

BRITISH STANDARD 4663 : Part 1 : 1971

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METRIC UNITS

**SPECIFICATION FOR
ENAMELLED
COPPER CONDUCTORS
TEMPERATURE INDEX 220
(Aromatic polyimide base)**

Part 1. Round wire

BRITISH STANDARDS INSTITUTION



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BRITISH STANDARDS INSTITUTION

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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, numbering over 5000, fully indexed and with a note of the contents of each, will be found in the British Standards Yearbook, price £1.50. The BS Yearbook may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

BS 1036. Electrolytic tough pitch high conductivity copper.
BS 1489. The packaging of covered winding wires for electrical purposes.

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 BSI references relate to the work on this standard :
Committee reference ELE/36
Draft for comment 68/30296

CONTENTS

	Page
Co-operating organizations	5
Foreword	6

SPECIFICATION

1. Scope	7
2. Definitions	7
3. General notes and test conditions	8
4. Conductor	8
5. Enamel covering	10
6. Elongation and springiness	14
7. Thermal endurance	15
8. Cure test	15
9. Packaging	15

APPENDICES

A. Measurement of conductor diameter and overall diameter	17
B. Electrical resistance	18
C. Jerk test	21
D. Peel test	22
E. Cut-through test	24
F. Resistance to abrasion	27
G. Breakdown voltage	29
H. Continuity of covering	33
J. Springiness test	37
K. Test for thermal endurance	40
L. Determination of dielectric dissipation factor ($\tan \delta$)	46
M. Determination of weight loss	46

TABLES

1. Tolerances on conductor diameter	9
2. Mandrel diameters for winding test	11
3. Loads for abrasion test	12
4. Breakdown voltages (for conductors up to and including 0.040 mm diameter)	12
5. Breakdown voltages (for conductors over 0.040 mm diameter up to and including 2.500 mm diameter)	13

TABLES

	Page
6. Breakdown voltages (for conductors over 2.500 mm diameter)	14
7. Number of faults	14
8. Springiness test	16
9. Temperature correction factors	19
10. Resistance ratios	20
11. Loads for peel test	22
12. Time of heating for cut-through test	26
13. Loads for cut-through test	26
14. Tensions for breakdown voltage test (for conductors up to and including 0.040 mm diameter)	29
15. Tensions and twists for breakdown voltage test (for conductors over 0.040 mm diameter up to and including 2.500 mm diameter)	30
16. Details of mandrels for springiness test	39
17. Proof voltage	41
18. Suggested temperatures and exposure times in days per cycle	41
19. Suggested method of lay-out of data	45
20. Dimensions, resistances and elongation	48

FIGURES

1. Apparatus for the jerk test	21
2. Testing device for peel test	23
3. Scraper	23
4. Compression device for the cut-through test	25
5. Machine for the abrasion resistance test	28
6. Arrangement of mandrel and specimen for the breakdown voltage test	31
7. Device for twisting the wire samples	31
8. Arrangement of apparatus for testing the continuity of covering	34
9. Test circuit for continuity of covering including relay calibration	35
10. Test apparatus for springiness test	38
11. Construction and details of the mandrel	38

CO-OPERATING ORGANIZATIONS

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

- Associated Offices' Technical Committee
- Association of Consulting Engineers
- *Association of Manufacturers of Domestic Electrical Appliances
- Association of Mining Electrical and Mechanical Engineers
- Association of Supervisory and Executive Engineers
- *British Electrical and Allied Manufacturers' Association
- *British Radio Equipment Manufacturers' Association
- British Railways Board
- Crown Agents for Oversea Governments and Administrations
- Department of Employment and Productivity
- *Electric Cable Makers' Confederation
- Electrical Contractors' Association (Incorporated)
- Electrical Contractors' Association of Scotland
- *Electrical Research Association
- Electricity Council, the Central Electricity Generating Board and the Area Boards in England and Wales
- *Electronic Engineering Association
- Engineering Equipment Users' Association
- Institution of Electrical Engineers
- Lighting Industry Federation Limited
- Ministry of Defence
- Ministry of Defence, Army Department
- Ministry of Defence, Navy Department
- Ministry of Public Building and Works
- *Ministry of Technology
- Municipal Passenger Transport Association (Incorporated)
- National Inspection Council for Electrical Installation Contracting
- National Physical Laboratory (Ministry of Technology)
- Oil Companies Materials Association
- Post Office
- *Public Transport Association (Incorporated)
- South of Scotland Electricity Board

The Government department 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:

- British Fractional Horsepower Electric Motor Manufacturers' Association
- British Non-Ferrous Metals Federation High Conductivity Copper Group
- Copper Development Association
- Covered Conductors Association
- Radio and Electronic Component Manufacturers' Federation
- Society of Motor Manufacturers and Traders Ltd.
- Telecommunication Engineering and Manufacturing Association
- Telephone Manufacturers' Technical Development Committee

BRITISH STANDARD SPECIFICATION FOR

ENAMELLED COPPER CONDUCTORS

TEMPERATURE INDEX 220

(Aromatic polyimide base)

Part 1. Round wire

FOREWORD

In accordance with the practice of publishing British Standards which conform as nearly as possible with internationally agreed recommendations, this standard closely follows the dimensions given in IEC Publication 182*, the methods of test in IEC Publication 251-1† and the requirements in IEC Publication . . . ‡.

Some wire sizes additional to those recommended in IEC Publication 182 have been included at the request of certain sections of the electrical industry. These are indicated as non-preferred sizes.

Unlike the IEC Recommendation for enamelled round copper wire with a temperature index 220, the scope of this British Standard has been limited to enamel with an aromatic polyimide base.

It has been found necessary to specify a minimum increase in diameter due to the enamel, which is not included in the IEC Recommendation. The tolerances on resistance of some of the smaller wires are less than those recommended by the IEC. This has been found necessary to meet the need for close control in these diameters.

The solvent test has been omitted, since it is not necessary for this type of enamel, which is inherently resistant to varnish solvents. A test for thermal endurance has been introduced. The test procedure is in accordance with IEC Publication 172§, except that the median value has been adopted to shorten the duration of the test. The test may also be used for the assessment of the comparative thermal endurance of enamelled wires in conjunction with varnishes but, because the manufacturer of the enamelled wire does not control the varnish used in treating windings, it must not be assumed that the stated life will be appropriate for varnished wires.

* IEC Publication 182, 'Basic dimensions of winding wires', Part 1, 'Diameters of conductors for round winding wires', Part 2, 'Maximum overall diameters of enamelled round winding wires'.

† IEC Publication 251-1, 'Methods of test for winding wires', Part 1, 'Enamelled round wires'.

‡ See IEC Recommendation for specification sheet for enamelled round copper wires with upgraded thermal endurance properties, temperature index 220 (in course of preparation).

§ IEC Publication 172, 'Test procedures for the evaluation of the thermal endurance of enamelled wire by the lowering of the electric strength between twisted wires'.

Enamelled wire which meets the requirements of this specification meets all the requirements of the IEC Publications, and to facilitate cross reference the clause numbers of the IEC Publications have been indicated.

SI units are used in preference to 'metric technical units'. The relationship between the units of force in the two systems is: $1 \text{ N} = 0.102 \text{ kgf}$.

Requirements for rectangular conductors covered with enamel having an aromatic polyimide base will be given in Part 2 of this British Standard.

SPECIFICATION

1. SCOPE

1.1 General. This part of BS 4663 specifies requirements and dimensions for round copper conductors covered with an aromatic polyimide enamel having a temperature index of 220.

1.2 Sizes. The requirements of the standard are applicable to wires having a bare diameter from 0.020 mm to 5.000 mm inclusive. The standard sizes are given in Table 20. The preferred sizes are given in bold type.

1.3 Thickness of covering. Two thicknesses of covering are specified as follows.

Grade 1. Applicable to wires having a bare diameter from 0.020 mm up to and including 5.000 mm. Range of preferred sizes, from 0.050 mm up to and including 0.560 mm.

Grade 2. Applicable to wires having a bare diameter from 0.020 mm up to and including 5.000 mm. Range of preferred sizes from 0.050 mm up to and including 4.50 mm.

2. DEFINITIONS

For the purposes of this British Standard, the following definitions apply:

- (1) *Wire.* The insulated material as received.
- (2) *Conductor.* The bare metal after removal of the enamel.
- (3) *Increase in diameter due to the covering.* The difference between the diameter over the enamel and the diameter of the conductor.
- (4) *Tolerance.* The permissible divergence of an actual magnitude from that prescribed.
- (5) *Crack.* Any discontinuity in the enamel which penetrates significantly below the surface and which is visible at the stated magnification.

BS 4663 : Part 1 : 1971

(6) *Temperature index.* The temperature in degrees Celsius corresponding to an extrapolated life of 20 000 h on an Arrhenius plot.

NOTE. The plot uses the straight line of best fit to the measured lives of groups of specimens aged at not less than three elevated temperatures complying with the requirements of IEC Publication 172, 'Test procedures for the evaluation of the thermal endurance of enamelled wire by the lowering of the electric strength between twisted wires'.

(7) *Dielectric dissipation factor ($\tan \delta$).* The tangent of the loss angle, δ , of an insulating material.

3. GENERAL NOTES AND TEST CONDITIONS

3.1 Unless otherwise specified all tests shall be carried out within a temperature range of 15°C to 35°C and a relative humidity of 45 % to 75 %. Before measurements are made, the specimens shall be preconditioned under these atmospheric conditions for a time sufficient to allow specimens to reach stability.

3.2 The wire to be tested shall be removed from the packaging in such a way that the wire will not be subjected to tension or unnecessary bends; before each test sufficient wire shall be discarded to ensure that any damaged wire is not included in the test specimens.

3.3 When no specific range of sizes is given for a test, the test is applicable to all sizes.

4. CONDUCTOR

4.1 **Material.** The conductor shall be manufactured from high conductivity copper complying with the requirements of BS 1036*.

4.2 **Tolerance on conductor diameter.** (IEC Publication 251-1, Clause 4.) The conductor diameters shall be within the limits specified in 4.2.1, 4.2.2 and 4.2.3.

4.2.1 *Wires of conductor diameter 0.071 mm and larger.* When measured by the method described in Appendix A, the conductor diameters shall be within the appropriate limits given in Table 20. These have been obtained by applying the tolerances given in Table 1.

4.2.2 *Out of roundness of conductor (wires of conductor diameter 0.071 mm and larger).* The out of roundness, as defined in Appendix A, shall not exceed the figure given in Column 2 of Table 1.

4.2.3 *Wires of diameter smaller than 0.071 mm.* The conductor diameters shall be deemed to be correct if the resistances are within the appropriate limits given in Table 20.

* BS 1036, 'Electrolytic tough pitch high conductivity copper'.

BS 4663 : Part 1 : 1971

TABLE 1. TOLERANCES ON CONDUCTOR DIAMETER

1	2	1	2
Nominal conductor diameter	Tolerance + —	Nominal conductor diameter	Tolerance + —
mm	mm	mm	mm
0.071	0.003	0.710	0.007
0.080	0.003	0.750	0.008
0.090	0.003	0.800	0.008
0.100	0.003	0.850	0.009
0.112	0.003	0.900	0.009
0.125	0.003	0.950	0.010
0.132	0.003	1.000	0.010
0.140	0.003	1.060	0.011
0.150	0.003	1.120	0.011
0.160	0.003	1.180	0.012
0.170	0.003	1.250	0.013
0.180	0.003	1.320	0.013
0.190	0.003	1.400	0.014
0.200	0.003	1.500	0.015
0.212	0.003	1.600	0.016
0.224	0.003	1.700	0.017
0.236	0.004	1.800	0.018
0.250	0.004	1.900	0.019
0.265	0.004	2.000	0.020
0.280	0.004	2.120	0.021
0.300	0.004	2.240	0.022
0.315	0.004	2.360	0.024
0.335	0.004	2.500	0.025
0.355	0.004	2.650	0.027
0.375	0.005	2.800	0.028
0.400	0.005	3.000	0.030
0.425	0.005	3.150	0.032
0.450	0.005	3.350	0.034
0.475	0.005	3.550	0.036
0.500	0.005	3.750	0.038
0.530	0.006	4.000	0.040
0.560	0.006	4.250	0.043
0.600	0.006	4.500	0.045
0.630	0.006	4.750	0.048
0.670	0.007	5.000	0.050

BS 4663 : Part 1 : 1971

4.3 Resistance (wires of conductor diameter up to and including 1.0 mm). (IEC Publication 251-1, Clause 5.) The resistance of the conductor at 20 °C shall be within the limits given in Table 20 when measured in accordance with Appendix B. The maximum and minimum resistance values given in the table include tolerances on both the resistivity of the material and the diameter of the wire, and no further tolerance is applicable.

NOTE. The nominal resistances of conductors above 1.00 mm diameter are included in Table 20 for information only.

5. ENAMEL COVERING

5.1 General. The conductor shall be completely and uniformly covered with a durable, flexible, synthetic enamel based on an aromatic polyimide resin. The enamel shall have a smooth surface free from embedded particles of dust and other deleterious material.

Unless otherwise agreed, the wire shall be lubricated with a neutral hydrocarbon oil or wax. Unless otherwise specified the quantity of oil shall be a minimum and shall not fling during the winding operation. The lubricant shall have no deleterious effect on impregnants in normal use.

5.2 Overall diameter and increase in diameter. When determined by the method described in Appendix A, the overall diameter of the enamelled wire shall not exceed the appropriate value for the thickness of covering and diameter of wire given in Table 20, and the increase in diameter due to the enamel shall not be less than the appropriate value given in Table 20.

5.3 Flexibility and adherence. (IEC Publication 251-1, Clause 8.)

5.3.1 Mandrel winding test. After winding ten contiguous turns on a polished mandrel, the diameter of which is specified in Table 2, the covering of the sample shall show no cracks when examined under a magnification of six to ten times.

The mandrel shall be rotated at between one and three turns per second, the tension on the wire being just sufficient to keep it in contact with the mandrel. Care shall be taken to avoid elongation or twisting of the wire. Three tests shall be made.

5.3.2 Jerk test (wires of conductor diameter up to and including 1.0 mm). The covering shall show no cracks or loss of adhesion when tested in accordance with Appendix C.

5.3.3 Peel test (wires of conductor diameter over 1.0 mm). When tested in accordance with Appendix D, the covering shall show no sign of loss of flexibility or adhesion.

TABLE 2. MANDREL DIAMETERS FOR WINDING TEST

Nominal conductor diameter		Mandrel diameter (d = nominal diameter of conductor in mm)
Over	Up to and including	
mm	mm	
—	0.040	0.150 mm*
0.040	0.250	$3d^*$
0.250	2.000	d
2.000	5.000	$2d$

* The wire is stretched 20 % or to the breaking point of the copper, whichever is less, before winding on the mandrel.

5.4 Heat shock. (IEC Publication 251-1, Clause 9.) Three test specimens shall be prepared as prescribed in 5.3.1 and shall be put for 30 min into a hot electrically heated oven with forced-air circulation at a temperature between 240°C and 250°C.

After removal from the oven the specimens shall be allowed to cool to room temperature and shall be examined for cracks under a magnification of 6 to 10 times. Each specimen shall be free from cracks.

5.5 Cut-through. (IEC Publication 251-1, Clause 10.) When tested in accordance with Appendix E, specimens shall show no failure after 2 min at 350°C.

5.6 Resistance to abrasion (wires of diameter 0.250 mm up to and including 2.500 mm). (IEC Publication 251-1, Clause 11.) When tested in accordance with Appendix F the average of the number of strokes shall not be less than 20 and no individual value shall be less than 8. The load applied shall be as given in Table 3.

5.7 Breakdown voltages. (IEC Publication 251-1, Clause 13.) The wire shall meet the requirements of 5.7.1, 5.7.2 and 5.7.3, as appropriate, when tested at room temperature in accordance with Appendix G.

5.7.1 Wires of conductor diameter up to and including 0.040 mm. At least four of the five samples tested shall not break down at a voltage less than the appropriate value given in Table 4.

BS 4663 : Part 1 : 1971

TABLE 3. LOADS FOR ABRASION TEST

Nominal conductor diameter*	Load		Nominal conductor diameter*	Load	
	Grade 1	Grade 2		Grade 1	Grade 2
mm	N	N	mm	N	N
0.250	1.6	2.0	1.060	4.7	5.9
0.280	1.7	2.2	1.120	4.9	6.1
0.315	1.9	2.4	1.180	5.1	6.3
0.355	2.1	2.7	1.250	5.3	6.6
0.400	2.3	2.9	1.320	5.5	6.8
0.450	2.6	3.2	1.400	5.7	7.1
0.500	2.7	3.4	1.500	6.0	7.4
0.560	3.0	3.7	1.600	6.2	7.7
0.630	3.2	4.0	1.700	6.5	8.0
0.710	3.5	4.4	1.800	6.8	8.3
0.750	3.7	4.7	1.900	6.8	8.3
0.800	3.8	4.9	2.000	6.8	8.3
0.850	4.0	5.1	2.120	6.8	8.3
0.900	4.2	5.3	2.240	6.8	8.3
0.950	4.4	5.5	2.360	6.8	8.3
1.000	4.5	5.7	2.500	6.8	8.3

*For intermediate sizes the appropriate load is that given for the next finest size.

TABLE 4. BREAKDOWN VOLTAGES (FOR CONDUCTORS UP TO AND INCLUDING 0.040 mm DIAMETER)

Nominal conductor diameter	Minimum breakdown voltage (r.m.s.)	
	Grade 1	Grade 2
mm	V	V
0.020	40	115
0.0224	40	115
0.025	60	140
0.028	60	140
0.030	60	140
0.032	70	175
0.036	70	175
0.040	100	230

5.7.2 Wires of conductor diameter over 0.040 mm up to and including 2.500 mm.
 No sample tested shall break down at a voltage less than the appropriate value given in Table 5. If one of the first five specimens fails, the test shall be repeated with a second series of five specimens, and then no breakdown shall occur.

TABLE 5. BREAKDOWN VOLTAGES (FOR CONDUCTORS OVER 0.040 mm DIAMETER UP TO AND INCLUDING 2.500 mm DIAMETER)

Nominal conductor diameter		Minimum breakdown voltage (r.m.s.)	
		Grade 1	Grade 2
mm		V	V
0.045		350	700
0.050		350	700
0.056		375	750
0.060		375	750
0.063		400	800
Over	Up to and including		
mm	mm		
0.063	0.080	500	950
0.080	0.100	600	1200
0.100	0.125	700	1300
0.125	0.160	800	1500
0.160	0.200	900	1700
0.200	0.250	1000	2000
0.250	0.315	1200	2200
0.315	0.400	1400	2400
0.400	0.500	1600	2800
0.500	0.710	1800	3100
0.710	0.850	1900	3500
0.850	0.950	2000	3700
0.950	1.120	2100	3800
1.120	1.320	2200	3900
1.320	1.600	2300	4000
1.600	1.900	2400	4300
1.900	2.500	2500	4400

BS 4663 : Part 1 : 1971

5.7.3 Wires of conductor diameter over 2.500 mm. At least four of five samples tested shall not break down at voltages less than those given in Table 6.

TABLE 6. BREAKDOWN VOLTAGES (FOR CONDUCTORS OVER 2.500 mm DIAMETER)

Nominal conductor diameter	Minimum breakdown voltage (r.m.s.)	
	Grade 1	Grade 2
Over	V	V
mm		
2.500	1000	1600

5.7.4 Test at 220°C. When required by the purchaser this test shall be carried out at 220°C as described in Appendix G and the wire shall have a breakdown voltage not less than 75 % of the values given in Tables 4, 5 and 6.

5.8 Continuity of covering (wires of conductor diameter up to and including 0.500 mm). (IEC Publication 251-1, Clause 14.) When tested in accordance with Appendix H, the number of faults shall not exceed the appropriate value given in Table 7.

A continuous fault shall cause rejection.

TABLE 7. NUMBER OF FAULTS

Nominal conductor diameter		Maximum number of faults per 30 m	
Over	Up to and including	Grade 1	Grade 2
mm	mm		
—	0.040	30	12
0.040	0.500	15	6

6. ELONGATION AND SPRINGINESS

6.1 Elongation. (IEC Publication 251-1, Clause 6.) The elongation to fracture of the enamelled wire shall be measured with an elongation tester or a tensile test machine. The free measuring length shall be between 200 mm and 250 mm.

The wire shall be stretched at a rate of not more than 5 mm/s. The elongation shall be expressed as a percentage of the free measuring length.

Three measurements shall be made and the mean value taken as 'elongation'. This shall not be less than the appropriate value in Table 20.

6.2 Springiness (wires of conductor diameter 0.050 mm up to and including 1.600 mm). (IEC Publication 251-1, Clause 7.) The springback of the wire when tested in accordance with Appendix J shall not exceed the value given in Table 8, using the appropriate mandrel and tension.

7. THERMAL ENDURANCE

When tested by the method given in Appendix K, the temperature corresponding to an extrapolated life of 20 000 h shall be not less than 220°C. The median life at 240°C shall be not less than 5000 h.

When required by the purchaser, the manufacturer shall certify that the enamelled wire has been made using materials and processes that have been shown to give a product which will meet these requirements.

NOTE. The conductor specified in Clause 4 oxidizes at an increasing rate at temperatures of 200°C and above. Where extended life is desired at temperatures above 200°C it is advisable to protect the copper with nickel of sufficient thickness to overcome oxidation. Nickel is recommended because it has been found that silver plating, which is often used, can result in a significant reduction in thermal endurance.

8. CURE TEST

8.1 Dielectric dissipation factor ($\tan \delta$). When determined by the method described in Appendix L the dielectric dissipation factor ($\tan \delta$) of the enamel shall not exceed 60×10^{-4} when measured at a frequency of 1000 ± 200 Hz at room temperature.

Alternatively the weight loss may be determined by the method described in Appendix M. In cases of dispute, the dielectric dissipation factor method shall be used.

8.2 Weight loss. When determined by the method described in Appendix M the weight loss shall not exceed 3 % of the weight of the enamel.

9. PACKAGING

Unless otherwise specified, the enamelled wire shall be packed, wrapped and labelled so that the requirements of BS 1489* are satisfied.

* BS 1489, 'The packaging of covered winding wires for electrical purposes'.

BS 4663 : Part 1 : 1971

TABLE 8. SPRINGINESS TEST

Nominal conductor diameter	Mandrel diameter	Tension	Maximum springback	
			Grade 1	Grade 2
mm	mm	N		
0.050	3	0.1	72	87
0.063	3	0.1	68	82
0.071	3	0.1	65	77
0.080	5	0.25	70	80
0.090	5	0.25	67	77
0.100	5	0.25	64	73
0.112	7	0.50	64	73
0.125	7	0.50	62	70
0.140	7	0.50	59	67
0.160	10	1.0	59	67
0.180	10	1.0	57	65
0.200	10	1.0	54	62
0.224	12.5	2.0	51	59
0.250	12.5	2.0	49	56
0.280	12.5	2.0	47	53
0.315	19	4.0	50	55
0.355	19	4.0	48	53
0.400	19	4.0	45	50
0.450	25	8.0	44	48
0.500	25	8.0	43	47
0.560	25	8.0	41	44
0.630	37.5	12.0	46	50
0.710	37.5	12.0	44	47
0.750	37.5	12.0	43	45
0.800	37.5	12.0	41	43
0.850	50	15.0	47	49
0.900	50	15.0	45	48
0.950	50	15.0	44	46
1.000	50	15.0	42	45
1.060	50	15.0	41	43
1.120	50	15.0	39	41
1.180	50	15.0	37	39
1.250	50	15.0	35	37
1.320	50	15.0	34	36
1.400	50	15.0	32	34
1.500	50	15.0	30	32
1.600	50	15.0	28	30

NOTE. The maximum springback for intermediate sizes will be the maximum specified for the next smaller size in the table.

APPENDIX A

MEASUREMENT OF CONDUCTOR DIAMETER AND OVERALL DIAMETER

A.1 Measuring equipment. Measurements should be made with an accuracy better than 0.002 mm. If a micrometer is used it should be fitted with a pressure indicator, and measurements should be made with a force of 0.75 N to 1.25 N (76gf to 128gf). Alternatively, for wires over 0.5 mm diameter, a force of 1 N to 3 N (102gf to 306gf) may be used.

The spindle and anvil of the micrometer should have a diameter of 5 mm to 8 mm.

A.2 Measuring methods

A.2.1 Overall diameter of the wire (applicable to all sizes). Three measurements are made, evenly distributed around the circumference of the wire, at each of two places 1 m apart.

The average of the six results is reported as 'overall diameter'.

A.2.2 Conductor diameter (applicable to sizes 0.071 mm and larger). The enamel is removed at the two places already measured, by any method which does not damage the conductor.

Three measurements are made, evenly distributed around the circumference of the conductor, at these places.

The average of the six results for the bare diameter is reported as 'conductor diameter'.

A.3 Increase in diameter. The difference between the overall diameter and the conductor diameter is taken as the increase in diameter due to the enamel covering.

A.4 Out of roundness of the conductor (applicable to sizes 0.071 mm and larger). The out of roundness is defined as the greatest difference between the maximum and minimum readings at each cross section.