BRITISH STANDARD

METHODS OF TESTING VULCANIZED RUBBER

PART C 4. DETERMINATION OF ELECTRIC STRENGTH OF INSULATING SOFT VULCANIZED RUBBER AND EBONITE

B.S. 903 : Part C 4 : 1957

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

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

A complete list of British Standards, number over 2500, indexed and cross-indexed for reference, together with an abstract of each standard, will be found in the Institution's Yearbook, price 15s.

This standard makes reference to the following British Standards :

B.S. 148 Insulating oil (low viscosity) for transformers and switchgear.
B.S. 358 Rules for the measurement of voltage with sphere-gaps.

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

The following B.S.I. references relate to the work on this standard :—
Committee references RUC/10 and RUC/10/6
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CO-OPERATING ORGANIZATIONS

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

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

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

Admiralty
Air Ministry
Association of British Chemical Manufacturers
Association of British Ebonite Manufacturers
British Cellular Rubber Manufacturers' Association
British Chemical Plant Manufacturers' Association
British Electrical and Allied Industries Research Association
British Railways, The British Transport Commission
British Rubber and Resin Adhesive Manufacturers' Association
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Rubber Trade Association of London
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BRITISH STANDARD

METHODS OF TESTING VULCANIZED RUBBER

Part C 4. Determination of Electric Strength of Insulating Soft Vulcanized Rubber and Ebonite

FOREWORD

This British Standard has been published under the authority of the Rubber Industry Standards Committee. In deciding to issue a revision of the 1950 edition, the Committee considered it desirable to publish B.S. 903 in separate parts and the present part replaces Part 32 of 1950.

The main changes in the revision are the omission of the method of measurement for unloaded ebonite, in which the electrodes are spheres inserted into closely fitting recesses in the test piece, and the inclusion of the '*20-second step-by-step*' *test using specified cylindrical electrodes*. All the methods now given are suitable for both soft rubber and ebonite.

The group of parts to which this part belongs covers methods of testing the electrical properties of rubber and ebonite and is marked with the prefix letter ' C'. Further parts in the group have been issued as follows:—

Part C 1. Determination of surface resistivity of insulating soft vulcanized rubber and ebonite.

Part C 2. Determination of volume resistivity of insulating soft vulcanized rubber and ebonite.

Part C 3. Determination of permittivity and power factor of insulating soft vulcanized rubber and ebonite.

SECTION 1 DEFINITIONS

For the purpose of this British Standard, the following definitions shall apply :—

Voltage. The peak value of the voltage applied to the electrodes divided by $\sqrt{2}$.

Voltage gradient. The voltage divided by the mean thickness of the test piece.

Electric strength. The voltage gradient at which electrical breakdown of an insulating material occurs under prescribed conditions of test. In the step-by-step test, this definition is modified, the *electric strength* being

the voltage gradient corresponding to the highest of the specified series of voltages, successively applied, which does not cause breakdown in the prescribed time.

SECTION 2 EXPLANATORY NOTES

The electric strength as ordinarily measured is not the intrinsic electric strength, i.e. the voltage gradient at which the material will fail under ideal conditions, but a value which may be from a tenth to a hundredth of this and which is usually controlled by such factors as the presence of ionization in the ambient gas or liquid or in gaseous inclusions in the material. The value obtained is very dependent upon particular conditions such as test temperature, time of stressing, thickness of the test piece and moisture content, and the conditions for the test are closely defined.

The ability of a material to withstand an alternating electrical stress is generally related to the peak value of the voltage and the definitions are based on this value in order to permit unambiguous test results over the tolerance range of the ratios of peak to r.m.s. voltages. The division of the peak value by $\sqrt{2}$ permits the results to be readily compared with r.m.s. values.

SECTION 3 MEASUREMENT OF ELECTRIC STRENGTH (' ONE-MINUTE ' VALUE)

3.1 Summary. For comparison purposes a determination of the electric strength (' one-minute ' breakdown value) of a material may be required. This value is the voltage gradient which, if maintained continuously, will cause breakdown in an average time of one minute. It is obtained by producing an electric strength/time curve and reading off the ' one-minute ' value.

3.2 Test piece. *Soft rubber.* The test piece shall be a disk with smooth surfaces not less than 100 mm in diameter and 1·25 ± 0·2 mm in mean thickness. The variation of thickness within any test piece shall not exceed 0·1 mm.

Ebonite. The test piece shall be a disk with smooth surfaces not less than 100 mm in diameter and 3·2 ± 0·2 mm in mean thickness. The variation of thickness within any test piece shall not exceed 0·2 mm.

3.3 Electrodes. The lower electrode shall consist of a solid cylinder of brass 76 ± 1 mm in diameter and not less than 25 mm thick, and the upper electrode shall consist of a solid cylinder of brass 38 ± 1 mm in diameter and not less than 37 mm thick, the plane faces of the electrodes being in contact with the test piece and concentric with each other during the test.

The sharp edges shall be removed from the electrodes, the radius at the edge being approximately 0·8 mm.

3.4 Apparatus. The test voltages shall be provided by a transformer and shall be alternating, of nominal frequency 50 c/s. They shall be of approximately sine wave form and the ratio of the peak value to the root mean square value shall be within the limits $\sqrt{2}(1{\cdot}00 \pm 0{\cdot}05)$, i.e. 1·34–1·48. The output of the testing set shall be sufficient to maintain on the test piece the necessary voltage for the maximum time required.

The test voltage shall be determined by means of a peak or other type of voltmeter connected across the output winding of the transformer ; alternatively it shall be measured by means of a voltmeter connected across the input winding, or across a portion of the output winding. Any instrument used except the peak voltmeter shall be calibrated against a peak voltmeter (e.g. a sphere-gap*) connected across the output winding of the transformer. If there is any risk of the current taken by the test piece altering the no-load calibration appreciably, the calibration against a peak voltmeter shall be made with a test piece in circuit.

3.5 Procedure.

3.5.1 *Conditioning of samples and test pieces.* Tests shall not be carried out less than 24 hours after vulcanization, and for accurate comparison between different rubbers it may be necessary to ensure that they are tested at substantially the same interval after vulcanization.

Samples and test pieces shall be protected from light as completely as possible during the interval between vulcanization and testing, and care should be taken to avoid handling and contamination of the surface.

Before being conditioned, each test piece shall be wiped carefully with absorbent paper or with a soft cloth.

The test pieces shall be conditioned at a temperature of 20 ± 2°C and a relative humidity of 65 ± 5 per cent, for not less than 18 hours immediately before test.

NOTE. A temperature of 20 ± 2°C for conditioning is not practicable for all countries. In tropical countries an alternative temperature of 27 ± 2°C is permitted.

3.5.2 *Measurement of electric strength.* The test piece shall be placed concentrically between the electrodes and the test shall be made under insulating oil complying with the B.S. 148.† The larger of the electrodes shall be connected to the earthed end of the high voltage winding of the testing transformer (or to the end nearest to earth potential if both poles of the transformer are insulated). The test shall be commenced as soon as possible after immersion of the test piece in oil.

When the test is commenced the voltage to be applied to the electrodes

* B.S. 358, ' Measurement of voltage with sphere-gaps '.
† B.S. 148, ' Insulating oil (low viscosity) for transformers and switchgear '.

shall be raised, as rapidly as is consistent with avoiding transient over-voltages, from zero until the selected voltage is reached.

A number of test pieces shall be tested at each of a series of selected voltages. For each test piece the selected voltage shall be applied continuously between the electrodes until breakdown occurs, the time for failure being recorded. Time is computed from the instant at which the selected voltage is reached. An attempt should be made to choose voltages giving breakdown in about 1 minute. It is rarely profitable to continue tests beyond 2 or 3 minutes because the dispersion of the times to breakdown at a given voltage then becomes very marked. Times of the order of 2 or 3 seconds may give uncertain results because they depend upon the rapidity with which the selected voltage is attained. The voltage gradients shall then be plotted against the breakdown time and a smooth curve drawn through the points to form a voltage gradient/breakdown time curve from which the voltage gradient which causes breakdown in 1 minute shall be interpolated and reported as the electric strength of the material. The use of a logarithmic time scale facilitates this procedure as the curve then often approximates to a straight line. At least ten test pieces shall show breakdown times between 10 and 100 seconds.

3.5.3 *Temperature of test.* The test shall be made at a temperature of 20 ± 5°C or at any other temperature deemed necessary in view of particular service requirements.

3.5.4 *Report.* The report shall state :—

1. The ' *one-minute* ' *value of the electric strength in kilovolts per* millimetre.
2. The individual data from which the ' one-minute ' value is obtained.
3. Nominal thickness of the test pieces.
4. Immersion medium.
5. Temperature of test.

SECTION 4 MEASUREMENT OF ELECTRIC STRENGTH (' STEP-BY-STEP ' METHOD)

4.1 Summary. Measurement of the ' one-minute ' value of electric strength by the method specified in Section 3 has the disadvantage that a considerable number of separate tests must be made in order to obtain the required smooth curve.

An approximation to the 'one-minute ' value may be obtained by the ' 20-second step-by-step ' test in which the voltage on each test piece is raised quickly in prescribed steps every 20 seconds until breakdown occurs. The initial voltage and the increments specified in this standard have been selected with the object of obtaining an electric strength value which is close to the ' one-minute ' value.

Since a numerical result is obtained for each test piece, fewer test pieces

are required for the ' step-by-step ' test, which therefore requires less time and also enables a useful result to be obtained when the available number of test pieces is small. It must be appreciated, however, that the ' 20-second step-by-step ' value may in some cases differ appreciably from the 1-minute value.

4.2 Test piece. *Soft rubber.* The test piece shall be a disk with smooth surfaces not less than 100 mm in diameter and 1·25 ± 0·2 mm in mean thickness. The variation in thickness within any test piece shall not exceed 0·1 mm.

Ebonite. The test piece shall be a disk with smooth surfaces not less than 100 mm in diameter and 3·2 ± 0·2 mm in mean thickness. The variation in thickness within any test piece shall not exceed 0·2 mm.

4.3 Electrodes. The lower electrode shall consist of a solid cylinder of brass 76 ± 1 mm in diameter and not less than 25 mm thick, and the upper electrode shall consist of a solid cylinder of brass 38 ± 1·0 mm in diameter and not less than 37 mm thick, the plane faces of the electrodes being in contact with the test piece and concentric with each other during the test. The sharp edges shall be removed from the electrodes, the radius at the edge being approximately 0·8 mm.

4.4 Apparatus. The test voltages shall be provided by a transformer and shall be alternating, of nominal frequency 50 c/s. They shall be of approximately sine wave form, and the ratio of the peak value to the root mean square value shall be within the limits $\sqrt{2}(1{\cdot}00 \pm 0{\cdot}05)$, i.e. 1·34–1·48. The output of the testing set shall be sufficient to maintain on the test piece the necessary voltage for the maximum time required.

The test voltage shall be determined by means of a peak or other type of voltmeter connected across the output winding of the transformer; alternatively it shall be measured by means of a voltmeter connected across the input winding, or across a portion of the output winding. Any instrument used except the peak voltmeter shall be calibrated against a peak voltmeter (e.g. a sphere-gap*) connected across the output winding of the transformer. If there is any risk of the current taken by the test piece altering the no-load calibration appreciably, the calibration against a peak voltmeter shall be made with a test piece in circuit.

4.5 Procedure.

4.5.1 *Conditioning of samples and test pieces.* Tests shall not be carried out less than 24 hours after vulcanization, and for accurate comparison between different rubbers it may be necessary to ensure that these are tested at substantially the same interval after vulcanization.

Samples and test pieces shall be protected from light as completely as possible during the interval between vulcanization and testing, and care should be taken to avoid handling and contamination of the surface.

* B.S. 358, ' Measurement of voltage with sphere-gaps '

Before being conditioned, each test piece shall be wiped carefully with absorbent paper or with a soft cloth.

The test pieces shall be conditioned at a temperature of 20 ± 2°C and a relative humidity of 65 ± 5 per cent, for not less than 18 hours immediately before test.

NOTE. A temperature of 20 ± 2°C for conditioning is not practicable for all countries. In tropical countries an alternative temperature of 27 ± 2°C is permitted.

4.5.2 *Measurement of electric strength.* The test piece shall be placed concentrically between the electrodes and the test shall be made under insulating oil complying with B.S. 148.* The larger of the electrodes shall be connected to the earthed end of the high voltage winding of the testing transformer (or to the end nearest to earth potential if both poles of the transformer are insulated). The test shall be commenced as soon as possible after immersion of the test piece in oil.

On the first test piece, the voltage applied to the electrodes shall be increased from zero at a uniform rate of approximately 30 kV/min until breakdown occurs.

The nearest voltage to one half the breakdown voltage of the first test piece shall be selected from Table 1 and shall be applied to the second test piece and maintained for 20 seconds. If the test piece withstands this voltage without failure, the next higher and subsequent voltages in Table 1 shall be applied in turn.

TABLE 1. SUCCESSIVE VOLTAGES TO BE APPLIED (KILOVOLTS)

0·50	0·55	0·60	0·65	0·70	0·75	0·80	0·85	0·90	0·95			
1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9			
2·0	2·2	2·4	2·6	2·8	3·0	3·2	3·4	3·6	3·8	4·0	4·2	4·4
										4·6	4·8	
5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5	9·0	9·5			
10	11	12	13	14	15	16	17	18	19			
20	22	24	26	28	30	32	34	36	38	40	42	44
										46	48	
50	55	60	65	70	75	80	85	90	95	100		

Each value of test voltage shall be maintained for 20 seconds unless failure occurs. Subsequent test pieces shall be tested in accordance with the procedure specified for the second test piece. Should the second or any subsequent test piece fail less than 20 seconds after the application of the initial voltage, the results shall be disregarded and the test repeated on a fresh test piece, except that the initially applied voltage shall be lower

* B.S. 148, ' Insulating oil (low viscosity) for transformers and switchgear '.

than one half of the breakdown voltage of the first test piece by an amount considered appropriate.

If it is the second test piece which so fails, the same reduced initial voltage shall be applied to subsequent test pieces.

4.5.3 *Temperature of test.* The test shall be made at a temperature of 20 ± 5°C or at any other temperature deemed necessary in view of particular service requirements.

4.5.4 *Number of test pieces.* Four test pieces (including the initial test piece) shall be tested.

4.5.5 *Calculation of results.* The electric strengths of the second and subsequent test pieces shall be calculated by dividing the highest voltage, which a test piece withstands for 20 seconds, by the thickness of the test piece. The median of these three values shall be taken as the electric strength of the material.

4.5.6 *Report.* The report shall state :—

1. The '20-second step-by-step' value of the electric strength in kilovolts per millimetre.
2. Nominal thickness of test pieces.
3. Immersion medium.
4. Temperature of test.

SECTION 5 ONE-MINUTE PROOF TEST

5.1 Summary. In the proof test the material, as set up between the specified electrodes under given conditions, must withstand a prescribed voltage gradient for a period of one minute without failure.

5.2 Test piece. *Soft rubber.* The test piece shall be a disk with smooth surfaces not less than 100 mm in diameter and 1·25 ± 0·2 mm in mean thickness. The variation in thickness within any test piece shall not exceed 0·1 mm.

Ebonite. The test piece shall be a disk with smooth surfaces not less than 100 mm in diameter and 3·2 ± 0·2 mm in mean thickness. The variation in thickness within any test piece shall not exceed 0·2 mm.

5.3 Electrodes. The lower electrode shall consist of a solid cylinder of brass 76 ± 1 mm in diameter and not less than 25 mm thick, and the upper electrode shall consist of a solid cylinder of brass 38 ± 1·0 mm in diameter and not less than 37 mm thick, the plane faces of the electrodes being in contact with the test piece and concentric with each other during the test. The sharp edges shall be removed from the electrodes, the radius at the edge being approximately 0·8 mm.

5.4 Apparatus. The test voltages shall be provided by a transformer and

shall be alternating of nominal frequency 50 c/s. They shall be of approximately sine wave form, and the ratio of the peak value to the root mean square value shall be within the limits $\sqrt{2}(1{\cdot}00 \pm 0{\cdot}05)$, i.e. 1·34–1·48. The output of the testing set shall be sufficient to maintain on the test piece the necessary voltage for the maximum time required.

The test voltage shall be determined by means of a peak or other type of voltmeter connected across the output winding of the transformer ; alternatively, it shall be measured by means of a voltmeter connected across the input winding, or across a portion of the output winding. Any instrument used except the peak voltmeter shall be calibrated against a peak voltmeter (e.g. a sphere-gap*) connected across the output winding of the transformer. If there is any risk of the current taken by the test piece altering the no-load calibration appreciably, the calibration against a peak voltmeter shall be made with a test piece in circuit.

5.5 Procedure.

5.5.1 *Conditioning of samples and test pieces.* Tests shall not be carried out less than 24 hours after vulcanization, and for accurate comparison between different rubbers it may be necessary to ensure that these are tested at substantially the same interval after vulcanization.

Samples and test pieces shall be protected from light as completely as possible during the interval between vulcanization and testing, and care should be taken to avoid handling and contamination of the surface.

Before being conditioned, each test piece should be wiped carefully with absorbent paper or with a soft cloth.

The test pieces shall be conditioned at a temperature of 20 ± 2°C and a relative humidity of 65 ± 5 per cent, for not less than 18 hours immediately before test.

NOTE. A temperature of 20 ± 2°C is not practicable for all countries. In tropical countries an alternative temperature of 27 ± 2°C is permitted.

5.5.2 *Application of the proof voltage gradient.* The test piece shall be placed concentrically between the electrodes and the test shall be made under insulating oil complying with B.S. 148.† The larger of the electrodes shall be connected to the earthed end of the high voltage winding of the testing transformer (or to the end nearest to earth potential if both poles of the transformer are insulated). The test shall be commenced as soon as possible after immersion of the test piece in oil.

When the test is commenced the voltage applied to the electrodes shall be raised, as rapidly as is consistent with avoiding transient over-voltages, from zero until the prescribed voltage gradient is reached. The prescribed voltage gradient shall then be maintained for one minute. The test piece

* B.S. 358, ' Measurement of voltage with sphere-gaps '.
† B.S. 148, ' Insulating oil (low viscosity) for transformers and switchgear '.

shall be deemed to have passed the test if no breakdown occurs before the end of this period.

5.5.3 *Temperature of test.* The test shall be made at a temperature of 20 ± 5°C or at any other temperature deemed necessary in view of particular service requirements.

5.5.4 *Number of test pieces.* Five test pieces shall be tested.

5.5.5 *Report.* The report shall state :—

1. Magnitude of the applied proof voltage gradient in kilovolts per millimetre.
2. Number of test pieces tested.
3. Number of test pieces which pass the test.
4. Nominal thickness of the test pieces.
5. Immersion medium.
6. Temperature of test.

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