

Physical testing of rubber —

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

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
- Ministry of Defence
- RAPRA Technology Ltd.
- SATRA Footwear Technology Centre

This British Standard, having been prepared under the direction of the Materials and Chemicals (I/-), was published under the authority of the Standards Board and comes into effect on 15 March 1995

© BSI 02-2000

The following BSI references relate to the work on this standard:
Committee reference PRI/22
Draft for comment 92/43990 DC

ISBN 0 580 23322 7

Amendments issued since publication

Amd. No.	Date	Comments

Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
Introduction	1
1 Scope	1
2 References	2
3 Definitions	2
4 General information for test laboratories	2
5 Tests available	3
6 Samples for testing	3
7 Test pieces	6
8 Applications of the BS 903 test methods	7
9 Testing for processability	13
10 Testing for design purposes	15
11 Testing for durability	16
12 Evaluation and characterization of materials	18
13 Designing a specification	19
14 Product testing	20
15 Quality	21
16 Testing thermoplastic rubbers	23
Annex A (informative) Property gradations in material specifications	34
Annex B (informative) Bibliography of useful publications on rubber testing and associated topics	38
Annex C (informative) International equivalents of British Standards referred to in this guide	39
Annex D (informative) Guide to test methods for properties of rubber	41
Annex E (informative) Testing for low temperature resistance	48
Annex F (informative) Testing for ozone resistance	50
Annex G (informative) Acquisition and presentation of comparable data for rubbers and rubber compounds	52
Figure 1 — Inter-relationship of methods of test	4
Figure 2 — Durability testing	17
Figure 3 — Adhesion testing	22
Table 1 — Test piece thickness for physical testing	25
Table 2 — Multi-purpose test pieces	26
Table 3 — Test methods for measuring processability	27
Table 4 — Test methods suitable for design data	27
Table 5 — Evaluation of rubbers	28
Table 6 — Evaluation of compounding ingredients and ancillary materials	29
Table 7 — Small test pieces suitable for product testing	29
Table 8 — Test methods for quality control	32
Table 9 — Quality control of materials, processing and vulcanization	33
Table A.1 — List of properties with preferred gradations and methods of test	35
Table G.1 — Recommended options for acquisition, and presentation of comparable data	53
List of references	55

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 originally intended to limit the scope of the guide to the selection and use of methods of test in the BS 903-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.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 58, an inside back cover and a back cover.

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

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 3502-2:1991.

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 $23\text{ °C} \pm 2\text{ °C}$, 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 $50\% \pm 5\%$ relative humidity at $23\text{ °C} \pm 2\text{ °C}$.

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-A51), tension set (BS 903-A5) and ageing in tension (BS 903-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 5214-1 and BS 5214-2.

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 5781-1.

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-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-A43 and BS 903-A44) and some fluids used for swelling measurements (BS 903-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-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 6920-1 and BS 6920-2, (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.

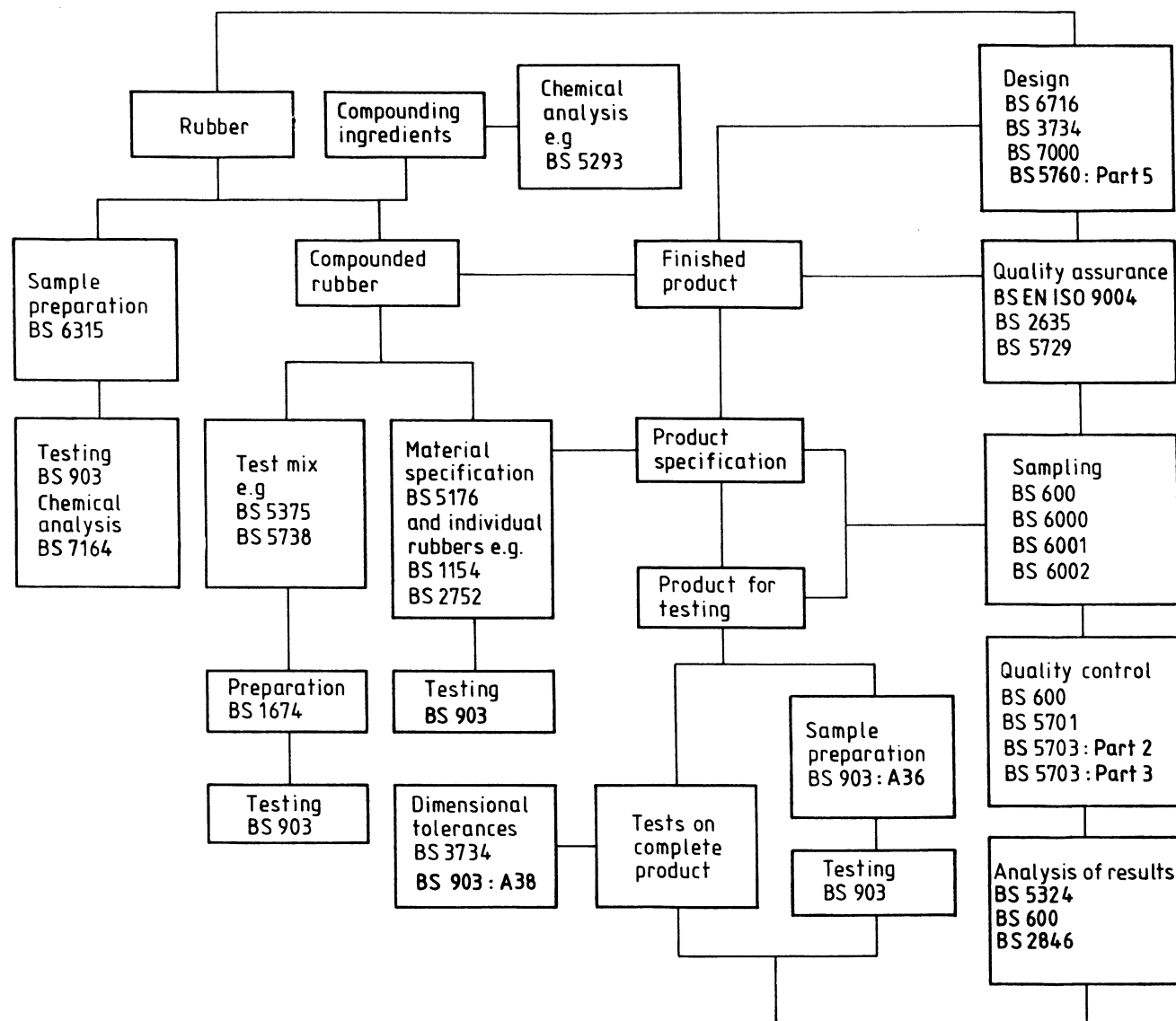


Figure 1 — Inter-relationship of methods of test

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

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-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 $6.3 \text{ mm} \pm 0.3 \text{ mm}$, and the remainder a thickness of $2.0 \text{ mm} \pm 0.2 \text{ mm}$. If required the thicker part may be replaced by moulded cylindrical discs suitable for use as test pieces without further preparation.

Test sheets of $2.0 \text{ mm} \pm 0.2 \text{ mm}$ 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 $23\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, 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-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-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-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-A53).

Test pieces used for some low temperature tests (see Annex E) need to be heated for 30 min to 45 min at $70\text{ }^{\circ}\text{C}$ 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-A58, BS 903-A59 and BS 903-A60, see clause 9.

8.2.1 BS 903-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-A9 (abrasion resistance) and BS 903-A16 (resistance to liquids).

8.2.2 BS 903-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-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-A16) and weathering (with BS 903-A53, BS 903-A54 and BS 903-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-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-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-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-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-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-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-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-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-A51.

8.2.10 BS 903-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-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 promoters.

8.2.12 BS 903-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-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-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-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-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-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-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-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-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-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-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-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-A19), or after exposure to liquids (BS 903-A16) or weathering (BS 903-A53, BS 903-A54 and BS 903-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-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-A12, (but see also BS 3424-7).

8.2.24 BS 903-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-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 903-31 (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-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-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-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-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-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-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-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-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-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-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-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-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-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 3424-5 and BS 3424-10.

8.2.40 BS 903-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 promoters and pre-treatment processes.

8.2.41 BS 903-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-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-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-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-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-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-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-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 promoters and pre-treatment processes.

8.2.49 BS 903-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-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-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-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-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-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-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-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-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 $1\,000 \text{ s}^{-1}$ for extrusion and as high as $10\,000 \text{ s}^{-1}$ 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, calendaring, 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-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-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:A60:60.1, 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 5400-9.2) 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-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-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-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 Annex F and Annex 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. 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-A19 may be used with *any* test method.