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**Specification for
Phenolic resin bonded paper
laminated sheets for
electrical applications**

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Committee references ELE/16, ELE/16/53, ELE/16/53/2 Draft for comment 71/20352

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Telephone 01-629 9000

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Foreword

This British Standard supersedes BS 1137 : 1966 'Phenolic resin bonded paper sheets for electrical purposes at power frequencies' and BS 2076 : 1954 'Thermosetting synthetic-resin bonded-paper insulating sheets for use at radio frequencies' and covers the materials specified in both of them. Five of the types of laminated sheets specified in this standard correspond to those previously specified in BS 1137 and BS 2076 as follows:

Type 1 to Type I of BS 1137 and Type L of BS 2076.

Type 2A and Type 2B to Type II of BS 1137.

Type 3 to Type III of BS 1137.

Type 4 to Type H of BS 2076.

Type 5 a new type with electrical properties similar to Type 1 which is suitable for cold punching (see 2.12).

Requirements for sheets sanded on one side to achieve reduced tolerances on thickness are now included.

The methods used to test electric strength, both flatwise and edgewise, insulation resistance and deformation have been changed. Where applicable the methods of BS 2782 'Methods of testing plastics' have been used but in some cases amendments have been made where they have been found necessary. A flammability test has been included. The punching test previously used in BS 2076 has been replaced by an optional piercing test which is applicable to sheets of thickness up to 3 mm.

The atmosphere in which specimens are conditioned prior to testing is now $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ r.h. in accordance with agreement reached in Technical Committee 15 – Insulating materials, of the International Electrotechnical Commission (IEC).

By Amendment No. 2 all requirements for impact strength were deleted from this British Standard. This action was in line with the decision of Technical Committee 61, Plastics, of the International Organization for Standardization (ISO), that impact strength requirements should not be applied to paper base industrial laminated sheets. During the relevant international discussions it was agreed that for such brittle materials impact strength measurements were of little practical significance and the variability of the results obtained made it difficult to set meaningful limiting values.

Certification Attention is drawn to the certification facilities described on the inside back cover of this standard.

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British Standard Specification for

Phenolic resin bonded paper laminated sheets
for electrical applications

1. General

1.1 Scope

This British Standard specifies test requirements and preferred nominal thicknesses for five types of phenolic resin bonded paper laminated sheets classified as in 1.3.

The range of thicknesses is as follows:

Types 1, 2B and 3	0.4 mm up to and including 25 mm
Type 4	0.4 mm up to and including 8 mm
Type 5	0.4 mm up to and including 4 mm

Requirements for sheets of Types 1, 2, 4 and 5 sanded on one side, of nominal thicknesses in the range 0.4 mm to 3 mm inclusive, are included.

The sheets covered by this standard are intended for electrical insulating purposes, for use with direct current and with alternating current at power frequencies and, according to type, at higher frequencies.

NOTE 1. Density is not necessarily a guide to the quality of the material, but it may be noted that the density of the material covered by this standard is usually between 1300 kg/m³ and 1400 kg/m³.

NOTE 2. The titles of the British Standards referred to in this standard are listed on the inside back cover.

1.2 Definitions

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

- (1) *Phenolic resin bonded paper laminated sheet.* Sheet or board made from layers of cellulosic paper treated with thermosetting synthetic resin of phenolic type and bonded together under heat and pressure.
- (2) *Flatwise.* Perpendicular to the plane of lamination.
- (3) *Edgewise.* Parallel with the plane of lamination.
- (4) *Direction 'A' and direction 'B'.* Two directions in the plane of lamination, mutually at right-angles, one of which is parallel with an edge of the sheet.

1.3 Classification

The five types of phenolic resin bonded paper laminated sheets specified in this British Standard are 1, 2B, 3, 4 and 5. For comparison between the types, the following limiting values for five properties have been extracted from Tables 1 and 4.

Property	Type					
	1		2B	3	4	5
Edgewise electric strength, kV	25		20	20	30	25
Insulation resistance, MΩ	1000		100	10	30 000	1000
Cross-breaking strength, MN/m ²	85		130	130	70	70
Water absorption, 4 mm thick, mg	100		186	509	54	100

1.4 Compliance

All materials purporting to be in accordance with this British Standard shall comply with the basic requirements given in 2.1 to 2.13. Material will normally comply with the optional requirements given in 3.1 to 3.9, or,

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for sanded sheet, Clause 4, but if assurance is necessary for one or more of the requirements, this should be stated in the enquiry and order.

1.5 Colour

Unless otherwise specified, the material shall be of natural colour, but colouring matter or other additives may be incorporated, by agreement between the purchaser and the supplier, provided that the laminated sheet meets the requirements of this standard.

1.6 Conditioning

Where conditioning of test pieces is specified in the method of test, this shall be carried out in accordance with Appendix A.

2. Basic requirements

2.1 Summary of basic requirements

The requirements of Section 2 are summarized in Table 1.

NOTE. As indicated in the individual clauses, some of these requirements are applicable only to certain types and thicknesses of sheet.



Table 1. Basic requirements and associated limits

Clause	Property	Test method appendix	Limits		Max. or min.	Type					
			Unit				1	2B	3	4	5
2.2	Appearance	—	—		—	←	←	←	See 2.2	←	←
2.3	Flatness of sheets of nominal thickness 3 mm and above	—	—		—	←	←	←	See 2.3	←	←
2.4	Thickness and deviation	—	—		—	←	←	←	See Table 2	←	←
2.5	Edgewise electric strength in oil at 90 °C for sheets of nominal thickness 1.6 mm and above	B	kV r.m.s.		min.	25	25	20	20	30	25
2.6	Flatwise electric strength in oil at 90 °C for sheets of nominal thickness up to and including 3 mm	C	—		—	←	←	←	See Table 3	←	←
2.7	Flatwise loss tangent at 1 MHz	D (Note 1)	—		max.	0.045	← Not applicable	←	0.038	←	0.045
2.7	Flatwise relative permittivity at 1 MHz	D (Note 1)	—		max.	5.7	← Not applicable	←	5.0	←	5.2
2.8	Insulation resistance	E	MΩ		min.	1000	100	10	30000	1000	1000
2.9	Water absorption	F	—		—	←	←	←	See Table 4	←	←
2.10	Flatwise shear strength for sheets of nominal thickness up to and including 1.6 mm	G	MN/m ²		min.	60	70	70	60 (Note 2)	50	40 (Note 2)
2.11	Resistance to hot oil Types 1, 2A, 2B, 3 and 4	H	—		—	←	←	←	See 2.11	←	←
2.12	Machinability	—	—		—	←	←	←	See 2.12	←	←
2.13	Cross-breaking strength for sheets of nominal thickness 1.6 mm and above	J	MN/m ²		min.	85	130	130	70	70	70

NOTE 1. Or other suitable method.
NOTE 2. 60 for thicknesses greater than 0.8 mm, 40 for thicknesses of 0.8 mm and below.

2.2 Appearance

Sheets shall be of generally uniform appearance and shall be free from blisters, wrinkles and cracks. They shall be substantially free from other small defects, for example, scratches, dents and discoloration, and shall be supplied with trimmed edges.

NOTE. For Type 3 sheets it is desirable that, after machining, component parts intended for use for electrical purposes in air be dried, and the machined surfaces sealed with suitable moisture-resisting insulating varnish. It should be noted also that Type 3 sheets are less dimensionally stable than those which absorb less water.

2.3 Flatness

When any sheet of nominal thickness 3 mm or more is placed without restraint, concave side up, on a flat horizontal surface, the departure at any part of the upper surface of the sheet from a light straight edge laid in any direction upon it shall not exceed either of the appropriate values given below.

Thickness	1 m straight edge	0.5 m straight edge
3 mm up to and including 8 mm	8 mm	2 mm
Above 8 mm	6 mm	1.5 mm

2.4 Preferred nominal thicknesses and permissible deviations

The preferred nominal thicknesses are given in Table 2. The thickness of a sheet at any point shall not deviate from the nominal thickness by more than the appropriate value shown in Table 2. Where the nominal thickness is not one of the preferred values, then the deviation for the next higher preferred nominal thickness shall apply.

Table 2. Preferred nominal thicknesses and permissible deviations

Preferred nominal thickness	Permissible deviation from nominal thickness, plus or minus
mm	mm
0.4	0.06
0.5	0.07
0.6	0.08
0.8	0.09
1	0.11
1.2	0.12
1.6	0.14
2	0.16
2.5	0.18
3	0.20
4	0.24
5	0.28
6	0.32
8	0.39
10	0.45
12	0.50
14	0.56
16	0.61
20	0.72
25	0.85

2.5 Edgewise electric strength

This clause applies to sheets of a nominal thickness of 1.6 mm or above. The edgewise electric strength of the sheet shall be determined in oil at 90 °C, as described in Appendix B. The test result shall be not less than the value given in Table 1.

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2.6 Flatwise electric strength

This clause is a basic requirement of sheets of a nominal thickness of 3 mm or below. For thicker sheets up to 14 mm nominal thickness the requirement is optional. See 3.2.

The flatwise electric strength of the sheet shall be determined in oil at 90 °C, as described in Appendix C. The test result shall be not less than the limit given in Table 3. Where the measured thickness of the test piece is intermediate between two of the thicknesses shown in Table 3, the limit shall be obtained to the nearest 0.1 MV/m by straight line interpolation.

Table 3. Flatwise electric strength

Electric strength (r.m.s.)	
Measured thickness	Types 1, 2B, 3, 4 and 5
	min.
mm	MV/m
0.34 up to and including 0.4	17.5
0.5	16.0
0.6	15.0
0.8	13.4
1.0	12.3
1.2	11.4
1.6	10.0
2.0	9.1
2.5	8.3
3.0	7.7
4.0	6.8
5.0	6.1
6.0	5.5
8.0	4.7
10.0	4.1
12.0	3.7
14.0 up to and including 14.56	3.4



2.7 Flatwise loss tangent and relative permittivity at 1 MHz

This clause applies only to sheets of Types 1, 4 and 5 and only to sheets of nominal thicknesses from 1 mm to 3 mm inclusive. The flatwise loss tangent and relative permittivity shall be determined in the condition as received by a suitable method, for example that given in Appendix D, and when so determined the test results shall be not greater than the values given in Table 1.

2.8 Insulation resistance after water immersion

The insulation resistance of the sheet after water immersion shall be determined as described in Appendix E. The test result shall be not less than the value given in Table 1.

2.9 Water absorption

The sheet shall be tested for water absorption as described in Appendix F. The test result shall be not greater than the value given in Table 4.

When the mean of the measured thicknesses of the test pieces is intermediate between two consecutive thicknesses shown in Table 4, the limit shall be obtained to the nearest milligram by straight line interpolation. Where the mean of the measured thicknesses of the test pieces is below 0.4 mm the limit appropriate to 0.4 mm shall apply. Where the nominal thickness is 25 mm and the mean of the measured thicknesses of the test pieces exceeds 25 mm the limit appropriate to 25 mm shall apply. Similarly, for Type 4, where the nominal thickness is 8 mm and the mean of the measured thicknesses exceeds 8 mm, the limit appropriate to 8 mm shall apply,

and for Type 5 where the nominal thickness is 4 mm and the mean of the measured thicknesses exceeds 4 mm the limit appropriate to 4 mm shall apply.

Table 4. Water absorption

Water absorption of 50 mm square					
Measured thickness	Type 1	Type 2B	Type 3	Type 4	Type 5
	max.	max.	max.	max.	max.
mm	mg	mg	mg	mg	mg
0.4	62	111	330	35	62
0.5	63	115	343	36	63
0.6	65	119	354	37	65
0.8	67	125	374	39	67
1	69	129	393	40	69
1.2	71	134	403	41	71
1.6	76	142	426	43	76
2	80	150	448	46	80
2.5	85	160	465	48	85
3	90	169	482	50	90
4	100	186	509	54	100
5	110	200	527	57	
6	118	216	545	60	
8	135	242	579	63	
10	149	268	601		
12	162	292	621	Outside scope of standard	
14	175	315	642		
16	186	332	662		
20	202	364	692		
25	219	397	718		



2.10 Flatwise shear strength

This clause applies only to sheets of a nominal thickness of 1.6 mm or below. For thicker sheets this requirement is optional. See 3.5. The shear strength of the sheet shall be determined as described in Appendix G. The test result shall be not less than the value given in Table 1.

2.11 Resistance to hot oil

This clause applies only to sheets of Types 1, 2B, 3 and 4. The sheet shall be tested as described in Appendix H. It shall show no sign of splitting, blistering or delamination.

2.12 Machinability

2.12.1 When sawn, drilled, turned, routed, milled or punched in accordance with the recommendations of the manufacturer, the sheet shall not show undue chipping or any sign of splitting, cracking or delamination.

2.12.2 For materials designated cold punching, e.g. Type 5, with good punching practice, sheets up to and including 1.6 mm in thickness may be punched at a temperature not less than 23 °C and in thicknesses over 1.6 mm up to and including 3 mm when heated to a temperature up to 60 °C.

2.13 Cross-breaking strength

This clause applies to sheets of a nominal thickness of 1.6 mm or above. The cross-breaking strength of the sheet shall be determined as described in Appendix J. The test result shall be not less than the value given in Table 1.

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3. Optional requirements

3.1 Summary of optional requirements

The requirements of Section 3, which are applicable only when specified by the purchaser, are summarized in Table 5.

NOTE. As indicated in the individual clauses, some of these requirements are applicable only to certain types and thicknesses of sheet.

Table 5. Optional requirements and associated limits

Clause	Property	Test method appendix	Limits Unit	Max. or min.	Type	1	2B	3	4	5
3.2	Flatwise electric strength in oil at 90 °C for sheets of nominal thickness above 3 mm up to and including 14 mm	D	—	—	See Table 3					
3.3	Flatwise loss tangent at 50 Hz or 0.8 kHz to 1.6 kHz	K	—	max.	To be agreed between purchaser and supplier					
3.4	Resistance to flatwise compression (reduction in thickness)	L	%	max.	3	3	3	2.5	3.5	
3.5	Flatwise shear strength for sheets of nominal thickness above 1.6 mm up to and including 6 mm	G	MN/m ²	min.	60	70	70	60	50	
3.6	Tensile strength of sheets of nominal thickness 6 mm and above	M	MN/m ²	min.	55	70	70	Not applicable		
3.7	Temperature for specified deformation under load for sheets of nominal thickness 3 mm and above	N	°C	min.	To be agreed between purchaser and supplier					
3.8										
3.9	Flammability	Q	—	—	See 3.9					
3.10	Piercing	R	—	—	See 3.10					