

# JIS

**JAPANESE INDUSTRIAL STANDARD**

## **Test methods of copper-clad laminates for printed wiring boards**

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## JAPANESE INDUSTRIAL STANDARD

J I S

Test methods of copper-clad laminates  
for printed wiring boards

C 6481-1996

1. Scope This Japanese Industrial Standard specifies test methods of copper-clad laminates for printed wiring boards (hereafter referred to as "copper-clad laminates").

Remarks 1. The standards cited in this Standard are given in Attached Table 1.

2. The International Standard corresponding to this Standard is given below.

IEC 249-1 (1982) Base materials for printed circuits. Part 1:  
Test methods.  
Amendment No. 1 (1984)

2. Definitions For the purpose of this Standard, in addition to the definitions in JIS C 5603, JIS K 6900 and JIS Z 8103, the following principal definitions apply:

- (1) dynamic viscoelastic analysis (DMA) A method to measure the dynamic viscoelasticity of a specimen as the function of temperature while the temperature of the specimen is changed in accordance with the prepared program.
- (2) shear modulus of elasticity The quotient of the shear stress by the shear angle in a very small deformation within the elastic limit.
- (3) logarithmic decrement The natural logarithm of the ratio of two consecutive amplitudes in a vibration.
- (4) complex rigidity Complex rigidity of shear. The ratio of the stress to a sinusoidal vibration strain.
- (5) storage rigidity The real part of a complex rigidity.
- (6) loss rigidity The imaginary part of a complex rigidity.
- (7) loss tangent The tangent of phase difference between vibration strain and generated stress. This shows the ratio of the loss rigidity to the storage rigidity.
- (8) non-resonance method in forced torsional vibration without additional mass A method to obtain a complex rigidity by measuring directly the stress (or strain) generated by vibration strain (or stress) at a fixed frequency in a low frequency range where the inertial force of the measuring system is negligible.

3. Test items The test items shall be as given in Table 1.

Table 1. Test items

| Test items                                   | Test method | Test items                                                | Test method |
|----------------------------------------------|-------------|-----------------------------------------------------------|-------------|
| Appearance                                   | 5.2         | Resistance to chemicals                                   | 5.13        |
| Dimensions                                   | 5.3         | Water absorption                                          | 5.14        |
| Bow and twist (suspension method)            | 5.4         | Flammability (flame retardance)                           | 5.15        |
| Resistance to soldering heat                 | 5.5         | Dimensional change rate                                   | 5.16        |
| Resistance to dry heat                       | 5.6         | Glass-transition temperature $T_g$                        | 5.17        |
| Peel strength                                | 5.7         | Cure factor of resin                                      | 5.18        |
| Flexural strength                            | 5.8         | Coefficient of linear thermal expansion                   | 5.19        |
| Volume resistivity                           | 5.9         | Surface roughness (average roughness on 10 points $R_z$ ) | 5.20        |
| Surface resistance                           | 5.10        | Resistance to tracking                                    | 5.21        |
| Insulation resistance                        | 5.11        | Bow and twist (stationary method)                         | 5.22        |
| Relative permittivity and dissipation factor | 5.12        |                                                           |             |

#### 4. Procedure for making specimen

**4.1 Sampling of specimen** The specimen shall, unless otherwise specified in the detail specification, be cut out from a position 6 mm or more inside from the end of the copper-clad laminate to the specified size. This sampling is not applicable to 5.2, 5.3, 5.4 and 5.22. Care shall be taken that the test specimen does not generate heat during machining.

Dimensional tolerances of the specimen shall be  $\pm 5\%$  of the specified dimensions, where no tolerance is specified.

**4.2 Making of specimen by etching** When the copper foil is removed by etching, procedures described below shall be employed.

- (1) Wash the specimen in running clear water for 2 min to 5 min immediately after removal of the copper foil.
- (2) Further cleanse it with distilled water.
- (3) Finally, dry it in a thermostatic oven at  $80 \pm 3^\circ\text{C}$  for about 60 min.

Remarks: When the specimen is subjected to electrical performance test, handle it with special care so that the specimen does not get dirt.

#### 5. Test methods

##### 5.1 Test conditions

**5.1.1 Standard condition** Unless otherwise specified, the tests and measurements excluding electrical performance tests shall be carried out under the standard conditions specified in 5.3 of JIS C 0010 (temperature of  $15^\circ\text{C}$  to  $35^\circ\text{C}$ , relative humidity of 25% to 75%, and air pressure of 86 kPa to 106 kPa).

**5.1.2 Illumination level of test place** The illumination level of test place shall be not less than 200 lx (illuminance range of 150 lx to 300 lx) specified in JIS Z 9110.

**5.1.3 Test condition and preconditioning for electrical performance** The test condition and preconditioning for electrical performance shall be as follows:

- (1) **Test condition** The test condition shall be the condition for referee test specified in 5.2 of JIS C 0010 (temperature of  $20 \pm 2^\circ\text{C}$ , relative humidity of 60% to 70%).
- (2) **Preconditioning** The preconditioning shall be made under the test condition of (1) for  $96 \pm 4$  h.

## **5.2 Appearance**

**5.2.1 Equipment** Use a magnifier with a magnification of approximately three.

**5.2.2 Specimen** Employ the as-received copper-clad laminate and the sample prepared by removing the copper foil as specified in 4.2, as the specimens.

**5.2.3 Test** Carry out visual examination by naked eye or using a magnifier for surface conditions of the specimens.

## **5.3 Dimensions**

### **5.3.1 Size**

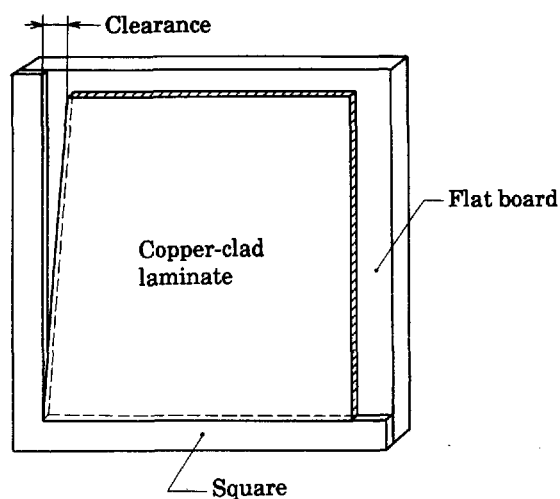
- (1) **Equipment** Use the steel tape measure of grade 1 specified in JIS B 7512 (with 1 mm scale interval), or an equipment at least equivalent in accuracy.
- (2) **Specimen** Employ the as-received copper-clad laminate as the specimen.
- (3) **Test** Hold the specimen vertically or horizontally, and measure lengths of four sides of the specimen to the nearest 1 mm.

### **5.3.2 Perpendicularity**

- (1) **Equipment** The equipment shall be as follows:
  - (a) A square having a side of 1200 mm or more in length, being at least equivalent in accuracy to a flat square or square with a base of grade 2 specified in JIS B 7526.
  - (b) The metal rule of grade 1 (with 0.5 mm scale interval) specified in JIS B 7516, or the one at least equivalent in accuracy.
- (2) **Specimen** Employ the as-received copper-clad laminate as the specimen.
- (3) **Test** Hold one side of the copper-clad laminate on one side of a square fixed on a flat board, and measure the maximum of the clearance left between the other side of the laminate perpendicular to the said side and another side of the square with a metal rule to the nearest 0.5 mm (see Fig. 1).

Carry out the measurements at four corners and take the maximum measured value out of the four as the perpendicularity.

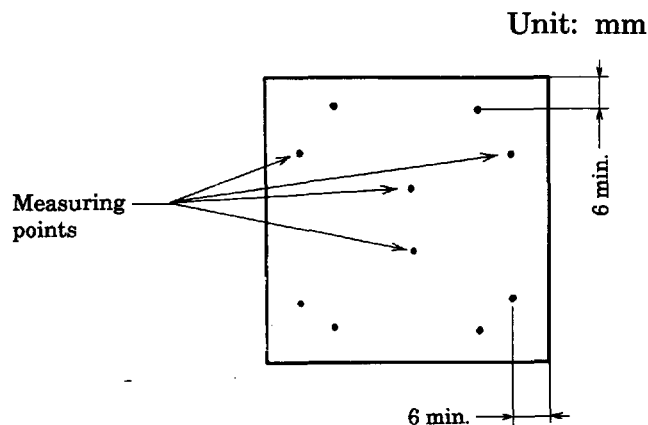
Fig. 1. Measurement of perpendicularity



### 5.3.3 Thickness

- (1) **Equipment** Use the external micrometer specified in JIS B 7502, or that at least equivalent in accuracy.
- (2) **Specimen** The specimen shall be as follows:
  - (a) As-received copper-clad laminate.
  - (b) Base material prepared by completely removing the copper foil according to 4.2.
- (3) **Test** Hold the copper-clad laminate vertically or horizontally, and measure the thickness to the nearest 0.01 mm at two points 6 mm or more inside from each edge, namely at 8 points, and at two points in the middle part, that is 10 points in total, as shown in Fig. 2. Ensure that the measurement is made twice at each point, and the mean value is determined as the thickness of each point.

Fig. 2. Thickness measuring points



**5.4 Bow and twist (suspension method)****5.4.1 Equipment** The equipment shall be as follows:

- (1) The steel straightedge of grade B specified in JIS B 7514 (with rectangular cross section) having an effective length of 1500 mm or more.
- (2) The metal rule of grade 1 specified in JIS B 7516 (with 1 mm scale interval), or that at least equivalent in accuracy.

**5.4.2 Specimen** Employ the as-received copper-clad laminate as the specimen.**5.4.3 Test** The test shall be as follows:

- (1) **Measurement of maximum bow** Suspend the copper-clad laminate vertically at the center of an edge as shown in Fig. 3 (1) and hold the steel straightedge parallel to the edge.

Hold the steel straightedge on concave surface of the copper-clad laminate and measure the maximum clearance between the steel straightedge and the surface of copper-clad laminate to the nearest 1 mm with the metal rule.

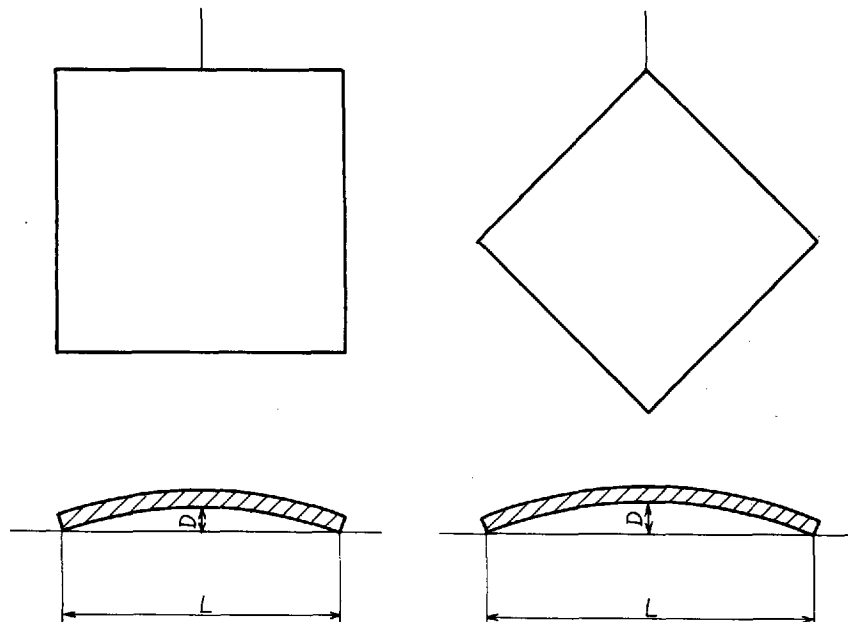
Proceed the measurement successively suspending other edges and record the maximum clearance so measured as the maximum bow of the specimen.

- (2) **Measurement of maximum twist** Suspend the copper-clad laminate at a corner vertically and hold the steel straightedge along another diagonal line than the suspended direction of the copper-clad laminate as shown in Fig. 3 (2), measure the maximum clearance in the same way as that for maximum bow, and record the maximum value so measured as the maximum twist of the specimen.

Fig. 3. Measurement of bow and twist by suspension method

(1) Measurement of bow

(2) Measurement of twist



**5.4.4 Calculation** Calculate the rate  $W_{1000}$  (%) of bow or twist to 1000 mm from the following equation. But when length of each edge is less than 500 mm, record  $D$  in Fig. 3 as the bow or twist.

$$W_{1000} = \frac{D_{1000} \times 100}{1000}$$

where,  $D_{1000}$ : bow or twist per 1000 mm (mm)

Provided that  $D_{1000}$  is calculated from the following equation:

$$D_{1000} = \frac{D}{L^2} \times 1000^2 \quad (1)$$

where,  $D$ : maximum bow or twist (mm)

$L$ : length of a part of the specimen along which the straightedge is held (mm)

Note (1) This equation shall not apply to specimen of which  $L$  is less than 500 mm.

## 5.5 Resistance to soldering heat

**5.5.1 Equipment** The equipment shall be as follows:

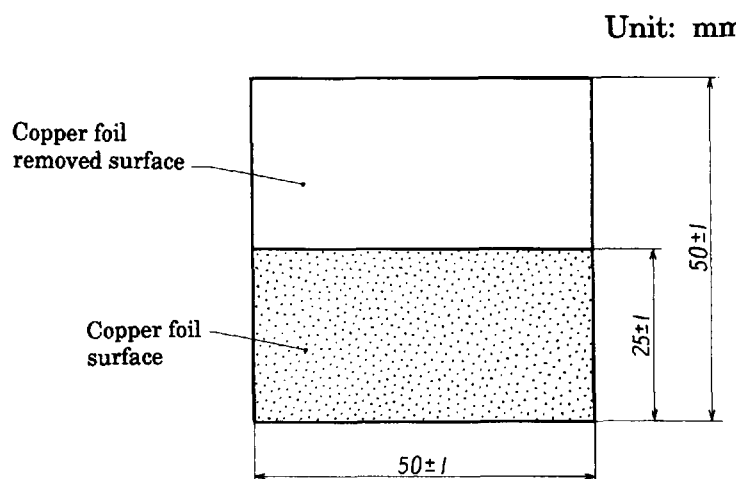
- (1) Thermostatic oven The thermostatic oven provided with air circulating device, which can keep the specified temperature within tolerances of  $\pm 2^\circ\text{C}$ .
- (2) Solder bath A bath filled with molten solder (H 60 A or H 63 A specified in JIS Z 3282) to a depth of 50 mm or more, and provided with a control which can adjust the temperature at the intended position of the solder to the specified temperature within tolerances of  $\pm 1^\circ\text{C}$  throughout the temperature range of  $200^\circ\text{C}$  to  $300^\circ\text{C}$ .
- (3) Thermometer A thermocouple or L shaped mercury thermometer which can measure temperatures  $200^\circ\text{C}$  to  $300^\circ\text{C}$ .
- (4) Stopwatch A stopwatch of 0.2 s scale.
- (5) A pair of tweezers or a similar specimen gripper.

**5.5.2 Specimen** Specimen shall be as follows:

- (1) Specimen for ordinary test As regards the specimen for ordinary test for resistance to soldering heat, cut out a piece of  $25 \pm 1$  mm square from the copper-clad laminate allowing the thickness as it is. Carry out no surface grinding or other treatments, and no burr shall lie on the section.
- (2) Specimen for test after boiling As regards the specimen for the test of resistance to soldering heat after boiling, cut out a piece of  $50 \pm 1$  mm square from the sample allowing the thickness as it is, finish the section

completely smooth, and remove a half of the copper foil by the method defined in 4.2 as shown in Fig. 4. In the case of double-sided copper-clad laminate, remove all copper foil on one side, and remove a half of the copper foil on another side by the method of 4.2 as shown in Fig. 4.

Fig. 4. Specimen for resistance to soldering heat after boiling



**5.5.3 Preconditioning** The preconditioning shall be made by placing the specimen in a thermostatic oven equipped with air circulating device kept at a temperature of  $105 \pm 2^\circ\text{C}$ , for  $75^{+6}_0$  min.

**5.5.4 Test** Carry out the test as follows:

- (1) **Measurement under normal condition** After preconditioning, measure the temperature of solder, by placing the measuring joint of the thermocouple or approximate center of the bulb of the L-shaped mercury thermometer in the middle part of the molten solder at a depth of 25 mm, and adjust the temperature so that it becomes within the range of either  $246^{+2}_0^\circ\text{C}$  or  $260^{+2}_0^\circ\text{C}$ , whichever is specified in the relevant detail specification. Put the preconditioned specimen with its copper-clad side facing downwards on the surface of the solder at the upper vertical point above the measuring joint of the thermocouple or the bulb of the L-shaped mercury thermometer so that the whole face of the specimen comes in contact with the solder, take out the specimen with the pair of tweezers or the specimen gripper after elapse of the time specified in the relevant detail specification, cool it to room temperature, and check the copper foil surface, copper foil removed surface, edge surface and laminate surface visually to see whether any blister or delamination exists or not.

Use stopwatch for time measurement. Keep the temperature at the specified temperature  $\pm 2^\circ\text{C}$  from floating of the specimen to its take out.

During the measurement do not stir the molten solder or move the soldering bath.

Remove oxide film or other dirt from the surface of solder <sup>(2)</sup>.

Note <sup>(2)</sup> Wiping with a piece of polytetrafluoroethylene (PTFE) of about 50 mm wide is recommended, for example.

(2) Measurement after boiling

- (a) Conditioning Boil the specimen in boiling distilled water for 1 h, cool it for 30 min in running clear water at a temperature of  $20 \pm 10^\circ\text{C}$ , take it out and wipe the water on the surface with clean dry gauze or the like, and then test it within 5 min.
- (b) Measurement Same as (1).

5.6 Resistance to dry heat5.6.1 Equipment The equipment shall be as follows:

- (1) Thermostatic oven As specified in 5.5.1 (1).
- (2) A specimen holder which holds the specimen (non-metallic)

5.6.2 Specimen The specimen shall be the one made by cutting out a piece of 50 mm square from the copper-clad laminate, allowing the thickness as it is.

5.6.3 Test Insert the specimen into the specimen holder, place it in the thermostatic oven kept at a temperature specified in the relevant detail specification so that circulating air flows approximately parallel to the surface of specimen. Take out the specimen after elapse of the time specified in the relevant detail specification, and immediately check the surfaces of the copper foil, the laminate and the section visually to see whether any blister or delamination exists or not.

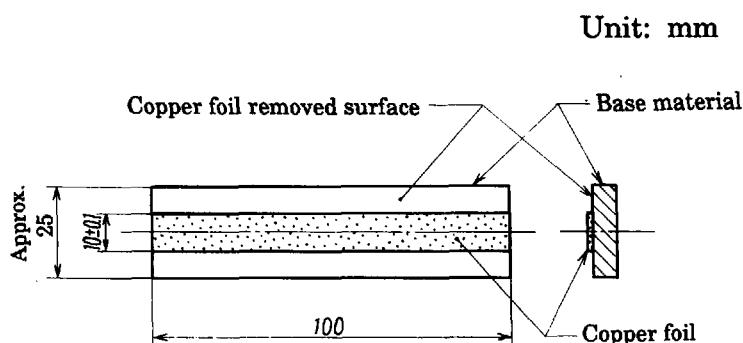
5.7 Peel strength5.7.1 Equipment The equipment shall be as follows:

- (1) Tension tester A tension tester with a error of  $\pm 1\%$  which can keep its cross-head speed at about 50 mm per minute. The peeling force shall fall within 15% to 85% of the capacity of tester.
- (2) Supporting device A supporting device which can keep the direction of peeling at  $90^\circ$  to the surface where the copper foil is removed from the base material.
- (3) Vernier calliper The vernier calliper specified in JIS B 7507 with minimum readable scale of 0.05 mm, or a measuring apparatus at least equivalent in accuracy.
- (4) Fixture A fixture which can fix specimen by adhesion or another method to keep the flatness.
- (5) Solder bath As specified in 5.5.1 (2).
- (6) Thermometer As specified in 5.5.1 (3).
- (7) Stopwatch As specified in 5.5.1 (4).

- (8) **Specimen gripper** A pair of tweezers or a similar specimen gripper.
- (9) **Heating and heat insulating device** A heating and heat insulating device which can keep the specimen holder at a constant temperature.

5.7.2 **Specimen** A specimen shall be the one made as follows: Cut out a piece of dimensions specified in Fig. 5 from the copper-clad laminate, and remove the copper foil on both sides by cutting with a knife or etching of 4.2, leaving the copper foil of  $10 \pm 0.1$  mm width on the middle part of one side.

Fig. 5. Peel strength specimen

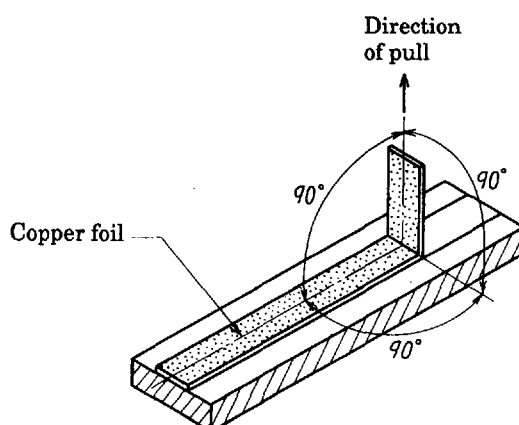


5.7.3 **Test** The test shall be as follows:

- (1) **Measurement under normal condition** Set the specimen on the supporting device after detaching the copper foil on one end to an appropriate length, clamp the end of detached copper foil with the clamping device. Peel the copper foil about 50 mm continuously at a speed of about 50 mm per minute in a direction perpendicular to the copper foil surface as shown in Fig. 6. Define the minimum value of the load during this operation as the peel strength and express it in kN/m. If the copper foil breaks in this process, carry out a retest.

If it is difficult to carry out the measurement because the thickness of specimen is too thin, fix the specimen on an appropriate board as stated in 5.7.1 (4).

Fig. 6. Measurement of peel strength



(2) Measurement after soldering

- (a) Conditioning Float the specimen on the solder bath at a specified temperature for a specified duration in the same manner as that for the test of resistance to soldering heat given in 5.5.4.

Soldering conditions ( $S_0$  to  $S_4$ ) shall be specified in the relevant detail specification (specified temperature and duration are given in Table 2).

Table 2. Condition for soldering

| Symbol denoting condition | Specified temperature<br>°C | Specified duration<br>s |
|---------------------------|-----------------------------|-------------------------|
| $S_0$                     | $246^{+2}_0$                | $5 \pm 1$               |
| $S_1$                     |                             | $10 \pm 1$              |
| $S_2$                     | $260^{+2}_0$                | $5 \pm 1$               |
| $S_3$                     |                             | $10 \pm 1$              |
| $S_4$                     |                             | $20 \pm 1$              |

Remarks: The specified temperature means the temperature before putting the specimen into the solder.

- (b) Measurement Check delaminations and blisters on copper foil surface, copper foil removed surface and edge surface after removing the adhered solder. Cool it to room temperature if there is no abnormality, and measure the peel strength in the same manner as given in (1) normal condition.

(3) Measurement at elevated temperature

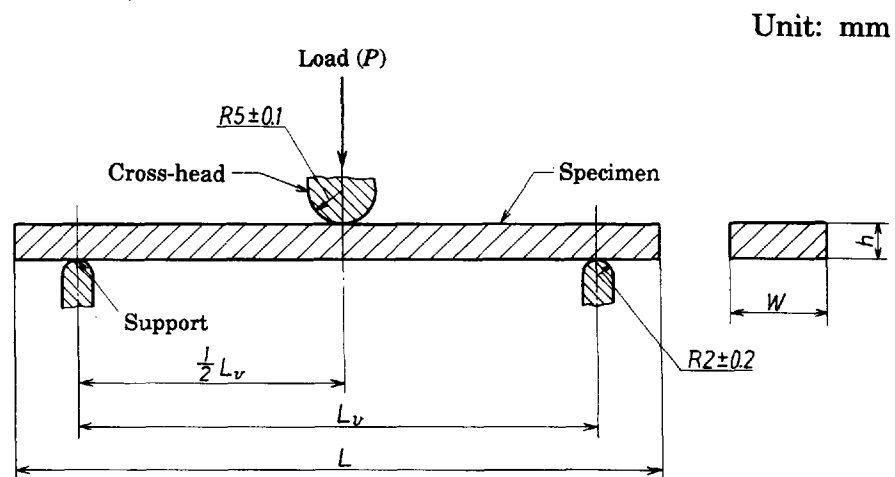
- (a) Conditioning Detach the copper foil from one end to an appropriate length, and then condition the specimen for  $60 \pm 5$  min at a temperature specified in the relevant detail specification.
- (b) Measurement Set the specimen on the supporting device of the testing apparatus which has already been kept at the temperature specified in the relevant detail specification. Keep the specified temperature for another 3 min or over, then measure the peel strength keeping the conditions as they are in the same way as given in (1) normal condition. Carry out the setting of specimen on the supporting device quickly in order to keep the specimen at the specified temperature.

5.8 Flexural strength5.8.1 Equipment The equipment shall be as follows:

- (1) Tester An appropriate material tester which can keep its cross-head speed constant. The tolerances shall be  $\pm 1\%$  of the standard load of the material tester and the load at rupture shall fall within 15% to 85% of the capacity of the tester.

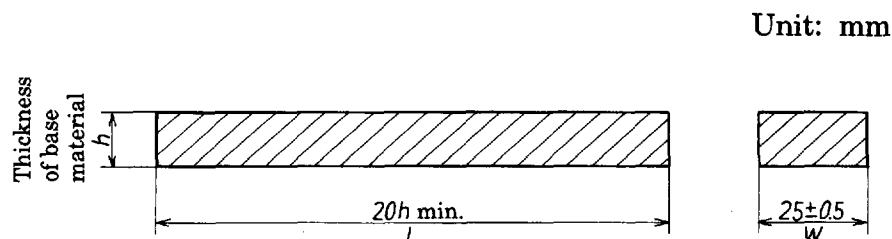
- (2) Heating and heat-insulating device A device which can keep the specimen holder at a constant temperature.
- (3) Thermostatic oven As specified in 5.5.1 (1).
- (4) Cross-head A metal with the edge rounded at  $5 \pm 0.1$  mm radius as shown in Fig. 7.
- (5) Supports A pair of metals with the edge rounded at  $2 \pm 0.2$  mm radius and the distance between the supports is adjustable, as shown in Fig. 7.
- (6) Micrometer The external micrometer specified in JIS B 7502, or the one at least equivalent in accuracy.

Fig. 7. Measurement of flexural strength



5.8.2 Specimen The specimen shall be made as follows: Cut out a piece of dimensions specified in Fig. 8 from the copper-clad laminate allowing the thickness as it is, machine the section to make it smooth enough and remove the copper foil from the surface by the method defined in 4.2.

Fig. 8. Flexural strength specimen



### 5.8.3 Test The test shall be as follows:

#### (1) Normal flexural strength

- (a) Measurement Measure thickness and width of the specimen accurately to the nearest 0.01 mm with the external micrometer. Support the specimen at the distance between supports ( $16 h \pm 0.5$  mm), apply suitable force to its center through the wedge as shown in Fig. 7, and measure the force when the specimen breaks with an accuracy of 1 N.

If the broken point of specimen lies other than middle part of the parts made by trisecting the distance between supports  $L_v$ , carry out a retest without recording the measured values as the tested value. Apply the force to the specimen at a speed  $\frac{h}{2} \pm 0.2$  mm per minute.

In the case of single-sided copper-clad laminate, carry out the test facing the adhesive side upward.

- (b) Calculation Calculate the normal flexural strength  $\sigma_{FB}$  (N/mm<sup>2</sup>) from the following equation:

$$\sigma_{FB} = \frac{3PL_v}{2Wh^2}$$

where,  $P$ : force when specimen breaks (N)

$L_v$ : distance between supports (mm)

$W$ : width of specimen (mm)

$h$ : thickness of base material of specimen after removal of copper foil by the method defined in 4.2 (mm)

#### (2) Retention of flexural strength at elevated temperature

- (2.1) Conditioning After measuring the thickness and width of the specimen in the same way as in (1) (a), heat it at a temperature specified for a duration specified in the relevant detail specification.
- (2.2) Measurement Set the conditioned specimen on the specimen holder which has already been kept at a temperature specified in the relevant detail specification, leave it for 3 min or more, and calculate the flexural strength at an elevated temperature  $\sigma_{hFB}$  (N/mm<sup>2</sup>) in the same way as in (1) (b).
- (2.3) Calculation Calculate the retention of flexural strength at elevated temperature from the following equation:

$$K = \frac{\sigma_{hFB}}{\sigma_{FB}} \times 100$$

where,  $K$ : retention of flexural strength at elevated temperature (%)

$\sigma_{hFB}$ : flexural strength at an elevated temperature (N/mm<sup>2</sup>)

$\sigma_{FB}$ : normal flexural strength (N/mm<sup>2</sup>)

## 5.9 Volume resistivity

### 5.9.1 Equipment The equipment shall be as follows:

- (1) The power supply shall be a d.c. power supply which can keep a constant d.c. voltage of 500 V.
- (2) When the measuring range is  $5 \times 10^6 \Omega$  or less, the insulation resistance tester specified in JIS C 1302, or a measuring apparatus at least equivalent in accuracy.
- (3) When the measuring range is  $10^6 \Omega$  or over but less than  $10^{12} \Omega$ , the high insulation resistance meter specified in JIS C 1303.
- (4) The external micrometer specified in JIS B 7502, or an apparatus at least equivalent in accuracy.
- (5) The vernier calliper specified in JIS B 7507 which has the minimum readable length of 0.05 mm, or an apparatus at least equivalent in accuracy.

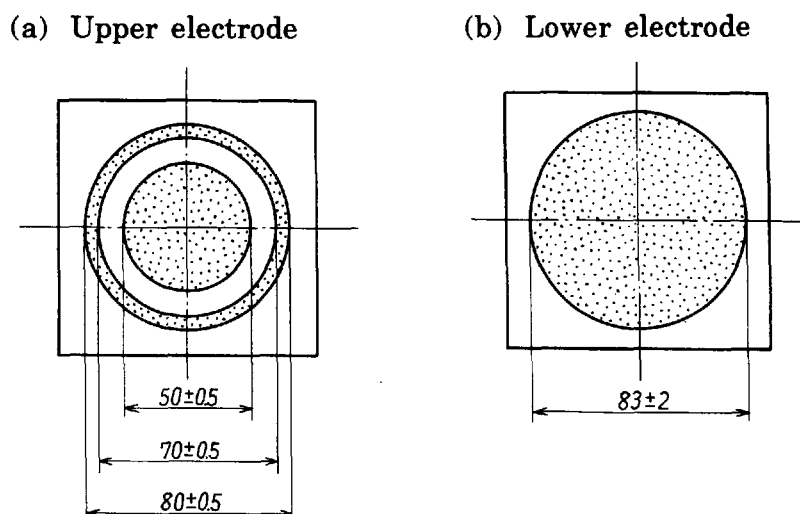
**5.9.2 Specimen** The specimen shall be made as follows: Cut out a piece of 100 mm square from the copper-clad laminate allowing the thickness as it is, and remove the copper foil leaving the shape of the electrode as illustrated in Fig. 9 or all the copper foil, according to the method in 4.2.

Make electrodes with the copper foil or conductive silver paint. Shape and dimensions of them shall be as shown in Fig. 9. Arrange the upper and lower electrodes so that centers of the electrodes coincide each other as possible. The lower electrode may, however, spread on whole rear side, in addition to that illustrated in Fig. 9 (b).

Where conductive silver paint is used as electrodes, the volume resistivity after coating shall be  $10^{-2} \Omega \cdot \text{cm}$  or less, and coat it before the preconditioning.

Fig. 9. Shape of electrodes

Unit: mm



5.9.3 **Preconditioning** Carry out the preconditioning as specified in 5.1.3.

5.9.4 **Test** The test shall be as follows:

(1) **Measurement under normal condition**

- (a) **Measurement** Measure the thickness of preconditioned base material with the external micrometer to the nearest 0.01 mm and measure the inner diameter of the ring form clearance between the upper electrodes with the vernier calliper to the nearest 0.05 mm.

Connect the electrodes to the measuring circuit schematically shown in Fig. 10, charge the electrodes by applying d.c. 500 V for 1 min, and measure the volume resistance. Carry out this test under the conditions specified in 5.1.3.

- (b) **Calculation** Calculate the volume resistivity  $\rho_v$  ( $\Omega \cdot \text{cm}$ ) from the following equation:

$$\rho_v = \frac{\pi d^2}{4t} \times R_v$$

where,  $d$ : outer diameter of inside upper circular electrode (cm)

$t$ : thickness of base material (cm)

$R_v$ : volume resistance ( $\Omega$ )

$\pi$ : the ratio of the circumference of a circle to its diameter

Fig. 10. Example of circuit connection

