (× 3)	
A25	Type A	25 × 6 × 2 (× 4)	Strip test piece
A26	Microtest	6 × 6 × 2	No test is made less than 2 mm from edge
	Normal (N)	30 × 30 (× 8)	No test is made less than 9 mm from edge. See note 7.
A27		32 × 32 (× 5)	No thickness requirement
A29		63 × 6.5 × 2 (× 3)	50 mm reference length
A30		50 diameter (× 1)	800 mm^3 min. surface area
A31		40 × 4 × 1 (× 2)	
A33	Method A	25 × 12 × 2 (× 1)	
	Method B	150 × 25 × 2 (× 1)	
	Method C	25 × 12 × 2 (× 1)	
A37	Method A	20 × 20 × 2 (× 2)	
	Method B	50 × 25 × 2 (× 2)	
A42	Small cylindrical disc	13 diameter × 6.3 (× 2)	
	Ring	19 external diameter × 2 (× 2)	
A43	Procedures B and C	50 × 12 × 2 (× 3)	T50 dumb-bell
A44		50 × 12 × 2 (× 3)	T50 dumb-bell
A46		ca 50 diameter × 0.2-2 (× 3)	2 mm thickness if test sheet is used
A50		17.8 diameter × 25 (× 1)	Normally moulded test piece
A51	Dumb-bell	75 × 12.5 × 1.5 (× 5)	Type 2 dumb-bell
	Ring	52.6 ext diameter × 1.5 (× 5)	
A52	Methods A and B	80 × 4 × 1 (× 3)	
	Method C	150 × 10 × 1 (× 3)	
A53	Varies	As required by other tests	e.g. BS 903 : Part A43
A54	Colour change	15 × 15 × 2 (× 3)	
	Other tests	As required	e.g. BS 903 : Part A2

Table 7. Small test pieces suitable for product testing *(concluded)*

Relevant Part of BS 903	**Type of test piece or procedure, where choice exists**	**Smallest test piece, length × width × thickness (× number required)[1)2)]**	**Comments**
A57		30 × 30 × 6 (× 1)	Centre of indentor to be at least 12 mm from edge. See note 7.
A63		30 × 30 × 8 (× 1)	No test is made less than 9 mm from edge. See note 7.

1) All dimensions in millimetres unless otherwise indicated.

2) For dumb-bell test pieces the width given in that of the tab end.

NOTE 1. The need for small tensile test pieces for product testing is recognized in specifications such as BS 2494 and BS 6469. In BS 903 : Part A2, 2 mm is a preferred thickness for types 1 and 2 dumb-bells. However, it is understood that neither this thickness nor the 1 mm specified for the type 4 dumb-bell can be achieved for many thin-walled products, such as those produced by latex dipping. In these cases, the test thickness is that of the product, provided it is uniform. The same allowance extends to BS 903 : Parts A3, A5, A16, A33, A44, A52, A53, A54 and A55.

NOTE 2. A small test piece suitable for testing finished products is the Delft test piece described in ISO 816. The dimensions are 60 mm × 9 mm × 2 mm. The test has not been adopted as a British Standard.
Smaller, non-standard, trouser test pieces have been used.

NOTE 3. Test pieces for measuring compression set may be prepared by laminating discs of rubber cut from sheets or flat thin-walled products provided that the number of discs does not exceed three for the small type B test piece and seven for the 29 mm dia. 12.5 mm thick, large type A test piece. The thickness of each disk in the laminate will normally be at least 2 mm. Lamination of a standard test piece is not always possible and for routine testing or product specifications it is sometimes more convenient to prepare test pieces of a different size or shape or both than those in BS 903 : Part A6. In BS 2494 test pieces measuring 5 mm or 7 mm in diameter and 3.5 mm in thickness are permitted alternatives to the standard small test piece.

NOTE 4. BS 903 : Part A8 gives some guidance on the resilience testing of samples which are thinner than the standard test pieces. Two procedures may be used for this purpose:

a) the adjustment of the conditions of impact so that the same constant value of apparent strain energy density is maintained; and

b) the stacking of no more than three thin test pieces to obtain a greater thickness.

NOTE 5. The standard test piece for the Method A abrasion resistance test measures 16 mm diameter and 6 mm in height and is still smaller than the test pieces required for the other three methods in BS 903 : Part A9. One test piece is permissible if the mass loss is low. For products in sheet form, Method D (Rotary platform double head type) is particularly suitable as it applies to a minimum sheet thickness of 2 mm.

NOTE 6. Test piece shape and dimensions for dynamic properties will vary with the mode of deformation and the type and capacity of the testing machine. The dimensions given in the table are the smallest of the preferred dimensions in BS 903 : Part A24. For tests in shear, double shear test pieces are preferred.

NOTE 7. Lateral dimensions are no longer specified for hardness tests, but they need to be such that no test is made from a distance from the edge of the test piece less than the distance quoted. Non-standard test pieces 4 mm thick may be used for BS 903 : Part A63. Non-standard test pieces 1 mm thick may be used for the microtest in BS 903 : Part A26.

Table 8. Test methods for quality control

Method	Test property	Measurement of	Principal compounding ingredients involved
Raw rubbers and mixes			
BS 903 : Part A58	Mooney viscosity	Mastication, mixing	Rubber, peptizer, process aids, fillers and extenders (see note 1)
BS 903 : Part A59	Wallace rapid plasticity	Mastication, mixing	Rubber, peptizer, process aids, fillers and extenders
BS 903 : Part A60	Curemetering	Scorch safety, cure rate, state of cure	Vulcanizing system
BS 903 : Part A58	Mooney scorch	Heat history	Vulcanizing system (see note 2)
Vulcanized rubbers			
BS 903 : Part A1	Density	Composition, degree of expansion (see note 3)	Fillers, blowing agents
BS 903 : Part A2	Tensile strength and elongation at break	Dispersion, freedom from adulterants, state of cure	Rubber, fillers, extenders and vulcanizing system
BS 903 : Part A2	Modulus	State of cure, reinforcment, extension, anisotropy	Vulcanizing system, fillers and extenders
BS 903 : Part A6	Compression set	State of cure	Vulcanizing system
BS 903 : Part A16	Swelling, gravimetric or volumetric	Oil resistance, state of cure	Rubber type, vulcanizing system
BS 903 : Part A19	Accelerated ageing (see note 4)	Thermal-oxidative stability	Antioxidants, type of vulcanizing system
BS 903 : Part A26	Hardness	State of cure, reinforcement, oil extension	Vulcanizing system, fillers and extenders

NOTE 1. Extenders include process oils and plasticizers.

NOTE 2. Scorch safety is affected not only by choice of vulcanizing system and other ingredients, but by the heat input of the compound during mixing and subsequent processing.

NOTE 3. Density is a measure of how closely a mix or vulcanizate matches its formulation, with particular respect to bulk fillers having higher densities than that of the base rubber. Density is also used as a measure of the degree of expansion in cellular rubber products.

NOTE 4. Change in properties after accelerated ageing is usually assessed by BS 903 : Part A2.

Table 9. Quality control of materials, processing and vulcanization

Item	Test property	Method
Ingredients		
Rubber type	Tensile strength and elongation at break Oil resistance Heat resistance Low temperature resistance	BS 903 : Part A2 BS 903 : Part A16 BS 903 : Part A19 BS 903 : Part A13
Vulcanizing system	Curemetering Mooney scorch Compression set Heat resistance	BS 903 : Part A60 BS 903 : Part A58 BS 903 : Part A6 BS 903 : Part A19
Fillers	Tensile strength and elongation at break Modulus Hardness Density	BS 903 : Part A2 BS 903 : Part A2 BS 903 : Part A26 BS 903 : Part A1
Process aids	Mooney viscosity	BS 903 : Part A58
Plasticizers	Mooney viscosity Low temperature resistance	BS 903 : Part A58 BS 903 : Part A13
Antioxidants	Accelerated ageing	BS 903 : Part A19
Antiozonants	Ozone resistance	BS 903 : Part A43
Bonding systems	Adhesion tests	BS 903 : Part A40
Mixing, processing and vulcanization		
Mastication; mixing	Mooney viscosity Wallace rapid plasticity	BS 903 : Part A58 BS 903 : Part A59
Dispersion of ingredients	Tensile strength	BS 903 : Part A2
State of cure	Curemetering Tensile strength and elongation at break Hardness Compression set	BS 903 : Part A60 BS 903 : Part A2 BS 903 : Part A26 BS 903 : Part A6
Expansion; porosity	Density	BS 903 : Part A1
Freedom from adulterants	Tensile strength and elongation at break	BS 903 : Part A2

Annexes

Annex A (informative)

Property gradations in material specifications

A.1 General

This annex provides preferred numerical values for the gradation of various physical properties of rubber determined in accordance with standard methods of test. It is technically equivalent to ISO 1433 and although based on the properties of vulcanized rubber it should be applicable to thermoplastic rubbers.

It is intended to serve as a guide to anyone responsible for the specification of rubber materials. The intention is that the derived property limit will be selected from the list given in table A.1 so that unnecessary variations in requirements for rubber materials can be avoided.

The property values given for each property are representative of the values that can be achieved with existing rubber materials, but no one rubber material is expected to meet the range provided. Each property is considered individually, therefore, any combination of limits for different properties is not necessarily obtainable. Acceptable properties should be agreed between the parties concerned. It is recognized that the list will not be acceptable for all purposes.

If the dimensions of a rubber product do not permit the use of the standard test piece, an alternative test piece may be used. In this case, the results may differ from those obtainable using the standard test piece, and the acceptable deviations should be agreed between the manufacturer and the purchaser.

A.2 Selecting the gradations

Find the property to be specified in the table and examine the list of preferred gradations given alongside. Select the gradation or gradations most appropriate for the material being specified and for the test conditions being used.

It should be recognized that no relationship is intended between gradations given for different properties. Each group of gradations is independent of any other. For example, a rubber material having the lowest hardness gradation (20 IRHD) will not necessarily have the lowest tensile strength (3 MPa).

NOTE. In the case of tests for heat resistance and resistance to liquids, two gradations may be required for a given property, one applying to a permissible increase and the other to a permissible decrease. Care should be taken to ensure such combinations are practicable. Thus the gradation '0' may be used to indicate that either no increase or no decrease in property is allowed, but it should not be used for both. These two gradations, in the case of change in tensile strength and change in elongation, should be selected so that the range between the two values will not be less than 20 %. For example, 0 and − 20 and − 10 and + 10 give acceptable ranges; + 5 and − 5, or 0 and + 10, do not.

Table A.1 List of properties with preferred gradations and methods of test

NOTE. This table is identical to that given in ISO 1433 except that the ISO test methods have been replaced by their BS equivalents.

Property group	Property	Unit	Maximum or minimum or tolerances	Gradations	Method of test
Mechanical properties	Hardness	IRHD	+5 −4	20; 30; 40; 50; 60; 70; 80; 90	BS 903 : Part A26
	Tensile strength	MPa	min.	3; 5; 7; 10; 14; 17; 20; 25; 30; 35; 40	BS 903 : Part A2
	Elongation at break	%	min.	50; 100; 150; 200; 250; 300; 350; 400; 450; 500; 600; 700	BS 903 : Part A2
	Stress at specified elongation	MPa	range (min. to max.)	0.8; 0.8 to 1.5; 1.6 to 3.0; 3.1 to 7.0; 7.1 to 10.0; 10.1 to 15.0; 15.1 to 20.0; 20.1 to 25.0; 25.1 to 30.0; 30.1 to 35.0	BS 903 : Part A2
	Modulus in shear	MPa	range (min. to max.)	0.20 to 0.30; 0.31 to 0.40; 0.41 to 0.60; 0.61 to 0.80; 0.81 to 1.0; 1.1 to 1.5; 1.6 to 2.5; 2.6 to 4.0	BS 903 : Part A14
	Tear strength (trouser test piece)	kN/m	min.	2; 5; 10; 20; 30; 40	BS 903 : Part A3
	Tear strength (crescent test piece)	kN/m	min.	5; 10; 15; 20; 30; 60; 90	BS 903 : Part A3
	Tear strength (angle test piece)	kN/m	min.	5; 10; 15; 20; 30; 60; 90	BS 903 : Part A3
	Tear strength (Delft test piece)	N	min.	10; 30; 50; 70; 90; 110	ISO 816
	Abrasion resistance index	—	min.	40; 60; 90; 120; 160; 220; 300; 400	BS 903 : Part A9
Heat resistance and accelerated ageing	Increase in hardness	IRHD	max.	25; 20; 15; 10; 5; 0	BS 903 : Part A19 and BS 903 : Part A26
	Decrease in hardness	IRHD	max.	20; 15; 10; 5; 0	
	Increase in tensile strength	%	max.	0; 10; 20; 30	BS 903 : Part A19 and BS 903 : Part A2
	Decrease in tensile strength	%	max.	60; 50; 40; 30; 20; 10; 0	
	Increase in elongation at break	%	max.	0; 10; 20; 30	BS 903 : Part A19 and BS 903 : Part A2
	Decrease in elongation at break	%	max.	60; 50; 40; 30; 20; 10; 0	
Ozone-resistance	Static strain conditions – threshold strain	%	min.	10; 20; 30; 40; 50; 60; 80; 100; 120	BS 903 : Part A43
	Dynamic strain – time to first crack	h	min.	16; 24; 48; 72	BS 903 : Part A44

Table A.1 List of properties with preferred gradations and methods of test (*continued*)

NOTE. This table is identical to that given in ISO 1433 except that the ISO test methods have been replaced by their BS equivalents.

Property group	Property	Unit	Maximum or minimum or tolerances	Gradations	Method of test
Compression set and tension set	Compression set	%	max.	80; 60; 50; 45; 40; 35; 30; 25; 20; 15; 10	BS 903 : Part A6
	Tension set	%	max.	80; 60; 50; 40; 30; 25; 20; 15; 10; 5	BS 903 : Part A5
Stress relaxation and creep	Stress relaxation in compression	%	max.	30; 25; 20; 15; 10; 5	BS 903 : Part A42
Resistance to liquids (including chemical resistance)	Change in volume				
	Increase	%	max.	140; 120; 100; 80; 70; 60; 50; 40; 35; 30; 25; 20; 15; 10; 5; 0	BS 903 : Part A16
	decrease	%	max.	20; 15; 10; 5; 0	
	Change in mass				
	increase	%	max.	140; 100; 80; 60; 50; 25; 15; 10; 5; 0	BS 903 : Part A16
	decrease	%	max.	20; 15; 10; 5; 0	
	Change in hardness				
	increase	IRHD	max.	30; 25; 20; 15; 10; 5; 0	BS 903 : Part A16 and BS 903 : Part A26
	decrease	IRHD	max.	30; 25; 20; 15; 10; 5; 0	
	Change in tensile strength				
	increase	%	max.	0; 10; 20; 30	BS 903 : Part A16 and BS 903 : Part A2
	decrease	%	max.	60; 50; 40; 30; 20; 10; 0	
	Change in elongation at break				
	increase	%	max.	0; 10; 20; 30	BS 903 : Part A16 and BS 903 : Part A2
	decrease	%	max.	60; 50; 40; 30; 20; 10; 0	
Dynamic properties	Rebound resilience	%	min. or max.	10; 20; 30; 40; 50; 60; 70; 80; 90	BS 903 : Part A8
	Flexometer fatigue: compression flexometer test				
	temperature rise	°C	max.	50; 40; 30; 20	BS 903 : Part A50
	compression set	%	max.	60; 50; 40; 30; 25; 20; 15; 10; 5	
	resistance to fatigue	cycles (× 10^3)	min.	8; 15; 30; 60; 120; 250; 500	
	Flex resistance (de Mattia)				
	flex cracking	cycles (× 10^3)	min.	50; 100; 200; 500; 1000	BS 903 : Part A10
	crack growth	cycles (× 10^3)	min.	5; 10; 30; 50; 100; 200; 400	BS 903 : Part A11

Table A.1 List of properties with preferred gradations and methods of test (*continued*)

NOTE. This table is identical to that given in ISO 1433 except that the ISO test methods have been replaced by their BS equivalents.

Property group	Property	Unit	Maximum or minimum or tolerances	Gradations	Method of test
Low temperature resistance	Brittleness temperature	°C	max.	0; -5; -10; -15; -20; -25; -30; -35; -40; -45; -50; -55; -60; -65; -70; -75; -80	BS 903 : Part A25
	Torsional modulus test, T_2,T_5,T_{10},T_{100} and temperature to 70 MPa max.	°C	max.	0; -5; -10; -15; -20; -25; -30; -35; -40; -45; -50; -55; -60; -65; -70; -75; -80	BS 903 : Part A13
	Compression set	%	max.	80; 60; 50; 40; 30; 25; 20; 15; 10	BS 903 : Part A6
	Hardness increase	IRHD	max.	30; 25; 20; 15; 10; 5	BS 903 : Part A26 and BS 903 : Part A63
	Temperature retraction test (TR-test) TR10, TR30, TR50, TR70	°C	max.	0; -5; -10; -15; -20; -30; -35; -40; -45; -50; -55; -60; -65; -70; -75; -80	BS 903 : Part A29
Electrical properties	Volume resistivity	Ω m	range (min. to max.)	$< 5 \times 10^2$; 5×10^2 to 5×10^6; 5×10^6 to 5×10^{10}; 5×10^{10} to 5×10^{14}; $> 5 \times 10^{14}$	BS 903 : Part C2
	Electrical insulation resistance	Ω	(min. to max.)	5×10^4; 5×10^6; 5×10^8; 5×10^{10}; 5×10^{12}; 5×10^{14}; 5×10^{16}	BS 903 : Part C5
	Breakdown voltage	MV/m	min.	5; 10; 15; 20	BS 904 : Part C4
Staining and contact properties	Staining in contact with organic materials: degree of staining	grey scale	range (max. to min.)	<1; 1; 3 to 2; 5 to 4 (see note 1)	BS 903 : Part A33
	Corrosion of metals			See note 2	BS 903 : Part A37 Method A

Table A.1 List of properties with preferred gradations and methods of test *(concluded)*

NOTE. This table is identical to that given in ISO 1433 except that the ISO test methods have been replaced by their BS equivalents.

Property group	Property	Unit	Maximum or minimum or tolerances	Gradations	Method of test
Adhesion properties	Adhesion to textiles	kN/m	min.	1; 2; 3; 4; 5; 6; 7; 8	BS 903 : Part A12
	Adhesion to metal: One-plate method	kN/m	min.	3; 6; 9; 12; 15; 18; 21; 24	BS 903 : Part A21
	Adhesion to metal: Two-plate method	MPa	min.	1; 1.5; 2; 3; 5; 7; 9	BS 903 : Part A21
	Adhesion to rigid material: to rigid plate in shear	MPa	min.	0.5; 1.0; 1.5; 2.0; 2.5; 3.0; 4.0; 5.0; 6.0; 8.0	BS 903 : Part A14
	Adhesion to rigid material: to conical ends of rigid material	N	min.	0.5; 1.0; 1.5; 2.0; 2.5; 3.0; 4.0; 5.0; 6.0; 8.0; 10.0	BS 903 : Part A40
Permeability	Permeability to gases : constant volume	$m^2 \cdot Pa^{-1}s^{-1}$ ($\times 10^{-17}$)	max.	2; 5; 10; 15; 20; 25; 30; 40; 50; 60; 80; 100	BS 903 : Part A17
	Permeability to gases : constant pressure	$m^2 \cdot Pa^{-1}s^{-1}$ ($\times 10^{-17}$)	max.	2; 5; 10; 15; 20; 25; 30; 40; 50; 60; 80; 100	BS 903 : Part A30

NOTE 1. According to BS 903 : Part A33 these gradations correspond respectively to severe staining, moderate staining, slight staining and no staining as assessed by visual inspection.

NOTE 2. In BS 903 : Part A37 the degree of metal corrosion is assessed by visual inspection according to the following criteria:

a) no surface stain or corrosion;

b) surface stain or discoloration, but no pitting or erosion;

c) corrosion as evidenced by pitting and erosion.

Annex B (informative)

Bibliography of useful publications on rubber testing and associated topics

B.1 General

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Annex C (informative)
International equivalents of British Standards referred to in this guide

NOTE. Equivalence depends on the Part of the standard. Consult British Standards Catalogue for details.

≡ identical
= technically equivalent
≠ related
-- no equivalent

BS no.	ISO no.	BS no.	ISO no.
0.3	--	903 : Part A37	= 6505
476	See note	903 : Part A38	≡ 4648
600	--	903 : Part A40	≡ 5600
874 : Part 1	--	903 : Part A42	≡ 3384
874 : Part 2	≠ 8302	903 : Part A43	≡ 1431/1
903 : Part 0	--	903 : Part A44	≡ 1431/2
903 : Part A1	≡ 2781	903 : Part A45	≡ 1431/3
903 : Part A2	≡ 37	903 : Part A46	≡ 6179
903 : Part A3	≡ 34/1	903 : Part A47	≡ 6133
903 : Part A4	≡ 7743	903 : Part A48	≡ 4647
903 : Part A5	≡ 2285	903 : Part A49	≡ 4666/1
903 : Part A6	≡ 815	903 : Part A50	≡ 4666/3
903 : Part A8	≠ 4662	903 : Part A51	≡ 6943
903 : Part A9	≠ 4649, 5470	903 : Part A52	≡ 6914
903 : Part A10	≡ 132	903 : Part A53	≡ 4665/2
903 : Part A11	≡ 133	903 : Part A54	≡ 4665/3
903 : Part A12	≡ 36	903 : Part A55	≡ 4665/1
903 : Part A13	≡ 1432	903 : Part A56	≡ 7619
903 : Part A14	≡ 1827	903 : Part A57	≡ 5603
903 : Part A15	≡ 8013	903 : Part A58	≠ 289
903 : Part A16	≡ 1817	903 : Part A59	= 2007, 2930
903 : Part A17	= 1399	903 : Section 60.1	--
903 : Part A18	--	903 : Section 60.2	≡ 3417
903 : Part A19	≡ 188	903 : Part A61	--
903 : Part A21	= 813,814	903 : Part A62	≡ 9026
903 : Part A24	≠ 2856, 4664	903 : Part A63	≡ 3387
903 : Part A25	≡ 812	903 : Part C1	≠ IEC 93
903 : Part A26	≡ 48	903 : Part C2	≠ IEC 93
903 : Part A27	≡ 4637	903 : Part C4	≠ IEC 243
903 : Part A29	≡ 2921	903 : Part C5	≠ 2951, IEC 167
903 : Part A30	≠ 2782	1154	--
903 : Part A31	≠ 4663	1155	--
903 : Part A32	≡ 3383	2044	≠ 1853, 3915
903 : Part A33	≡ 3865	2494	≠ 4633, 6447, 6448
903 : Part A35	≡ 471	2635	--
903 : Part A36	≡ 4661/1	2751	--

BS no.	ISO no.
2752	--
2782 : Section 120A	≡ 306
2782 : Section 141	≡ 4589
2782 : Section 335A	≡ 178
2782 : Section 350	≡ 180
2782 : Section 720A	= 1133
2846 : Part 3	≡ 3207
3227	--
3424	See note
3424 : Part 5	--
3424 : Part 7	≠ 2411
3424 : Part 10	--
3502 : Part 2	= 1629
3558	≠ 1382
3574	≠ 2230
3734	≡ 3302
4470	≡ 2302
4618	--
4832	≡ 6072
4891	--
5047	≡ 2476
5173	See note
5176	≠ 4632, TR 8461
5214 : Part 1	≠ 5893
5214 : Part 2	--
5293	See note
5324	--
5375	≠ 2475
5400 : Section 9.2	≠ 6446
5421	--
5474	≡ 2303
5497 : Part 1	≡ 5725
5563	≡ 4659
5701	--
5703 : Part 3	--
5703 : Part 4	--
5729	--
5738	≠ 1658
5760 : Part 5	≠ IEC 812
5781 : Part 1	≡ 10012-1
6000	= 2859
6001	See note
6002	≡ 3951
6014	--
6063	≡ 4097
6064	≡ 4658
6177	--
6315	= 1765, 1796
6366	--
6449 : Part 2	≡ 5794/2
6469	See note
6716	--
6845	≡ 7663
6882	≠ TR 7664
6920 : Part 1	--
6920 : Part 2	--
6995	≡ 2322
6996	--
7000	--
7008 : Part 1	≡ 10350
7008 : Part 2	--
7164	See note
7229	≡ 10011/1-3
7373	--
7442 : Section 2.1	≡ 7267/1
7442 : Section 3.2	≡ 7267/2
7501	≠ Guide 2, Guide 25 ≡ EN 45501
7663	--
EN ISO 9000	≡ 9000
EN ISO 9001	≡ 9001
EN ISO 9004	≡ 9004

Annex D (informative)

Guide to test methods for properties of rubber

The following list is a property guide to BS 903 and other standards suitable for rubber (see clause 5). To assist users who may be unfamiliar with the methods, the list is not confined to terms used in the titles of the standards and in individual procedures. Some common names and synonyms are included.

Property standard

abrasion	BS 903 : Part A9
absorption	
liquids	BS 903 : Part A16
water vapour	BS 903 : Part A18
accelerated testing	
ageing	BS 903 : Part A19, A52
light	BS 903 : Part A54
ozone	BS 903 : Part A43, A44, A45
weathering	BS 903 : Part A54
adhesion	
analysis of traces	BS 903 : Part A47
conical test piece	BS 903 : Part A40
fabrics	BS 903 : Part A12, A27
fortuitous adhesion to metals	BS 903 : Part A37
metals	BS 903 : Part A14, A21, A40
quadruple shear test	BS 903 : Part A14
rigid substrates	BS 903 : Part A40
textile cord	BS 903 : Part A48
wire cord	BS 903 : Part A56
ageing	
accelerated	BS 903 : Part A19
air oven	BS 903 : Part A19
artificial light	BS 903 : Part A54
natural	BS 903 : Part A53
oxygen pressure	BS 903 : Part A19
stress retention	BS 903 : Part A52
air oven ageing	BS 903 : Part A19
Akron abrasion	BS 903 : Part A9
angle tear	BS 903 : Part A3
antistatic properties	BS 2044
apparent hardness	See hardness
artificial weathering	BS 903 : Part A54
biological attack	BS 4618 : Section 4.5
bonding	See adhesion
brittleness temperature	BS 903 : Part A25
chemical resistance	BS 903 : Part A16

colour change	
artificial light	BS 903 : Part A54
natural weathering	BS 903 : Part A53
staining	BS 903 : Part A33
compression	
creep	BS 903 : Part A15
crystallization effects	ISO 6471
flexometer	BS 903 : Part A50
set	BS 903 : Part A6
stress relaxation	BS 903 : Part A42
stress-strain	BS 903 : Part A4
conditioning	
environmental	BS 903 : Part A35
mechanical	See note 1
temperature control	BS 903 : Part A32
conductive rubber testing	BS 2044
contact staining	BS 903 : Part A33
corrosion of metals	BS 903 : Part A37
cracking	
De Mattia crack growth	BS 903 : Part A11
De Mattia flex cracking	BS 903 : Part A10
ozone	BS 903 : Part A43, A44, A45
tension fatigue	BS 903 : Part A51
weathering	BS 903 : Part A53
crazing	BS 903 : Part A53, A54
creep	BS 903 : Part A15
in flexometer testing	BS 903 : Part A49, A50
crescent tear	BS 903 : Part A3
crystallization resistance	
hardness change	BS 903 : Part A63
in compression	ISO 6471
cure	See vulcanization characteristics
curemetering	BS 903 : Part A60
oscillating disc curemeter	BS 903 : Section 60.2 and 60.1
rotorless curemeter	BS 903 : Section 60.1
cut growth	See De Mattia
damping properties	BS 903 : Part A24, A31
degradation	See ageing, light, ozone and weathering resistance
Delft tear	ISO 816
delta Mooney test	BS 903 : Part A58
De Mattia	
flex resistance	BS 903 : Part A10
crack growth	BS 903 : Part A11
density	BS 903 : Part A1
diffusion staining	BS 903 : Part A33

dimensions	
measurement	BS 903 : Part A38
change in liquids	BS 903 : Part A16
discoloration	BS 903 : Part A53, A54
Dunlop Tripsometer resilience	BS 903 : Part A8
DuPont abrasion	BS 903 : Part A9
durometer hardness	BS 903 : Part A57
dynamic properties	
guide	BS 903 : Part A24
torsion pendulum	BS 903 : Part A31
electrical properties	
electric strength	BS 903 : Part C4
insulation resistance	BS 903 : Part C5
loss tangent	BS 7663
permittivity	BS 7663
resistivity	
antistatic and conductive	BS 2044
surface	BS 903 : Part C1
volume	BS 903 : Part C2
elongation at break	BS 903 : Part A2
equilibrium water vapour absorption	BS 903 : Part A18
extraction staining	BS 903 : Part A33
extraction of soluble matter	BS 903 : Part A16
fabric adhesion	
ply adhesion	BS 903 : Part A12
tension test	BS 903 : Part A27
fatigue	
flexometer	
principles	BS 903 : Part A49
compression	BS 903 : Part A50
rotary	ISO 4666-2
tension	BS 903 : Part A51
first order transition effects	See low temperature properties
flammability	See note 2
oxygen index	BS 2782 : Part 1 : Method 141
flex cracking	BS 903 : Part A10, A11
flexometer testing	BS 903 : Part A49, A50; ISO 4666-2
flexural properties (plastics)	BS 2782 : Part 3 : Method 335A
friction	BS 903 : Part A61
gas permeability	BS 903 : Part A17, A30
Gehman test	BS 903 : Part A13
glass hardening	See low temperature properties
Goodrich flexometer	BS 903 : Part A50
green strength	BS 903 : Part A62

H-pull test	BS 903 : Part A48
hardness	
IRHD	BS 903 : Part A26
for crystallization	BS 903 : Part A63
micro-	BS 903 : Part A26
pocket meters	BS 903 : Part A57
Shore A and D	BS 903 : Part A57
heat build-up	See fatigue, flexometer
heat resistance	BS 903 : Part A19
hysteresis	See note 3
impact	
brittleness temperature	BS 903 : Part A25
Izod	BS 2782 : Part 3 : Method 350
indentation hardness	See hardness
inter-laboratory testing	
precision statements	ISO/TR 9272; BS 5497 : Part 1
confidence intervals	ISO/TR 11753
statistical analysis	BS 5324
light	
artificial weathering	BS 903 : Part A54
natural weathering	BS 903 : Part A53
staining	BS 903 : Part A33
liquid	
resistance	BS 903 : Part A16
stress relaxation	BS 903 : Part A42
transmission of volatile liquids	BS 903 : Part A46
loss properties	
electrical	BS 7663
mechanical	BS 903 : Part A24, A31
low temperature properties	
compression set	BS 903 : Part A6
crystallization by hardness change	BS 903 : Part A63
crystallization effects under compression	ISO 6471
Gehman test	BS 903 : Part A13
impact brittleness	BS 903 : Part A25
temperature retraction	BS 903 : Part A29
Lupke resilience	BS 903 : Part A8
marine exposure	BS 4618 : Section 4.4
melt flow index	BS 2782 : Part 7 : Method 720A
metals	
adhesion	BS 903 : Part A14, A21, A40
corrosion by rubber	BS 903 : Part A37
migration staining	BS 903 : Part A33

micro-hardness	BS 903 : Part A26
modulus	
compression	BS 903 : Part A4
dynamic	BS 903 : Part A24, A31
flexural	BS 2782 : Part 3 : Method 335A
shear	BS 903 : Part A14
tensile	BS 903 : Part A2
Mooney viscometer tests	
delta Mooney	BS 903 : Part A58
scorch	BS 903 : Part A58
viscosity	BS 903 : Part A58
natural weathering	BS 903 : Part A53
oil resistance	BS 903 : Part A16
optical properties	BS 4618 : Section 5.3
oscillating disc curemeter	BS 903 : Section 60.2 and 60.1
outdoor exposure	BS 903 : Part A53
oxygen pressure (bomb) ageing	BS 903 : Part A19
ozone	
accelerated dynamic	BS 903 : Part A44
accelerated static	BS 903 : Part A43
measurement of test concentration	BS 903 : Part A45
natural weathering	BS 903 : Part A53
permeability to gases	
constant pressure method	BS 903 : Part A30
constant volume method	BS 903 : Part A17
permittivity	BS 7663
penetration staining	BS 903 : Part A33
permanent set	
	See set
plastimeter tests	
plasticity retention index	BS 903 : Part A59
rapid plasticity number	BS 903 : Part A59
Williams (parallel plate)	ISO 7323
pocket hardness meters	BS 903 : Part A57
prevulcanization characteristics	See scorch time
recovery	See set
crystallization effects under compression	ISO 6471
parallel plate plastometer	ISO 7323
resilience (rebound)	BS 903 : Part A8
reversion	BS 903 : Part A60
rheological properties	
melt flow rate	BS 2782 : Part 7 : Method 720A
Mooney viscometer	BS 903 : Part A58
plastimeters	BS 903 : Part A59; ISO 7323

rotary flexometer	ISO 4666-2
rotary platform double head (abrasion)	BS 903 : Part A9
rotating cylindrical drum (abrasion)	BS 903 : Part A9
rotorless curemeter	BS 903 : Section 60.1
scorch time	
Mooney viscometer	BS 903 : Part A58
curemetering	BS 903 : Part A60
second order transition effects	See low temperature properties
set	
compression in flexometer	BS 903 : Part A6
testing	BS 903 : Part A49, A50
tension	BS 903 : Part A5
soil burial	BS 4618 : Section 4.5
shear	
creep	BS 903 : Part A15
modulus	BS 903 : Part A14
dynamic	BS 903 : Part A24
quadruple	BS 903 : Part A14
Shore hardness	BS 903 : Part A57
solvent resistance	BS 903 : Part A16
staining of organic finishes	BS 903 : Part A33
statistical analysis	BS 5324
strength	
adhesion	See adhesion
electric	BS 903 : Part C4
green	BS 903 : Part A62
tear	BS 903 : Part A3
tensile	BS 903 : Part A2
stress relaxation	
ageing	BS 903 : Part A52
compression	BS 903 : Part A42
sunlight resistance	BS 903 : Part A53
swelling resistance	BS 903 : Part A16
Taber abrasion	BS 903 : Part A9
tear strength	BS 903 : Part A3
analysis of traces	BS 903 : Part A47
Delft test piece	ISO 816
temperature rise (flexometers)	BS 903 : Part A49, A50; ISO 4666-2
temperature retraction (TR)	BS 903 : Part A29
tension – fatigue	BS 903 : Part A51
set	BS 903 : Part A5
tensile stress/strain	BS 903 : Part A2
test conditions	
standard test atmospheres	BS 903 : Part A35
temperature control	BS 903 : Part A32

test pieces	
conditioning	BS 903 : Part A35
measurement of dimensions	BS 903 : Part A38
preparation	BS 903 : Part A36
raw rubber	BS 6315
test results	
analysis of multi-peak traces	BS 903 : Part A47
precision statements and individual tests	ISO/TR 9272
confidence intervals	ISO/TR 11753
rounding off	BS 903 : Part 0
use of statistics	BS 5324
testing machine	
tensile, flexural and compression machines	BS 5214 : Part 1
constant rate of force appln machines	BS 5214 : Part 2
textile adhesion	
cord	BS 903 : Part A48
fabrics	BS 903 : Part A12, A27
thermal properties	
conductivity	BS 874 : Section 2.1; BS 4618 : Section 3.3
coefficient of linear expansion	BS 4618 : Section 3.1
heat content	BS 4618 : Section 3.2
torsion	
modulus (low temperature)	BS 903 : Part A13
pendulum (dynamic properties)	BS 903 : Part A31
transmissibility	See dynamic properties
transparency	BS 4618 : Section 5.3
trouser tear	BS 903 : Part A3
TR test	BS 903 : Part A29
vapour resistance	
transmission rate	BS 903 : Part A46
equilibrium water absorption	BS 903 : Part A18
Vicat softening temperature	BS 2782 : Part 1 : Methods 120A, B, D and E
viscosity	See also plastimeter tests
Mooney	BS 903 : Part A58
vulcanization characteristics	
curemetering	BS 903 : Part A60
Mooney scorch	BS 903 : Part A58
Wallace plasticity	BS 903 : Part A59
water resistance	
equilibrium vapour	
absorption	BS 903 : Part A18
immersion	BS 903 : Part A16
marine exposure	BS 4618 : Section 4.4

weathering resistance	
assessment of properties	BS 903 : Part A55
artificial light	BS 903 : Part A54
natural	BS 903 : Part A53
wear	See abrasion
Williams Plastometer	ISO 7323
wire cord adhesion	BS 903 : Part A56
xenon arc lamp	BS 903 : Part A54
Young's modulus from compression modulus	BS 903 : Part A4

NOTE.1. There is no specific method for mechanical conditioning of test pieces. Procedures for particular tests are described in BS 903 : Part A14, A15, A31 and A42. Guidance on conditioning for dynamic tests is given in BS 903 : Part A24.

NOTE.2. Small-scale laboratory flammability tests, such as oxygen index, are primarily used for assistance in monitoring the consistency of a property and for evaluation purposes. They should not be used as a sole means of assessing the potential fire behaviour of a material in service. For general guidance on fire testing see BS 476 and BS 6336. Small-scale tests other than oxygen index are specified for plastics in BS 2782.

NOTE.3. Hysteresis is reflected in several properties and there are no simple correlations among them. Relevant test methods are BS 903 : Part A5, A6, A15 and A42 (Relaxation and set phenomena), BS 903 : Part A8 (Rebound resilience) and BS 903 : Part A24 and A31 (Dynamic properties).

Annex E (informative)

Testing for low temperature resistance

E.1 General

Annex F illustrates the importance of selecting the test conditions most appropriate to the intended application. Low temperature testing is a good example to show how important it is to select the correct test method. Five test methods are closely associated with low temperature properties and several others provide for measurements undertaken at sub-normal temperatures.

Low temperature resistance is often regarded as a single property of rubber but it is really a composite term because performance is dictated by two distinct parameters. The first is the proximity of the rubber to its glass transition temperature (T_g). As the test temperature is lowered towards the T_g the rubber stiffens and eventually reaches the point where it undergoes brittle failure upon impact. This change is accompanied by a decrease in resilience, which reaches a minimum before rising again near the T_g, a decrease in the rate of recovery from deformation and a decrease in diffusion coefficient of substances dissolved in the rubber. The last of these influences gas permeability and the efficacy of wax blooms for ozone resistance.

The second parameter, receiving far less attention in specifications, is crystallization, a time-dependent change confined to those rubbers having stereo-regular molecular structures or segments. Crystallization leads to an increased stiffness, a reduced rate of recovery from deformation and an enhanced rate of stress relaxation. It occurs at temperatures somewhat higher than the T_g.

Glass transition effects and crystallization are both reversible with temperature; that is the original properties are restored when the rubber is warmed. This is the reason why the changes on storage at low temperature need to be measured at the test temperature and why close temperature control is so important.

E.2 Methods

In principle, most low temperature tests can be adapted to measure both glass transition and crystallization effects, but in practice they are usually categorized as follows.

a) *Glass transition effects*

BS 903 : Part A13 Change in stiffness (Gehman test)

BS 903 : Part A25 Brittleness temperature

b) *Crystallization effects*

BS 903 : Part A63 Hardness change

c) *Either phenomenon depending on period of test*

BS 903 : Part A6 Compression set

BS 903 : Part A29 Recovery from deformation (temperature retraction)

The following methods are also suitable for low temperature use:

BS 903 : Part A4	Compression stress-strain
BS 903 : Part A8	Rebound resilience
BS 903 : Part A24	Dynamic properties
BS 903 : Part A26	Hardness

E.3 Factors influencing choice of test method

Factors influencing the choice of test method include the following.

a) *Period of exposure at low temperature*

If the product is to be exposed for long periods (typically several days) at low temperature, a crystallization resistance test becomes advisable. In case of doubt, look for any property change occurring during storage of more than a day. BS 903 : Part A63 is commonly used for crystallization studies provided the initial hardness is not above 85 IRHD but the test times can be quite long if a useful distinction between compounds is required. An indication of resistance can be obtained more quickly by carrying out a compression set test because a strained rubber crystallizes more rapidly than an unstrained one. This is also a feature of the temperature retraction test in BS 903 : Part A29. In addition, it is possible to shorten the exposure period by testing at the temperature at which a given type of rubber crystallizes most rapidly. This temperature is as follows:

Type of rubber	°C
Natural rubber	−25
Isoprene rubber, synthetic	−25
Butadiene rubber	−55
Chloroprene rubber	−10
Polydimethylsiloxane	−55
Polyurethane	+5 to −10

It is unlikely that an exposure period shorter than 7 days will be used for crystallization tests even under the most favourable conditions. The one day or three days commonly specified for compression set tests at higher temperatures is insufficient when BS 903 : Part A6 is used for this purpose. Neither is it appropriate to replace the method in BS 903 : Part A63 by BS 903 : Part A26 using a simple hardness change between the test temperature and the standard laboratory temperature (23 °C) after just one day or a little longer. That change is more likely to be due to the instantaneous effect of temperature upon hardness and hence more closely linked to the influence of glass transition.

NOTE. A test for measuring crystallization resistance in compression at strains up to 60 % is described in ISO 6471.

b) *Type of material*

The ability of certain rubbers to undergo crystallization will be a consideration when individual rubbers are evaluated or specified. Compounding ingredients, such as plasticizers, may also undergo time-dependent changes at low temperatures and thus justify use of BS 903 : Part A63, BS 903 : Part A29 or BS 903 : Part A6.

c) *Rate of deformation*

The glass transition of rubbers is dependent on test frequency. If rubber is flexed or subjected to rapid impact it will be stiffer than when deformed slowly. This is why the impact brittleness temperature measured by BS 903 : Part A25 is somewhat higher than the value of *Tg* usually quoted for a given type of rubber. As an approximate guide, *Tg* determined at a frequency of 10 Hz is about 15 °C higher than that measured at very slow deformation rates. It follows that if a rubber is to be used under cyclic stress conditions at low temperatures, the resistance it shows to stiffening ought to be measured, for example, by BS 903 : Part A24, rather than BS 903 : Part A14 (in the case of shear modulus).

E.4 Correlations between test methods

Various correlations have been established between low temperature tests and between test conditions. For example, in BS 903 : Part A29 it is stated that the difference between the temperature at which a rubber retracts 10 % (i.e. TR 10) and the temperature at which it retracts 70 % (i.e. TR 70) increases as the tendency to crystallize increases. Correlations between TR 70 and low temperature compression set and between TR 10 and impact brittleness temperatures have also been claimed. Such correlations, though valuable, are usually based on the behaviour of a limited number of rubbers, and their general applicability should never be assumed. It has been established, for example, that the crystallization resistance of NR is strongly influenced by the type of vulcanizing system being used, but vulcanization at normal crosslink densities has little effect on T_g. Conversely plasticizers will lower the T_g but have no beneficial effect on crystallization resistance and in some instances are known to impair it. By its very nature, crystallization needs a comparatively long exposure time, whereas the effects of glass hardening can be assessed as soon as temperature equilibrium has been established.

If a rubber is to be used at low temperatures it is advisable to measure its resistance in both ways. On the evidence of current specifications, including BS 5176 (Classification system), among the most popular methods for assessing instantaneous glass transition effects are BS 903 : Part A13 and BS 903 : Part A25, whereas BS 903 : Part A6 and BS 903 : Part A63 are used for the less widely specified effects of storage at low temperatures. Several British Standard specifications call for special low temperature tests conducted on the finished product.

There are tests which determine resistance to crystallization and tests which measure the influence of crystallization on another low temperature property. For example, a rubber that has undergone sufficient crystallization to increase stiffness, stress relaxation or set may remain resistant to brittle failure.

Annex F (informative)

Testing for ozone resistance

F.1 General

BS 903 : Part A43 (Static ozone resistance) allows several options for choice of test conditions; the principal variables are elongation, ozone concentration, temperature and exposure time.

It is important that these are related to the anticipated service conditions because they can determine the resistance of one rubber relative to another and the way a rubber responds to a protective agent.

Some of the following comments will also apply to testing under dynamic strain conditions (see BS 903 : Part A44).

WARNING NOTE ON TOXICITY

Attention is drawn to the highly toxic nature of ozone. Efforts should be made to minimize the exposure of workers at all times. See Guidance Notes EH 40/94 *Occupational exposure limits* [3] and EH 38/93 *Ozone health hazards and precautionary measures* [4], published by the Health and Safety Executive.

F.2 Elongation

A test strain of 20 % is specified for single point measurements and is broadly typical of many strained products. However, the elongation chosen should match service conditions because of the dependence of crack size on strain. The highest rate of crack growth is just above the characteristic threshold strain for the onset of cracking and then decreases as the strain is increased, even though accompanied by an increased crack density.

Measurements at several strains are more informative because protective agents can raise threshold strain or reduce rate of crack growth. Several elongations are required for estimation of threshold strain (which should be designed to be above the maximum strain in the product). The standard procedure calls for at least 4 elongations, with good starting points being 10 %, 20 %, 40 % and 60 %.

F.3 Ozone concentration

Ozone concentration should be the lowest possible because it can affect the efficiency of protective agents, especially chemical antiozonants. Generally the higher the severity the more protection is required, which will increase cost and possibly detract from other properties. The service environment should be checked, i.e. whether it is outdoor, indoors, under-bonnet, near electrical discharge etc, before selecting one of the four levels permitted in the test method.

50 pphm	This has become the preferred standard for general use, and for products exposed outdoors at an ambient concentration of a few pphm.
25 pphm	This low severity is intended for applications used indoors or outdoors at ambient concentration of less than 1 pphm, or where rubber is used under mild strain conditions, for example a bearing used in compression.
100 pphm or 200 pphm	This is intended for highly ozone-resistant rubbers (for which 25 pphm or 50 pphm would be unable to discriminate). Examples are EPDM and chlorosulfonated polyethylene.

F.4 Temperature

It is essential to match the cabinet temperature to that anticipated in service, because of the effect it has on waxes and hysteretic rubbers such as butyl. Temperature governs the solubility and diffusion coefficient of a wax and thus becomes the major environmental factor affecting blooming. Increasing the temperature increases the solubility and so reduces the level of wax available for blooming. Lowering the temperature reduces the rate of diffusion and so a bloom is slow to form or to repair. With butyl rubber the rate of cracking increases with temperature, and in the absence of protection its resistance at say 50 °C can be significantly lower than at standard laboratory temperature.

Note that service temperatures can be higher than the surrounding air temperature because of irradiation. Failure to take account of the increase can give misleading test results.

Example. A rubber passes a test at 50 pphm ozone and 30 °C but is then found to fail in service in summer. The first conclusion is to think that the test is too mild and therefore to increase the ozone concentration but the rubber still passes a test conducted at 200 pphm ozone. The rubber contains a wax which blooms at 30 °C but which is soluble at the temperatures reached by the rubber in summer. This is demonstrated by the cracking that occurs when the rubber is retested at 40 °C and 50 pphm or even 25 pphm ozone.

A temperature of 40 °C is specified for general purposes and it is especially suitable for summer exposure in the United Kingdom. Temperatures of 30 °C or 23 °C may be more suitable for shaded or indoor products. Refrigeration techniques are necessary for winter simulation and in this instance it is advisable to omit the normal pre-conditioning in the stretched state if waxes are present, unless it is conducted at the same temperature as the test cabinet.

For products used over a range of temperature it is important to test at least two temperatures representative of the extremes.

F.5 Exposure time

Accelerated ozone resistance tests are usually no more than a week long, and 3 days or 4 days is typical. The time to first crack increases as the test elongation is lowered towards the threshold strain, and it is important that the exposure period is sufficiently long to enable a clear distinction to be made between a rubber having an enhanced threshold strain and one which appears to be resistant simply because it has a very low rate of crack growth. Given time the latter rubber will, indeed, begin to crack. For single crack measurements there is, for some types of rubber, a linear relationship between the rate of crack growth and ozone concentration, from which some crude estimates can be made of service behaviour. However, this assumes the conditions of exposure, other than the level of ozone, are identical, which is unlikely to be the case, and agreement is less satisfactory in the presence of a protective agent.

F.6 Special conditions

BS 903 : Part A43 is primarily intended for tests on freshly moulded surfaces. In service, rubber may be simultaneously aged or leached. What is the ozone resistance after prolonged exposure? This may call for some modification of the test procedure. A high ozone concentration is an accelerating influence on ozone cracking, but a few days at 40 °C is not and is insufficient to assess the long term changes (say in antiozonant levels) that might impair ozone resistance.

Example. A rubber passes a test at 50 pphm ozone and even 200 pphm ozone at 40 °C but cracks in service after a year or after a summer period. In this instance a better approach may be to pre-age test pieces in an oven in accordance with BS 903 : Part A19 (i.e. under similar conditions to accelerated ageing) and then test for ozone resistance.

F.7 Precautions

Ozone resistance is affected by surface finish, vulcanizate stiffness and the time lapse between vulcanization and testing. These need to be similar for comparative tests. Always inspect surfaces for cracking before exposure to ozone. A reduction in vulcanizate modulus, e.g. by antiozonant interfering with the vulcanizing system, may give an apparent improvement in resistance.

Annex G (informative)

Acquisition and presentation of comparable data for rubbers and rubber compounds

G.1 Introduction

It is not always possible to compare test data from different sources and for different materials because of differences in the methods of test. A reference to the particular standard method used, although essential, does not itself guarantee that identical conditions have applied. Many Parts of BS 903 allow various options on test procedure, type of test piece and test conditions so that a specification can be drafted to match the intended application and thus minimize the need for non-standard tests. The test details should always be given in the test report to avoid any assumptions or misunderstandings. Such details sometimes reveal differences between organizations that could have been avoided in the interests of closer standardization.

G.2 Recommended test options

In table G.1 options have been selected to encourage the generation of test data under comparable conditions and to prevent unnecessary variation of test conditions. These options are as far as possible the preferred test procedures and conditions given in the test methods; in other cases they are among the most popular in existing British Standard specifications. Table G.1 may not be appropriate for individual materials and finished products. It has been confined to the tests most frequently found in specifications for vulcanized rubber and in technical literature. These options do not include tests used for measuring processability (see clauses **8** and **11**).

The approach pursued in table G.1 is best suited to physical and mechanical properties such as tear strength and hardness. It is less suitable for properties that vary with time, temperature and the presence of particular chemical environments. Thus the conditions for a heat resistance or accelerated ageing test (BS 903 : Part A19) should match the anticipated thermal stability or oxidation resistance of the rubber, and where this is not known the performance should be determined over a range of conditions (time, temperature or both) to fully characterize the material. Similar considerations apply to such properties as resistance to liquids (BS 903 : Part A16), ozone resistance (BS 903 : Part A43 and A44) and weathering resistance (BS 903 : Part A53 to A55). In the case of tension fatigue resistance (BS 903 : Part A51), measurements should be conducted over a range of elongations and attention should be paid to differences among materials with regard to initial modulus, stress-softening and set; further information and guidance are given in the test method.

In the interests of uniformity the following are also advised:

a) Prepare test pieces from moulded sheet where this is given as an option. The two-thickness sheet or mould specified in BS 1674 is recommended if the tests call for the use of 2.0 mm ± 0. 2 mm and 6.3 mm thick test pieces.

b) Cut dumb-bell or strip test pieces parallel to the grain of the sheet (if known) for tests to BS 903 : Part A2, A3, A5, A13, A25, A29, A43, A44 and A51. In some of these methods it is not made sufficiently clear that anisotropy in the sheet may influence the results. Obviously where a material is known to be anisotropic, and even designed to be so, it is important tests be undertaken both along and perpendicularly to the grain or lines of flow. This is particularly so with injection moulded thermoplastics rubbers and with compounds containing fibrous fillers.

c) If properties are to be measured after a period of accelerated ageing or exposure to heat or low temperatures, use times and temperatures from the lists given in BS 903 : Part A19 and BS 903 : Part A35.

d) Round off test results to the accuracy recommended in Appendix C of BS 903 : Part 0.

Attention is drawn to BS 7008 : Part 1 and 2 which give preferred test conditions for plastics materials.

Table G.1 Recommended options for acquisition and presentation of comparable data

Property	Method	Option
Density	BS 903 : Part A1	Method A
Tensile stress-strain properties	BS 903 : Part A2	Type 2 dumb-bell test piece
Tear strength	BS 903 : Part A3	Method A (trouser test piece)
Compression stress-strain properties	BS 903 : Part A4	Method A (bonded test piece)
Tension set	BS 903 : Part A5	Strip test piece, width 6 mm test strain : 100 % ± 10 %; test time: 24 h
Compression set	BS 903 : Part A6	Small disc (type B) test piece; lubricated; decrystallize for 45 min at 70 °C for low temperature tests
Rebound resilience	BS 903 : Part A8	Method B (ISO method) using Lupke pendulum
Abrasion resistance	BS 903 : Part A9	Method A.2, with rotating test piece, and abrasion resistance index measured against standard rubber S2
Low temperature stiffness (Gehman test)	BS 903 : Part A13	As specified: decrystallize for 30 min test at 70 °C before testing
Shear modulus	BS 903 : Part A14	As specified, with mechanical conditioning
Creep	BS 903 : Part A15	Compression, using type A or type B test pieces bonded to end piece; mechanical conditioning
Resistance to liquids	BS 903 : Part A16	Volume change using 2.0 mm ± 0.2 mm thick test piece
Heat resistance accelerated ageing	BS 903 : Part A19	Air ageing using a cell-type oven
Brittleness temperature	BS 903 : Part A25	Strip test piece
Hardness	BS 903 : Part A26	Dead-load test, using method N, H or L as appropriate
Temperature retraction (TR test)	BS 903 : Part A29	Standard test piece with reference length of 100 mm; decrystallize for 30 min at 70 °C before testing
Staining in contact with organic materials	BS 903 : Part A33	Test pieces having the minimum dimensions specified from 2. 0 mm ± 0.2 mm thick sheet
Adhesion to and corrosion of metals	BS 903 : Part A37	Method A (vulcanizates in contact with metal) using 2.0 mm ± 0.2 mm thick sheet
Stress relaxation	BS 903 : Part A42	Method A; small disc test piece; lubricated
Static strain ozone testing	BS 903 : Part A43	Strip test piece, 10 mm wide and length between grips of 40 mm, protected at ends with ozone-resistant lacquer; 50 pphm ozone; 20 % elongation; 72 h (see note 1)
Dynamic strain ozone testing	BS 903 : Part A44	As BS 903 : Part A43 with procedure A, continuous dynamic exposure; 0 % to 10 % elongation; 72 h (see note 1)
Flexometer fatigue	BS 903 : Part A50	Pre-stress: 1.0 MPa; stroke: 5.71 mm; chamber temperature: 55 °C or 100 °C

Table G.1 Recommended options for acquisition and presentation of comparable data (*concluded*)

Property	**Method**	**Option**
Tension fatigue	BS 903 : Part A51	Type 2 dumb-bell or standard ring test piece, 1.5 mm ± 0.2 mm thick; frequency: 1 Hz (dumb-bell) or 5 Hz (ring)
Ageing characteristics by measurement of stress	BS 903 : Part A52	Specified test pieces having the preferred dimensions; 50 % ± 5 % extension
Outdoor natural weathering	BS 903 : Part A53	Test samples and test pieces as specified in test method for property concerned. For stretched rubber, as BS 903 : Part A43 for test piece and elongation (see note 2)
Exposure to artificial light	BS 903 : Part A54	Black panel temperature: 55 °C ± 3 °C; relative humidity: 65 % ± 5 %
Pocket hardness meters (Shore and IRHD)	BS 903 : Part A57	Test piece from single sheet or slab 6 mm to 8 mm thick; 1 second reading
Friction	BS 903 : Part A61	Procedure A; planar test piece and test track made of a standard comparator; 500 mm/min
Low temperature crystallization by hardness change	BS 903 : Part A63	Test piece from single sheet or slab 8 mm to 10 mm thick

NOTE 1. In BS 903 : Part A43 and A44 the preferred test temperature for ozone testing is (40 ± 2) °C. It is also commonly used in specifications having an ozone resistance requirement. while it can be specified for making comparisions amoung rubbers, this temperature, as indeed any other used alone, can give misleading information on the ozone resistance of rubbers containing wax as part or all of the protective system. For these a second test at a lower temperature is recommended (see annex F).

NOTE 2. Outdoor exposure tests are not normally suitable for comparative purposes unless the rubbers being compared are exposed at the same time at the same site. Guidance on the measurement of severity of exposure, the largest source of variation, is given in BS 903 : Part A53. Obviously more reproducible indications of weathering resistance of rubbers, albeit under artificial conditions, are given by the methods specified in BS 903 : Part A54 and, for ozone resistance, BS 903 : Part A43.

List of references (see clause 2)

Informative references

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