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Base materials for printed circuits - Part 1: Test methods

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Base materials for printed circuits
Part 1. Test methods

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Matériaux de base pour circuits imprimés
Première partie: Méthodes d'essai
(CEI 249-1 : 1982 + A1 : 1984 + A2 : 1989 + A3 : 1991 + A4 : 1993)

Basismaterialien für gedruckte Schaltungen
Teil 1: Prüfverfahren
(IEC 249-1 : 1982 + A1 : 1984 + A2 : 1989 + A3 : 1991 + A4 : 1993)

This European Standard was approved by CENELEC on 1993-07-06. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

Foreword to EN 60249-1 : 1993

At the request of the 73rd Technical Board of CENELEC, HD 313.1 S5 : 1991 (IEC 249-1 : 1982 and its amendments 1 : 1984 and 2 : 1989) was submitted to the CENELEC voting procedure for conversion into a European Standard.

The CENELEC questionnaire procedure, performed for finding out whether or not amendment 3 : 1991 to the international standard IEC 249-1 : 1982 could be accepted without textual changes, has shown that no common modifications were necessary for the acceptance as European Standard. The reference document was submitted to the CENELEC members for formal vote.

The documents were combined and approved by CENELEC as EN 60249-1 on 6 July 1993.

This European Standard replaces HD 313.1 S5 : 1991.

The following dates were fixed:

- latest date of publication of an identical national standard (dop) 1994-03-01
- latest date of withdrawal of conflicting national standards (dow) 1994-03-01

Annexes designated 'normative' are part of the body of the standard. In this standard, annex ZA is normative.

Foreword to A4 : 1994

At the request of the 76th Technical Board of CENELEC, amendment 4 : 1993 to the International Standard IEC 249-1 : 1982 was submitted to the CENELEC members for formal vote.

The text of the International Standard was approved by CENELEC as amendment A4 to EN 60249-1 on 8 January 1994.

The following dates were fixed:

- latest date of publication of an identical amendment (dop) 1995-03-15
- latest date of withdrawal of conflicting national standards (dow) 1995-03-15

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BASE MATERIALS FOR PRINTED CIRCUITS

Part 1: Test methods

Scope

This standard describes methods for testing electrical, mechanical and other properties of base materials in sheet or roll form for application in the field of printed circuits irrespective of the nature of the insulating base material.

Note. — Those methods which are specific to the testing of the materials given in IEC Publication 249-3: Base Materials for Printed Circuits, Part 3: Special Materials Used in Connection with Printed Circuits, are contained in Part 3 and are not included in this part of the publication.

The methods described for the preparation of test specimens from metal-clad materials are complete for copper-clad materials only. They may be expanded in future to include materials clad with other metals.

The number of specimens stated to measure each property is the number required to produce a test result of sufficient precision to evaluate a single sample of material. For purposes of qualification approval this number of specimens should be taken from each sheet tested. For purposes of continuous assessment of quality, the number of specimens taken from each sheet (sample) tested depends on the quality assurance system used and on its sampling plans.

1. General

1.1 *Standard atmospheric conditions*

1.1.1 *Pre-conditioning*

Unless otherwise specified, each test specimen shall, before test and/or before measurements are made, be pre-conditioned in the standard atmospheric conditions for testing specified in Sub-clause 5.3 of IEC Publication 68-1: Basic Environmental Testing Procedures, Part 1: General, for a time sufficient to allow the entire specimen to reach temperature equilibrium.

1.1.2 *Testing*

Unless otherwise specified, all tests shall be carried out in the standard atmospheric conditions for testing specified in IEC Publication 68.

If required, the ambient temperature and the ambient relative humidity at which the test or measurement is made shall be stated in the report.

In case of dispute between purchaser and supplier concerning results, the tests shall be carried out in one of the "referee conditions" specified in Sub-clause 5.2 of IEC Publication 68-1.

1.2 *Precision of timing and measurements*

1.2.1 *Lengths of time*

Unless otherwise specified, the lengths of time allowed for conditioning and test procedure shall not deviate by more than $\pm 10\%$ from the durations stated.

1.2.2 *Numerical precision in reporting results*

Measurements to determine compliance with the requirements in the specifications in Part 2 onwards shall be expressed with the same number of significant figures as the requirements themselves, unless otherwise specified.

1.3 *Test specimens*

1.3.1 *Preparation of etched test specimens from copper-clad base materials*

1.3.1.1 *Washing and printing to form test patterns*

If a test pattern is to be formed, the copper face of a sample of the sheet under test shall first be washed with water, an abrasive powder, for example, pumice (see note) and, if necessary, trisodium phosphate, until water will remain in an unbroken film covering the whole face. An additional dip into a 10% HCl solution followed by rinsing may be necessary.

The pattern shall be printed on the copper face by means of photoengraving or other technique giving the specified accuracy.

1.3.1.2 *Method of etching*

Etching, whether for forming test patterns or for the complete removal of the foil, shall be carried out by a suitable etching procedure. In cases of dispute between purchaser and supplier, the etching shall be carried out with a spray or by an equivalent method, with an aqueous solution of ferric chloride of density 1.32 g/cm³ to 1.41 g/cm³. The temperature of the solution shall not exceed 37 °C.

If a test pattern is being formed, the etching time shall be sufficient to produce a clear and distinct image.

The etching times for foils of preferred mass per unit area shall not exceed those shown in the following table:

Nominal mass of foil, g/m²	152	230	305	610	915
oz/ft²	0.5	0.75	1.0	2.0	3.0
Etching time, max. minutes	6	6	7	14	21

For foils of intermediate mass, the maximum etching time shall be determined by linear interpolation.

For foils outside the given range, the maximum etching time shall be agreed between purchaser and supplier.

If particles of copper remain after the etching, the specimen shall not be used for testing.

1.3.1.3 *Cleaning and drying after etching*

Immediately after it is etched, the specimen shall be washed in cold running water of resistivity not less than 10 Ωm for as long as necessary to remove surface contamination (normally 15 min to 30 min).

If a test pattern has been formed, the resist shall be removed by any suitable means (for example, a light scrubbing with water and pumice (see note) applied with a felt pad mounted on a firm surface).

Care shall be taken to minimize abrasion of any adhesive layer.

The cleaning process shall be continued until water will remain in an unbroken film covering the whole face of the test specimen. Any residue of pumice or other cleaning agent shall be washed off with running water.

The specimen shall then be rinsed three times, for 2 min each time, in different lots of water of resistivity not less than 1 000 Ωm.

Surface water shall then be removed from it, and it shall be dried for 4 h ± 10 min at 55 ± 2 °C in an oven. All tests shall start within three weeks of removal from the oven. During this time, until pre-conditioning in accordance with Sub-clause 1.1.1 is started, the specimens shall be kept in a container suitable to avoid contamination.

Note. — Pumice with a grain dimension of 63 µm according to ISO Standard 565 is satisfactory.

1.3.2 *Preparation of test specimens from materials clad with metals other than copper*

No recommendations are made.

1.3.3 *Numbers and dimensions of test specimens*

The numbers and dimensions of test specimens are specified in each test method, but are also summarized for convenience in Table I, page 15.

2. Electrical tests

2.0 *Precautions to be taken in certain electrical tests*

In certain electrical tests it is necessary to guard against contamination of the test specimen. During these tests, handling of the specimens shall be kept to a minimum, the specimens being held by the edges or by the connecting wires as appropriate.

Rubber or polyethylene gloves shall be worn.

The use of fixtures with spring loaded contacts removes the need for connecting wires, solders and fluxes.

If connecting wires are being attached, care shall be taken to prevent any contamination of the surface of the insulating base material by solder flux. A mask should be used for this purpose.

The use of solvents for removing contaminants may result in spreading the contaminants over the whole surface.

The relevant clauses show where these precautions are needed.

TABLE I

Numbers and dimensions of test specimens

Sub-clause	Test method	Number of specimens to be tested	Dimension of test specimen
2.1	Resistance of foil	4	25 ± 0.2 mm × 330 mm (0.98 ± 0.008 in × 13 in)
2.2	Surface resistance	4	100 mm × 100 mm (4 in × 4 in) Figure 1
2.3	Volume resistivity		
2.4	Surface corrosion	4	As Sub-clauses 2.2/2.3, Figure 1
2.5	Corrosion at the edge	4	Length appr. 24 mm (0.94 in) Width: to suit apparatus
2.7	Permittivity and dissipation factor	4	To suit method used
2.8	Electric strength normal to plane of sheet	5 tests	100 mm × 100 mm, thickness 0.4 mm or less
2.9	Surface resistance and volume resistivity	4	As Sub-clauses 2.2/2.3
3.1	Bow	1	Sheet under test
3.3	Twist	1	Sheet under test, thickness not less than 0.8 mm
3.5	Pull-off strengh	10 lands	Any convenient size
3.6	Peel strength		
3.6.2	*a)* after heat shock	At least 1 (4 strips)	
3.6.3	*b)* after dry heat	At least 1 (4 strips)	
3.6.4	*c)* after exposure to solvent vapour	At least 1 (4 strips)	
3.6.5	*d)* after exposure to simulated plating conditions	At least 1 (4 strips)	≥ 75 mm × 50 ± 1 mm (≥ 3 in × 2 ± 0.04 in)
3.6.6	*e)* after immersion in solvent	At least 1 (4 strips)	
3.6.7	*f)* at high temperature	At least 1 (4 strips)	
3.7	Blistering after heat shock	1	100 mm × 100 mm (4 in × 4 in) Figure 1
3.9	Surface finish	1	Sheet under test
3.10	Solderability	10 of each side for wetting 10 of each side for de-wetting	30 ± 1 mm × 30 ± 1 mm (1.2 ± 0.04 in × 1.2 ± 0.04 in)
3.11	Dimensional stability	3	300 mm × 300 mm (12 in × 12 in) Figures 10 and 11
3.12	Flexural fatigue	2 in each of two directions	100 mm × 22 ± 2 mm (4 in × 0.9 ± 0.1 in) Figure 12
3.13	Mass per unit area of metal foil	1	100 mm × 100 mm (4 in × 4 in)
3.14	Thickness	1	Sheet under test
4.1	Flexural strength	5 in each of two directions	Length: at least 20 × thickness of base material Width: 10 ± 0.5 mm (0.394 ± 0.02 in) or 25 ± 0.5 mm (0.984 ± 0.02 in) according to thickness
4.3	Flammability		
4.3.3	Horizontal burning test for rigid materials	4	125 ± 5 mm × 13 ± 1 mm (4.92 ± 0.2 in × 0.51 ± 0.04 in)
4.3.4	Vertical burning test for rigid materials	10 or more	125 ± 5 mm × 13 ± 1 mm (4.92 ± 0.2 in × 0.51 ± 0.04 in)
4.3.5	Vertical burning test for flexible materials	4	450 mm × 25 mm (18 in × 1 in)
4.4	Water absorption	3	50 ± 1 mm × 50 ± 1 mm (1.97 ± 0.04 in × 1.97 ± 0.04 in)

2.1 *Resistance of foil*

2.1.1 *Object*

To measure the resistance of foil either before laminating or as part of a metal-clad base material.

2.1.2 *Test specimen*

The test specimen shall be cut from a sample of either the metal foil or the metal-clad base material, as required. It shall be 25 ± 0.2 mm wide and approximately 330 mm long (0.98 ± 0.008 in × 13 in).

Four specimens shall be tested.

2.1.3 *Procedure*

The test specimen shall be placed with its foil surface touching line or point contacts. Line contacts shall touch the foil across its whole width and shall be at right angles to the major axis of the test specimen. The current shall be supplied and measured between line contacts which are approximately 300 mm (11.8 in) apart. The resistance of the foil in milliohms shall be measured between line or point contacts which are 150 ± 1 mm (5.9 ± 0.04 in) apart and equidistant from the current supply contacts.

The current shall be kept small enough to avoid the temperature of the foil rising by more than 1 °C. The ambient temperature shall be measured, and the resistance value corrected to 20 °C.

For copper of 96% conductivity* the correction factor is given by the formula:

$$k = \frac{1}{1 + 0.00378\,(t - 20)}$$

The values of k for temperatures between +15 °C and +35 °C are given in the following table:

Correction factors

Temperature (°C)	Correction factor	Temperature (°C)	Correction factor
15	1.019	26	0.978
16	1.015	27	0.974
17	1.011	28	0.971
18	1.008	29	0.967
19	1.004	30	0.964
20	1.000	31	0.960
21	0.996	32	0.957
22	0.992	33	0.953
23	0.989	34	0.950
24	0.985	35	0.946
25	0.981		

2.1.4 *Report*

The maximum value of the four resistances measured or corrected shall be reported as the resistance of the foil.

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* International Annealed Copper Standard (I.A.C.S.).

2.2 *Surface resistance after damp heat, steady state*

To determine the resistance between two electrodes of defined dimensions which are on the surface of the insulating base material after storage at high humidity.

2.2.1 *Test specimen*

The test specimen shall be prepared from a sample of the metal-clad base material under test. It shall be approximately 100 mm (4 in) square and, before it is printed, its thickness shall be that of the material.

It shall be printed on one side with the ring and disk pattern of Figure 1, page 66, by the appropriate method of Sub-clause 1.3. If the sample is clad with metal on both sides, the metal on the other side of the specimen shall be completely removed by the appropriate method of Sub-clause 1.3.

Connecting wires or spring loaded contacts may then be attached to the ring and the disk.

Four specimens shall be tested.

2.2.2 *Procedure*

A three-electrode system as described in IEC Publication 93: Methods of Test for Volume Resistivity and Surface Resistivity of Solid Electrical Insulating Materials, shall be used. On the reverse face of the specimen, an electrode covering the whole of that face shall be applied by any convenient method, except that neither an evaporated nor a sputtered metal electrode shall be used.

The specimen shall then be subjected to Test Ca (severity four days) of IEC Publication 68-2-3: Part 2: Tests — Test Ca: Damp Heat, Steady State, (unless otherwise stated in the requirement), including recovery. The recovery conditions shall be: recovery period: 90 ± 15 min; relative humidity: 73% to 77%. The temperature shall not deviate by more than 1 °C from the actual laboratory temperature, which shall be within +18 °C to +28 °C.

The resistance between the ring and disk shall be measured by the method indicated below, either at the end of the damp heat period before removal of the specimen from the humidity chamber, or at the end of the recovery period, in which case the specimen shall be removed from the recovery conditions and the resistance between the ring and disk shall be measured within 5 min.

The measurement after recovery is the standard procedure, whereas the measurement within the humidity chamber is subject to agreement between purchaser and supplier.

The resistance measurements shall be made as described in IEC Publication 93 at 500 ± 50 V d.c. after electrification for 1 min. The electrical connections to the test specimen shall be made as shown in Figure 2, page 67. The apparatus used for measuring resistance shall be such that the error of measurement is less than ±50%.

The relevant precautions and requirements of Sub-clause 2.0 and of IEC Publication 68-2-3 shall be observed.

The measurements of surface resistance and volume resistance (to be converted into volume resistivity in accordance with Sub-clause 2.3) may be made on the same specimen, in which case the surface resistance shall be measured first. When the measurements succeed one another directly, only one conditioning is necessary.

2.2.3 *Report*

The minimum value of the four surface resistance measurements shall be reported as the surface resistance after damp heat, steady state, of the sample under test. It shall be expressed in megohms.

It shall be stated whether the measurements have been carried out within the chamber or after recovery.

2.3 *Volume resistivity after damp heat, steady state*

To determine the volume resistivity between electrodes on opposite sides of the insulating base material after storage at high humidity.

2.3.1 *Test specimens and procedure*

The test specimen and the procedure described in Sub-clauses 2.2.1 and 2.2.2 shall be used, except that the electrical connections shall be made as shown in Figure 3, page 67, and the volume resistance between the central disk and the electrode on the opposite face shall be measured.

The measurements of surface resistance (Sub-clause 2.2) and volume resistance may be made on the same specimen, in which case the surface resistance shall be measured first. When the measurements succeed one another directly, only one conditioning is necessary.

2.3.2 *Report*

The minimum value of the four resistances measured shall be converted to volume resistivity as described in IEC Publication 93, and reported as the volume resistivity after damp heat, steady state, of the sample under test. It shall be expressed in megohms-metres.

It shall be stated whether the measurements have been carried out within the chamber or after recovery.

2.4 *Surface corrosion*

To determine any tendency for electrolytic corrosion products to occur when an etched conductive pattern is subjected to a polarizing voltage and high humidity.

2.4.1 *Test specimen*

The test specimen shall be prepared from a sample of the metal-clad base material under test. It shall be approximately 100 mm (4 in) square and, before it is printed, its thickness shall be that of the material.

It shall be printed on one side with the ring and disk pattern of Figure 1, page 66, by the appropriate method of Sub-clause 1.3. If the sample is clad with metal on both sides, the metal on the other side shall be completely removed by the appropriate method of Sub-clause 1.3.

Connecting wires shall be attached to the ring and disk.

Four specimens shall be tested.

2.4.2 *Procedure*

The specimen shall be subjected to Test Ca (severity 21 days) of IEC Publication 68-2-3 without recovery. During the whole period that the specimen is in the damp heat conditions, a potential difference of 100 $\pm$ 5 V d.c. shall be applied between the ring and the disk through a resistor such that the current cannot exceed 1 mA.

The specimen shall be removed from the conditioning chamber and inspected for corrosion products.

The relevant precautions and requirements of Sub-clause 2.0 and of IEC Publication 68-2-3 shall be observed.

2.4.3 *Report*

It shall be stated whether corrosion products have been observed.

2.5 *Corrosion at the edge*

To determine whether the base material causes corrosion of metal parts in contact with it under the influence of a polarizing voltage and high humidity.

2.5.1 *General*

The test shall be carried out by the visual method given in Clauses 4 to 7 of IEC Publication 426: Test Methods for Determining Electrolytic Corrosion with Insulating Materials, including the following requirements.

2.5.2 *Test specimens*

The test specimens specified in IEC Publication 426, Sub-clause 3.2.2 (for rigid sheets) or 3.2.3 (for thin films), shall be prepared from a sample of the metal-clad base material under test from which the metal has been completely removed by the appropriate method of Sub-clause 1.3.

2.5.3 *Report*

The report shall state the characteristic corrosion indices for the material under test, as defined in Clause 6 of IEC Publication 426, (for example "A2" shall denote degree "A" for the positive pole foil and degree "2" for the negative pole foil).

2.6 *Comparative tracking index*

To determine the susceptibility of the insulating base material to surface tracking when exposed, under electric stress, to water and other contaminants from the surroundings.

The test shall be carried out as specified in IEC Publication 112: Method for Determining the Comparative and the Proof Tracking Indices of Solid Insulating Material under Moist Conditions, using platinum electrodes.

When the test is to be performed on a metal-clad face of a specimen, the metal shall be completely removed by the appropriate method of Sub-clause 1.3.

2.7 *Permittivity and dissipation factor after damp heat and recovery*

To determine the permittivity and dissipation factor of the insulating base material after being subjected to high humidity.

2.7.1 *Test specimen*

The test specimen shall be a sample of the metal-clad base material under test and, before it is etched, its thickness shall be that of the insulating base material under test.

Its other dimensions shall be suited to the method to be used for the measurement of permittivity and dissipation factor.

It shall be prepared by one of the following methods:

a) the metal shall be completely removed, or

b) the test specimen shall be printed on one side with a suitable electrode, and if the sample is clad with metal foil on both sides, the metal on the other side shall be completely removed.

The printing or the removal of metal shall be carried out by the appropriate method of Sub-clause 1.3.

Four specimens shall be used.

2.7.2 *Procedure*

Each specimen shall first be subjected to Test Ca (severity four days) of IEC Publication 68-2-3, including recovery, unless otherwise specified in the specification for the base material. It shall then be removed from the recovery conditions and tested immediately as described below.

The recovery conditions shall be: recovery period 90 $\pm$ 15 min; relative humidity: 73% to 75%. The temperature shall not deviate by more than 1 °C from the actual laboratory temperature, which shall be within + 18 °C to + 28 °C. It shall then be removed from the recovery conditions and tested immediately as described as follows.

Electrodes shall be applied or completed if required, according to the test method selected, except that neither evaporated nor sputtered electrodes shall be applied.

The relative permittivity and the dielectric dissipation factor (tan δ) of the insulating material between the electrodes shall then be measured at a frequency of 1 MHz by any suitable method as described in IEC Publication 250: Recommended Methods for the Determination of the Permittivity and Dielectric Dissipation Factor of Electrical Insulating Materials at Power, Audio and Radio Frequencies including Metre Wavelengths. The relevant precautions and requirements of IEC Publication 68 shall be observed.

Additional measurements at frequencies other than 1 MHz, and relevant requirements, may be agreed upon between purchaser and supplier.

Methods dependant on an accurate knowledge of the test specimen's thickness become unreliable when applied to the testing of thin materials. Although the resonance rise method using the Q-meter may be used for purpose of routine quality control on materials less than 0.8 mm thick, it cannot be used for precision measurements. For this purpose, or in cases of dispute, a fluid displacement method should be used, as described in Sub-clause 4.1.2.2.2 of IEC Publication 250.

2.7.3 *Report*

The report shall state:

1) that values have been obtained after damp heat and recovery (as specified in Sub-clause 2.7.2); otherwise the details of specimen conditioning shall be stated;
2) the electrode arrangement and type of electrode applied to the specimen, if any;
3) the measuring apparatus used;
4) the permittivity of the sample, expressed as the arithmetic mean of the four values obtained;
5) the dissipation factor of the sample, expressed as the arithmetic mean of the four values obtained.

2.8 *Electrical strength normal to plane of sheet*

To determine the resistance of the insulating base material to breakdown when subjected to a short time electric stress at power frequency.

2.8.1 *General*

This test shall only be applied to insulating materials 0.8 mm (0.032 in) or less in thickness. It shall be carried out as described in IEC Publication 243: Recommended Methods of Test for Electric Strength of Solid Insulating Materials at Power Frequencies, and as specified below.

2.8.2 *Test specimen*

The test specimen shall be a sample of the metal-clad base material from which the metal has been completely removed by the appropriate method of Sub-clause 1.3. Its thickness shall be the combined thickness of the base material and any bonding medium which may be present, and its other dimensions shall be as specified in Sub-clauses 6.2.1 and 6.3 of IEC Publication 243. (A square of approximately 100 mm (4 in) side is normally used).

Five tests shall be carried out on a sufficient number of specimens.

2.8.3 *Procedure*

The test shall be conducted in air as specified in Sub-clause 1.1.2 with electrodes in accordance with Sub-clause 6.1.1 of IEC Publication 243.

The voltage shall be applied by the 20 s step-by-step method to obtain two valid determinations. A preliminary test may be made first by the short-time method in order to determine the initial voltage, if this is not already known from previous experience.

The average thickness of the specimens shall be determined from measurements made in accordance with Sub-clause 3.14.

The electrical strength shall be determined from the average of the results.

2.8.4 *Report*

The report shall state the average electric strength of the material in kV/mm (V/mil).

2.9 *Properties of insulation at elevated temperature*

2.9.1 *Surface resistance and volume resistivity at elevated temperature*

To determine the surface resistance and volume resistivity of the insulating base material at a specified high temperature.

2.9.1.1 *Test specimen*

The test specimen shall be as described in Sub-clause 2.2.1 (ring and disk pattern).

2.9.1.2 *Procedure*

The surface resistance and volume resistivity of the specimen shall be measured in accordance with Sub-clauses 2.2 and 2.3. The humidity conditioning shall however be replaced by Test Ba of IEC Publication 68-2-2: Part 2: Tests — Test B: Dry Heat, except that the duration shall be 1 h instead of 16 h. Measurements shall be made at the end of this time while the specimen is still in the chamber. The test temperature shall be that indicated in the relevant specification. There shall be no recovery.

2.9.1.3 *Report*

The minimum value of the four surface resistance measurements shall be reported as the surface resistance at elevated temperature of the sample under test. It shall be expressed in megohms.

The minimum value of the four volume resistances measured shall be converted to volume resistivity as described in IEC Publication 93 and reported as the volume resistivity at elevated temperature of the sample under test. It shall be expressed in megohm metres.

3. Non-electrical tests on metal-clad materials

3.1 *Bow*

To measure the deviation from flatness of the copper-clad sheet in a direction parallel to its edges (see IEC Publication 194: Terms and Definitions for Printed Circuits).

3.1.1 *General*

This test is not applicable to sheets thinner than 0.8 mm (0.0315 in).

3.1.2 *Procedure*

The sheet or panel shall be placed unrestrained on a flat horizontal surface with its predominantly convex surface upward. The maximum vertical distance at the edge between the flat horizontal surface and the concave side of the material shall be determined using a taper gauge or feeler gauge.

The result shall be expressed as a percentage of the length of the side of the sheet or panel, corresponding to the measured value.