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PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

colour inside

Test methods for electrical materials, printed boards and other interconnection structures and assemblies –
Part 3-913: Test methods for interconnection structures (printed boards) – Electronic circuit board for high-brightness LEDs

IEC/PAS 61189-3-913:2011(E)

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CONTENTS

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TEST METHODS FOR ELECTRICAL MATERIALS, PRINTED BOARDS AND OTHER INTERCONNECTION STRUCTURES AND ASSEMBLIES –

Part 3-913: Test methods for interconnection structures (printed boards) – Electronic circuit board for high-brightness LEDs

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The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document

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91/928/PAS	91/943A/RVD

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned may transform it into an International Standard.

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TEST METHODS FOR ELECTRICAL MATERIALS, PRINTED BOARDS AND OTHER INTERCONNECTION STRUCTURES AND ASSEMBLIES –

Part 3-913: Test methods for interconnection structures (printed boards) – Electronic circuit board for high-brightness LEDs

1 Scope

This standard specifies the test methods of the electronic circuit board for high-brightness LEDs (hereafter described as electronic circuit board).

NOTE Reference documents to this standard are listed in Clause 11 Normative references and in the Bibliography.

2 Terms and definitions

For the purpose of this document, the terms used in this PAS shall be in accordance with JPCA-TD01, JIS C 60068-1 and JIC C 5603.

3 Test conditions

3.1 Standard condition

Tests shall be made unless otherwise specified in a specific standard under the standard condition specified in JIS C 60068-1, 5.3.1, Standard atmospheric condition (standard condition), temperature of 15 °C to 35 °C, relative humidity of 25 % to 75 % and atmospheric pressure of 86 kPa to 106 kPa. Condition specified in 3.1 shall be used in case there is any doubt to the experimental results or in case required by a specific standard.

3.2 Specified condition

The specified condition as specified in JIS C 60068-1, 5.2, Standard atmospheric condition (specified condition), is a temperature of 20 °C ± 2 °C, a relative humidity of 60 % to 70 % and an atmospheric pressure of 86 kPa to 106 kPa.

4 Specimen

4.1 Preparation of specimen

Specimen shall be prepared as in (1) or (2) below. The surface of a specimen shall not be contaminated by oil/grease, sweat and others.

1) Specimen by sampling: the specimen shall be sampled from the electronic circuit boards to be used in production. The specimen shall be cut to the defined size if its shape and size are defined in a specific standard. A test coupon may used as the specimen when such coupons are prepared.
2) Specimen using a test pattern: a specimen shall be prepared using the test pattern shown in 4.2 using the same materials and method to produce products.

4.2 Test pattern

The test pattern with the shape and dimension shown in Figures A.1 and A.2 shall be used depending on the type of the electronic circuit board.

5 Pre-conditioning

Pre-conditioning described in (1) or (2) below shall be made in accordance to the specific standard.

1) Leave a specimen for 24 h in the standard condition.
2) Leave a specimen for 60 min in a thermostat chamber at 85 °C and then leave the specimen for 24 h ± 4 h in the standard atmospheric condition.

6 Appearance, micro-sectioning and dimensions

6.1 Appearance

Appearance check shall be made by naked eyes or using a magnifying glass for appearance of the specimen, finish and conductor pattern according to its detailed specification. Use a micrograph of 250X to check a micro-section of a specimen by cutting it and polishing the cutting face of a specimen embedded usually in epoxy resin or polyester resin.

6.2 Micro-sectioning

Inside of a plated through-hole, conductor or electronic circuit board shall be checked by micro-sectioning to see its cross section.

1) Equipment: the equipment for the test is a micrograph capable of measuring a thickness of plated film with an accuracy of better than 0,001 mm, or equivalent.
2) Material: the materials needed are as follows: release agent, embedding resin, polishing cloth (#180, #400, #1000 and alike), polishing paper (#180, #400, #1000 and alike), and polishing powder (alumina, chromium oxide, etc.).
3) Specimen: the specimen shall be cut to an appropriate size not to make any damage to the observing face and embedded in resin. The cut specimen shall be polished using polishing cloth/paper from coarse to fine particle and then polish using a rotating disc with felt cloth and polishing powder. The polished surface shall be within 85 ° to 95 ° to the board layer.

   The diameter of the micro-sectioned hole for measurement of plated film on a through-hole shall be larger than 90 % of the diameter of the hole measured beforehand. If necessary, etch the polished surface to identify layer boundaries of a specimen.
4) Test: observe the polished surface of a specimen according to the requirement of specific standard using a micrograph of the specified magnification.

6.3 Dimension

6.3.1 Appearance

1) Equipment: use a slide caliper specified in JIS B 7507 or equivalent accuracy.
2) Measurement: measure its length and width with an accuracy of 0,01 mm.

6.3.2 Thickness

1) Equipment: use a micrometer specified in JIS B 7502 or equivalent accuracy.
2) Measurement: measure the thickness of a board or total thickness if multilayer board with an accuracy of 0,01 mm.

6.3.3 (Through-) Hole diameter

1) Equipment: use a magnifying glass with reading scale with an accuracy of 0,01 mm.
2) Measurement: measure the diameter of the specified hole.

6.3.4 Hole position

1) Equipment: use a coordination measuring instrument or a microscope with an accuracy of 0,01 mm, or an equivalent instrument.

2) Measurement

   a) Measurement of the position of a hole on a grid shall be made by measuring the X and Y coordinate distances by holding the specimen board in an appropriate method.

   b) Measurement of the position of a hole from an arbitrary hole shall be made by measuring the distance of the measuring hole from that reference hole by holding the specimen board in an appropriate method.

6.3.5 Conductor width and minimum conductor spacing

1) Equipment: use a coordination measuring instrument or a microscope with an accuracy of 0,01 mm, or an equivalent instrument.

2) Measure the conductor width and conductor spacing by holding the specimen board in an appropriate method.

6.3.6 Conductor nick and extraneous copper

1) Equipment: use the equipment specified in 6.3.3 (1) or 6.3.4 (1).

2) Measurement: measure the size of a conductor nick or of a extraneous copper of the length and width in the direction of the conductor.

6.3.7 Land

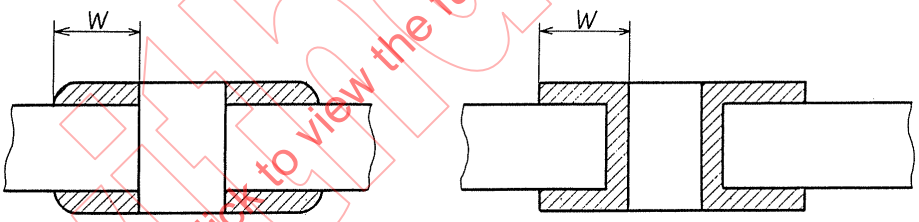
1) Equipment: use the equipment specified in 6.3.4 (1).

2) Measurement: observe the land to be measured from above and measure its maximum size.

6.3.8 Land width

1) Equipment: use the equipment specified in 6.3.4 (1).

2) Measurement: measure the distance (w) from the edge of a land and a hole.



(1) Non-plated through-hole (2) Plated through-hole

Figure 1 – Land width

6.3.9 Flatness

6.3.9.1 Warpage

1) Equipment: use the height-gauge specified in JIS B 7517 or an equipment with better accuracy.

2) Measurement: place the specimen as shown in Figure 2 on a precision base with its convex face upward. Measure the warpage as the maximum gap between the board and base (h_B) to an accuracy of 0,1 mm.

6.3.9.2 Twist

1) Equipment: Use the regular class gap gauge specified in JIS B 7524 or a height-gauge specified in JIS B 7517 or an equipment with better accuracy.

2) Measurement: place the specimen as shown in Figure 3 on a precision base with its convex face upward with three corners of the board in touch with the base. Measure the twist as the maximum gap between the remaining floating edge of the board and base (h_T) to an accuracy of 0,1 mm.

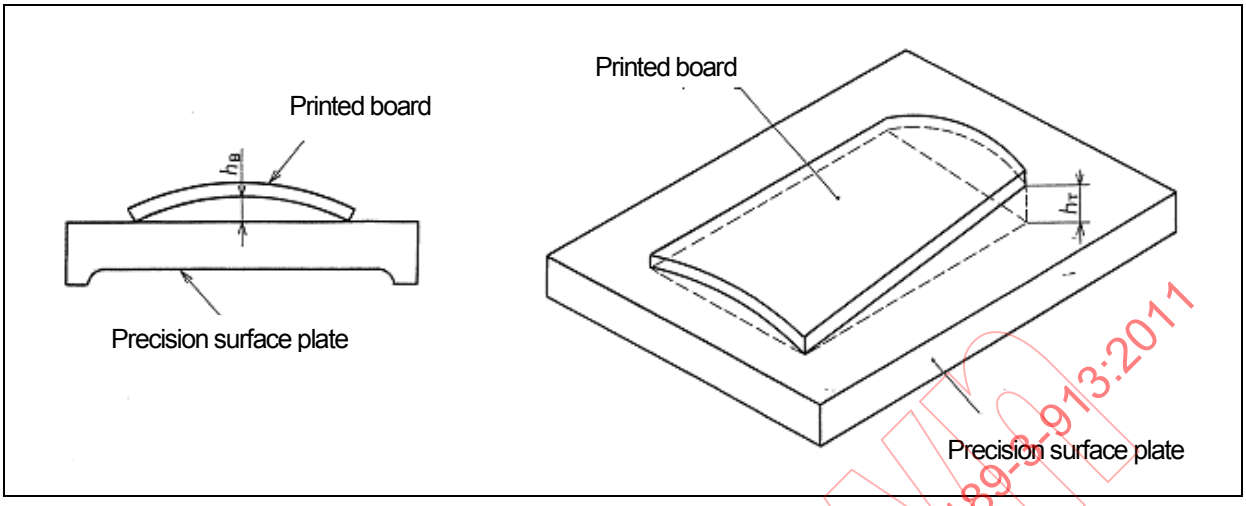


Figure 2 – Warpage

Figure 3 – Twist

7 Electrical tests

7.1 Conductor resistance

7.1.1 Conductor

1) Equipment: equipment is for the voltage-drop method (four-terminal method), or equivalent. The current used in the measurement is d.c.
2) Specimen: the specimen shall be a conductor long and narrow as much as possible, and shall comply with the detailed specification.
3) Pre-conditioning: the pre-conditioning shall be as specified in Clause 5.
4) Test: care shall be made to avoid influences caused by contact method of probe and of heating caused by the measuring current. Measure the resistance as shown in Figure 4 to an accuracy of ± 5 % using the equipment described in (1) above.

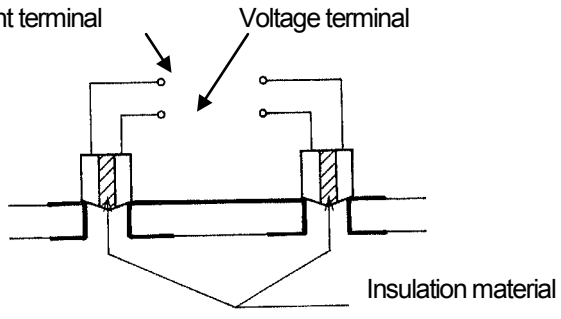


Figure 4 – Electrode arrangement for resistance measurement

7.1.2 Plated through-hole

1) Equipment: use the equipment specified in 7.1.1 (1).
2) Specimen: specimen is the specified part of a board or a test coupon or with the specified composite test pattern as shown in Figure A.1.

3) Pre-conditioning: the pre-conditioning shall be as specified in Clause 5.
4) Test: care shall be made to avoid influences caused by contact method of probe and of heating caused by the measuring current. Measure the resistance as shown in Figure 5 to an accuracy of ± 5 % using the equipment described in (1).

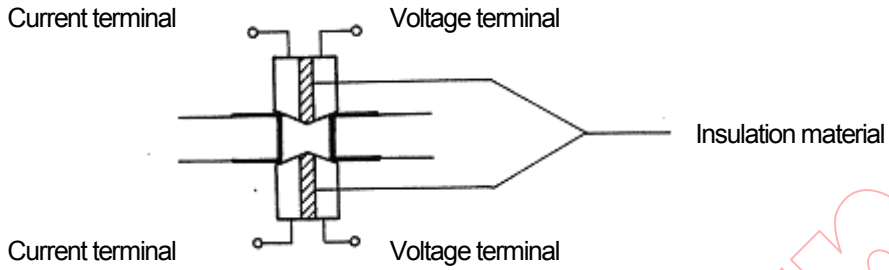


Figure 5 – Electrode arrangement for resistance measurement of a plated through-hole

7.1.3 Interconnection

1) Equipment: use the equipment specified in 7.1.1 (1).
2) Specimen: specimen is the specified part of a board or a test coupon or with the specified composite test pattern as shown in the Figure A.1.
3) Pre-conditioning: the pre-conditioning shall be as specified in Clause 5.
4) Test: care shall be made to avoid influences caused by contact method of probe and of heating caused by the measuring current. Measure the contact resistance as shown in Figure 6 to an accuracy of ± 5 % using the equipment described in (1).

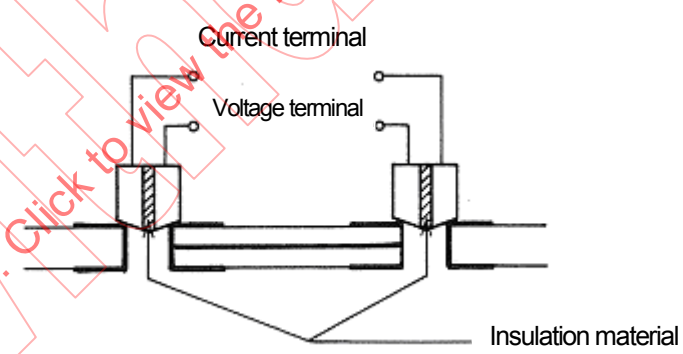


Figure 6 – Electrode arrangement for resistance measurement of interconnection measurement

7.2 Current tolerance of conductor (when specified in a detailed specification)

1) Equipment: equipment shall be a d.c. or an a. c. power supply capable of supplying the test current specified in 7.2.4), an ammeter and a temperature measuring instrument.
2) Specimen: the specimen shall be an electronic circuit board with the specified composite test pattern (select the pattern in reference to Figure A.2).
3) Pre-conditioning: the pre-conditioning shall be as specified in Clause 5.
4) Test: test shall be made by supplying the specified d.c. or a.c. current to the specimen for a specified time and measure the temperature rise of the specimen (see Figure A.3 for the current). This test shall be performed only when current tolerance is required.

7.3 Current tolerance of plated through-hole

1) Equipment: equipment shall be a d.c. or an a. c. power supply capable of supplying the test current specified in 7.2.3), and an ammeter.

2) Specimen: the specimen shall be an electronic circuit board or a test coupon with the specified composite test pattern with a plated through-hole.

3) Pre-conditioning: the pre-conditioning shall be as specified in Clause 5.

4) Test: test shall be made by supplying the specified current to the plated through-hole for 30s and check if there is any anomaly. Examples of test current are shown in Table 1.

Table 1 – Examples of test current

Hole diameter, mm	0,6	0,8	1,0	1,3	1,6	2,0
Test current, A	8	9	11	14	16	20

This test shall be made only when current tolerance is required.

7.4 Withstanding voltage of surface layer

1) Equipment: equipment shall be an current breaker specified in JIS C 2110-2, 8.1 or equivalent.

2) Specimen: the specimen shall be the specified section of an electronics circuit board with the specified composite test pattern (as shown in Figures A.1 and A.2, E). The damaged specimen in this test such as mechanical damage, flush over, spark over or breakdown shall be used in other test.

3) Pre-conditioning: the pre-conditioning shall be as specified in Clause 5.

4) Test: test shall be made by the specified d.c. voltage or 50 H or 60 H a.c. voltage with a peak voltage specified in the detailed specification. The applying voltage shall be increased to the specified voltage in 5 s and keep at the voltage for 1 min. Damages such as mechanical damage, flush over, spark over or breakdown shall be checked.

7.5 Interlayer withstanding voltage

1) Equipment: equipment shall be as specified in 7.4.1).

2) Specimen: the specimen shall be the specified section of an electronics circuit board with the specified composite test pattern (as shown in Figure A.2.1, M).

3) Pre-conditioning: the pre-conditioning shall be as specified in Clause 5.

4) Test: test shall be as specified in 7.4.4).

7.6 Insulation resistance of surface layer (normal and resistance to humidity (temperature-humidity cycle and steady state))

1) Equipment: equipment shall be as the insulation tester as specified in JIS C 1302, or a standard resistance, universal shunt and a galvanometer calibrated to an accuracy of ±10 %.

2) Specimen: the specimen shall be a solder resist coated test coupon as specified in Figure A.3 (1).

3) Pre-conditioning: the pre-conditioning shall be as follows for each condition.

   a) Normal: specimen shall be left in a thermostat chamber at 85 °C ± 2 °C for 4 h and then leave it at temperature 20 °C ± 2 °C and relative humidity of 60 ± 10 % for 24 h ± 4 h.

   b) Resistance to humidity (temperature-humidity cycle): specimen shall be conditioned for 10 cycles (9.4) and then measure the resistance in an environment of 20 °C ± 2 °C and relative humidity of 60 % ± 10 % within 30 min to 60 min after conditioning.

   c) Resistance to humidity (steady state): specimen shall be conditioned for 96 h with the condition of an environment of 40 °C ± 2 °C and relative humidity of 90 % ± 95 % and then measure the resistance in an environment of 20 °C ± 2 °C and relative humidity of 60 % ± 10 % within 30 min to 60 min after conditioning.

4) Test: measurement shall be made for insulation resistance after applying a voltage to the specimen for 1 min of a voltage as specified in the detailed specification of either 10 V ± 1 V, 100 V ± 15 V, 500 V ± 50 V.

7.7 Insulation resistance of inner layer (normal and resistance to humidity (temperature-humidity cycle and steady state))

1) Equipment: equipment shall be as specified in 7.6 (1).
2) Specimen: the specimen shall be a coupon with a comb pattern as shown in Figure A.3 (2). The conductor spacing of the specimen shall be the minimum spacing of actual production board.
3) Pre-conditioning: the pre-conditioning shall be as in 7.6 (4).
4) Test: test shall be as described in 7.6 (4).

7.8 Insulation resistance between inner layers (normal and resistance to humidity (temperature-humidity cycle and steady state))

1) Equipment: equipment shall be as specified in 7.6 (1).
2) Specimen: the specimen shall be a coupon with a comb pattern as shown in Figure A.3(3). The diameter of the hole, φ, shall be 10 mm, nominal hole diameter of through holes for interconnections to inner layers shall be 0,8 mm and nominal land diameter shall be 2 mm.
3) Pre-conditioning: the pre-conditioning shall be as in 7.6 (3).
4) Test: measurement shall be made for insulation resistance after applying a d.c. voltage to the specimen for 1 min of a voltage as specified in detailed specification of either 100 V ± 15 V, or 500 V ± 50 V.

7.9 Electric integrity

7.9.1 Circuit insulation

1) Equipment: equipment shall consist of a power supply which can supply the test voltage to a specimen, resistance meter and probes which can contact to the measuring points.
2) Specimen: specimen shall be a product or the specified part of a test coupon.
3) Pre-conditioning: preconditioning shall be as specified in Clause 5.
4) Test: measurement shall be made to confirm that no electric contacts exists to unintended section of the specimen in the intended specification (art-work, computer generated test data, or detailed specification). Apply the specified test voltage to the specified part of the test pattern and measure the resistance. Insulation shall be confirmed when the resistance is above the specified minimum resistance. The applied voltage and applying time, and the minimum allowed resistance shall be specified in detailed specification.

7.9.2 Conduction

1) Equipment: equipment shall consist of a power supply which can supply the test current to a specimen, resistance meter and probes which can contact to the measuring points.
2) Specimen: specimen shall be the specified part of a product.
3) Pre-conditioning: preconditioning shall be as specified in Clause 5.
4) Test: measurement shall be made to confirm that no electric contacts exists to unintended section of the specimen in the intended specification (art-work, computer generated test data, or detailed specification). Apply the specified test voltage to the specified part of the test pattern and measure the resistance. Insulation shall be confirmed when the resistance is above the specified minimum resistance. The applied voltage and applying time, and the minimum allowed resistance shall be specified in detailed specification.

8 Mechanical tests

8.1 Peel strength of conductor

1) Equipment: the instrument shall be a testing machine which can keep the pulling speed of the cross head to 50 mm/min. The accuracy shall be within ± 1 % of the indication within its effective measuring range and the pulling force shall be within 15 % to 85 % of the capability of the testing machine. Use a jig to hold the specimen to keep the peeling angle to 90 ^{o} to the specimen surface.

2) Specimen: the specimen shall have a straight conductor band with an appropriate length and uniform width (e.g. Figures A.1 to A.2, G). A specimen with a conductor band of 0,8 mm width shall not be used in the test.

3) Pre-conditioning: preconditioning shall be as specified in Clause 5.

4) Test: test shall be made in standard environmental condition. One end of the conductor shall be lifted for about 10 mm from the board and fastened to the peeling machine. The conductor shall be peeled from the board at 90 ° to the surface of the board at 50 mm/min for more than 25 mm. The minimum force per unit width, N/cm, in this peeling shall be the peel strength. Repeat the test if the conductor is cut in peelings of less than 25 mm.

8.2 Peeling strength of a land with non-plated hole

1) Equipment: equipment shall be as specified in 8.1.1) and 10.3.1.

2) Specimen: specimen shall have an round land (e.g. Figure A.1, J) with a hole to solder a lead wire as specified in Table 2. A lead wire and the land shall be pre-soldered using the solder specified in 10.3.2) using the equipment specified in 10.3.1) within 3 s. In case other dimensions are to be used, use the condition specified in the detailed specification.

Table 2 – Land, hole and lead wire

(mm)

Land diameter	Hole diameter	Diameter of lead wire
4	1,3	0,9 to 1,0
2	0,8	0,6 to 0,7

3) Preconditioning: preconditioning shall be as specified in Clause 5.

4) Test

a) Insert a lead wire to the hole of the land of a specimen and solder it to the land at the surface without bending the tip of the wire in the back. The tip of the soldering iron (diameter of the tip shall be 5,0 mm ± 0,1 mm) shall have a temperature of 270 ° C ± 10 ° C. Solder the wire without touching the tip to the land within 3 s to 5 s. Cool the specimen in room temperature for more than 30 min. Pull the soldered wire using the testing machine to the peeling of the land with a peeling speed of 50 mm/min and measure the force when the wire is pulled off from the land. Repeat the test if the wire is cut by pulling, or pulled off from the land.

b) In case peeling strength of a land is measured after repeated soldering of a wire to the land, use a specimen prepared as described in (a) and remove the wire in the same manner as to solder it to the land, and solder a wire again to the land of the specimen in the same way. Repeat soldering and removing of a wire for a number of times as specified in the detailed specification. Cool the specimen each time for more than 30 min at room temperature. Pull the soldered wire using the testing machine to the peeling of the land with a peeling speed of 50 mm/min and measure the force when the wire is pulled off from the land. Repeat the test if the wire is cut by pulling, or pulled off from the land.

8.3 Peeling strength of plated through-hole

1) Equipment: equipment shall be as specified in 8.1.1).

2) Specimen: an example of the test pattern is shown in Figure A.1 a and Figure A.2.1. Remove the land in case the plated through-hole is connected to a land before test. A lead wire which can pass through the hole freely shall be pre-soldered to the plated through-hole and the end of the wire shall project more than 15 mm from the hole. The projected end of the wire shall not be bent.

3) Preconditioning: preconditioning shall be as specified in Clause 5.

4) Test: insert a lead wire to the plated through-hole of the land of a specimen extruding more than 15 mm from the land and solder it to the plated through-hole. The tip of the soldering iron (diameter of the tip shall be 5,0 mm ± 0,1 mm) shall have a temperature of 270 ° C ± 10

° C. Solder the wire without touching the tip to the land within 3 s to 5 s. Cool the specimen in room temperature for more than 30 min. Pull the soldered wire using the testing machine to the peeling of the plated through-hole from the board with a peeling speed of 50 mm/min and measure the force when the wire is pulled off from the land. Repeat the test if the wire is cut by pulling, or pulled off from the land.

8.4 Peeling strength of foot print

1) Equipment: equipment shall be as specified in 8.1.1) and 10.3.1).
2) Specimen: the specimen shall be an isolated foot print. The size and the lead wire to be used shall be specified in the detailed specification. Pre-solder the wire and the foot print using appropriate solder flux and solder using the equipment described in 10.3.1) and the solder specified in 10.3.2).
3) Preconditioning: preconditioning shall be as specified in Clause 5.
4) Test
   a) Solder the lead wire vertically to the center of the specimen. The tip of the soldering iron (diameter of the tip shall be 5,0 mm ± 0,1 mm) shall have a temperature of 270 ° C ± 10 ° C. Solder the wire without touching the tip to the land within 3 to 5 sec. Cool the specimen in room temperature for more than 30 min. Pull the soldered wire using the testing machine to the peeling of the foot print from the board with a peeling speed of 50 mm/min and measure the force when the foot print is pulled off from the board. Repeat the test if the wire is cut by pulling, or pulled off from the foot print.
   b) In case peeling strength of a foot print is measured after repeated soldering of a wire to a foot print, use a specimen prepared as described in (a) and remove the wire in the same manner as to solder it to the foot print, and solder a wire again to the foot print of the specimen in the same way. Repeat soldering and removing of a wire for a number of times as specified in detailed specification. Cool the specimen each time for more than 30 min at room temperature. Pull the soldered wire using the testing machine to the peeling of the foot print with a peeling speed of 50 mm/min and measure the force when the wire is pulled off from the foot print. Repeat the test if the wire is cut by pulling, or pulled off from the foot print.

8.5 Adhesivity of plated film

1) Material used in the test: the material to be used in the test shall be the transparent adhesive tape (hereafter stated as tape) with a width of 12 mm specified in JIS Z 1522.
2) Specimen: an example of the test pattern to be used in specimen is shown in Figures A.1 and A.2, K.
3) Preconditioning: preconditioning shall be as specified in Clause 5.
4) Test: the test shall be made by adhering the new adhesive face of the adhesive tape to the specimen for a length of more than 50 mm by finger pressing or another appropriate way not to leave a bubble between the tape and the specimen. Pull the tape off rapidly after about 10 s to the direction perpendicular to the surface. The adhered area shall be no less than 100 mm^2. Peeling, floating, or attach to plated film to the adhesive tape shall be checked by a naked eye or using a magnifying glass. The plated film exfoliated from the overhang of the conductor shall not be the target of the test.

8.6 Adhesivity of solder resist and symbol mark

8.6.1 Tape peeling strength

1) Material used in the test: the material to be used in the test shall be as specified in 8.5.1).
2) Specimen: the specimen shall be an electronic circuit board with solder resist or symbol mark.
3) Preconditioning: the preconditioning shall be as specified in Clause 5.
4) Test: the test shall be made by adhering the new adhesive face of the adhesive tape to the specimen for a length of more than 50 mm by finger pressing or another appropriate way not to leave a bubble between the tape and the specimen. Pull the tape off rapidly after about 10 s to the direction perpendicular to the surface. Peeling, floating, or attach to plated film of

solder resist or symbol mark to the adhesive tape shall be checked by a naked eye or using a magnifying glass.

8.6.2 Grid line test (see JIS K 5600, 5 and 6)

1) Material used in the test: the material to be used in the test shall be the tape as specified in 8.5.1) and a cutter knife specified in the following section. The cutter knife to cut a coating surface shall have the shape and dimension illustrated in Figure 7, and made of the material SK2 specified in JIS G 4401 with a hardness of HV 820 ± 30. A new sharp edge of a blade shall be used by taking off an old edge and held the blade in a holder as shown in Figure 8.
2) Specimen: specimen shall be as specified in 8.6.1 (2).
3) Pre-conditioning: pre-conditioning shall be as specified in Clause 5. The pre-conditioning shall be specified in the detailed specification in case doing the grid line test for adhesivity after performing other tests.
4) Test: cut the specimen surface using a cutter knife to cut through the coated film or printed pattern spending about 0,5 s for each line of total of 11 parallel lines in each direction with a separation of 1 mm to obtain 100 small squares in an area of 100 mm^2. Clean the surface using a soft brush and test the adhesivity of the coating using the test method described in 8.6.1 (4).

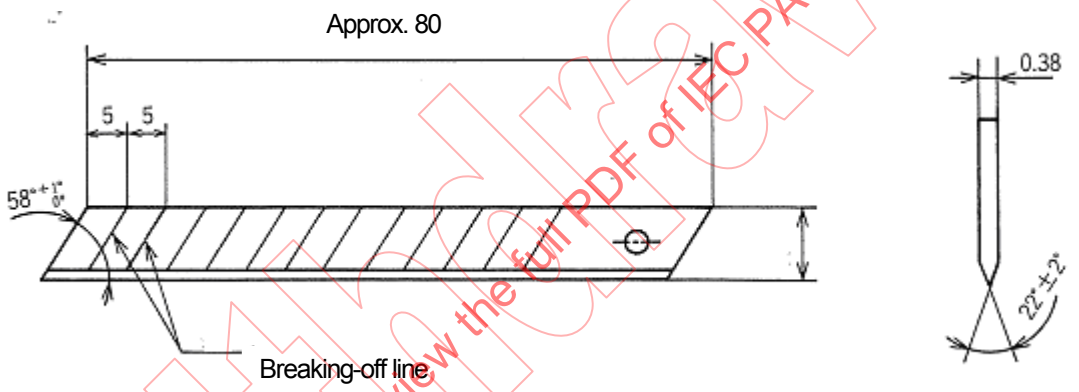


Figure 7 – An example of cutter knife blade (mm)

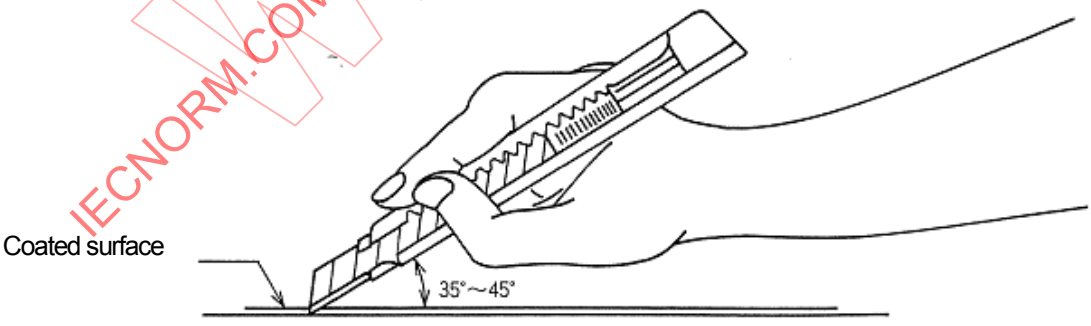


Figure 8 – Use of a cutter knife

8.6.3 Scratch test using pencil

1) Material used in the test: the material to be used in the test shall be the pencil specified in JIS SS 6006. Types of the pencils are as follows: 9H, 8H, 7H, 6H, 5H, 4H, 3H, 2H, H, F, B, 2B, 3B, 4B, 5B and 6B. Use the pencils produced by the same manufacturer. Cut the wood of a pencil to expose about 3 mm of the lead and then sharpen the lead using #400 lapping paper placed on a hard plate so that the lead is perpendicular to the lapping paper and a sharp

edge is obtained at the end of the lead. Pencil shall be newly sharpened each time it has been used to scratch the specimen surface.

2) Specimen: specimen shall be as specified in 8.6.1 (2).

3) Pre-conditioning: pre-conditioning shall be as specified in Clause 5. The pre-conditioning shall be specified in the detailed specification in case the pencil scratch test is made after performing other tests.

4) Test: place the specimen horizontally and apply the hardest pencil as shown in Figure 9 with an angle of 45 °. Push the pencil forward and write a line to form a scratch to the surface. Change the pencil to a softer pencil until the pencil does not form a scratch to the surface so as to obtain the hardest pencil that does not make a scratch to the surface of a specimen.

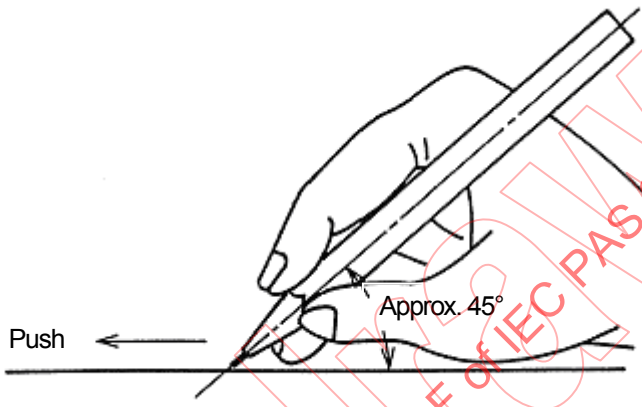


Figure 9 – Use of a pencil

8.7 Resistance to bending

1) Equipment: the equipment for this test shall be the test machine for bending as shown in Figure 10.

   a) The holder to apply the force can move to the vertical direction to the rotating axis of the test machine. The face to hold a specimen is on the same plane to the rotating axis. It is possible to apply a tension of 0 N to 14,7 N to a specimen. The distance from the holder to the rotating axis shall be 50 mm to 70 mm.

   b) The bending machine has parallel and smooth bending faces placed in symmetric positions. The bending machine has a holding device which can bend a specimen to 135 °± 5 ° from the non-bending position. Each of the bending faces shall have the radius of curve less than 19 mm. The spacing of bending faces shall be larger than the thickness of the specimen but shall not exceed 0,25 mm of the thickness of the unbent specimen.

   c) There shall be a driving scheme to give a specified rotating movement to the bending machine.

   d) There shall be an indicator of the number of bending.

2) Specimen: prepare a minimum number of 6 specimens of flexible wiring board, test coupons, or specimen with the test pattern specified in Figure A.5 and the cover-lay.

3) Pre-conditioning: pre-conditioning shall be as specified in Clause 5.

4) Test: apply a weight to the specimen equivalent to the tension to be applied to the plunger. Hold a specimen to the instrument with the specimen in a plane, and without touching the holding face of the machine. The specimen shall be handled at both ends but without touching the bending face. Loosen the holding screw of the plunger and apply the load to the specimen. Adjust the weight indicator, if its reading changes when a load is applied, by adjusting the adjustment screw to adjust the reading of the indicator to the value shown when a load is applied. Bend the specimen with a tension of 4,9 N at 175 bendings per minute until the specimen breaks. Register the number of bendings to breakage.

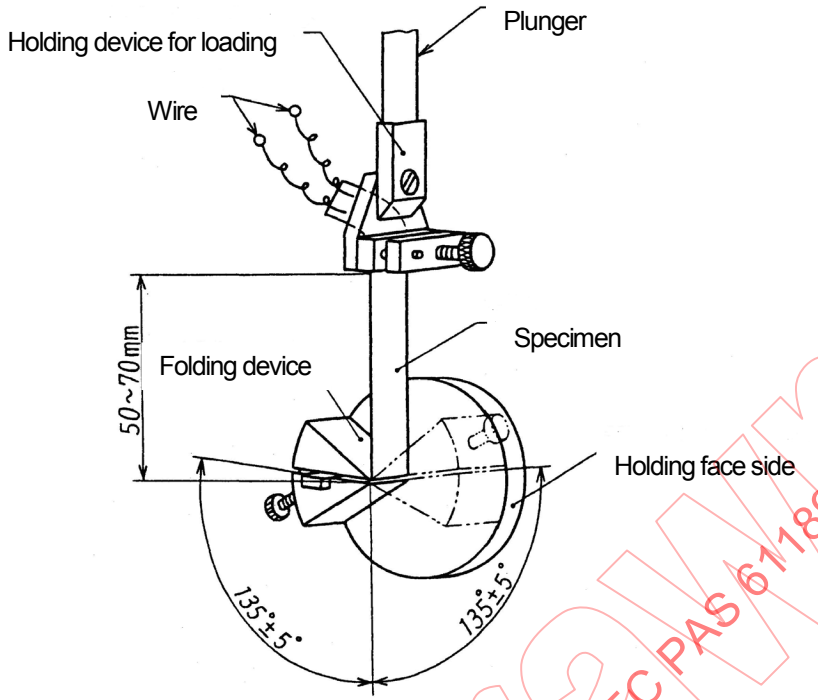


Figure 10 – An example of bending machine

9 Environmental tests

9.1 Temperature cycle

1) Equipment: the equipment shall be the high temperature and low temperature chambers to realize the temperature shown in Table 3.
2) Specimen: specimen shall be test coupons, coupons with composite test paterns (e.g. Figures A.1 and A.2, D, E or Figure A.2.1 L).
3) Test: the test shall be made on the specimen for the items specified in the detailed specification, and then a test shall be made selecting the temperature condition from Table 3, depending on the detailed specification for steps 1 to 4 for the specified cycles in the detailed specification. The number of cycles shall be five (5) if the number is not specified in the detailed specification.

Table 3 – Temperature cycle conditions

Step		Condition					
		Condition 1		Condition 2		Condition 3	
		Temp., °C	Time, min	Temp., °C	Time, min	Temp., °C	Time, min
Cycle	1	-65 ± 3	30	-65 ± 3	30	-55 ± 3	30
	2	20 ± 15	10 to 15	20 ± 15	15 to 15	20 ± 15	10 to 15
	3	125 ± 3	30	100 ± 2	30	100 ± 2	30
	4	20 ± 15	10 to 15	20 ± 15	10 to 15	20 ± 15	10 to 15

9.2 Thermal shock (low and high temperatures) (see JIS C 0025)

1) Equipment: equipment shall be thermostat chambers which can realize the temperatures shown in Table 4.
2) Specimen: specimen shall be prepared as described in 9.1.2).

3) Test: characteristics of a specimen specified in detailed specification shall be measured first. The specimen shall then be held in the chambers at temperature selected from Table 4 according to the condition specified in detailed specification for step 1 to step 2, then return step 2 to step1 within 30 s for the cycles specified in detailed specification. The number of cycles shall be 5 when the number is not specified in detailed specification.

Table 4 – Thermal shock conditions

Step	Condition							
	Condition 1		Condition 2		Condition 3		Condition 4	
	Temp. °C	Time, min	Temp. °C	Time, min	Temp. °C	Time, min	Temp. °C	Time, min
Step 1	-65 ± 3	30	-65 ± 3	30	-65 ± 3	30	-55 ± 3	30
Step 2	175 ± 3	30	125 ± 3	30	100 ± 2	30	100 ± 2	30

9.3 Thermal shock (immersion in high temperature)

1) Equipment: equipment shall satisfy the following conditions.
   a) A container to contain enough silicone oil to immerse a specimen in the oil and keep the temperature at 260 °C $^{+5}_{-0}$ °C.
   b) A container to contain enough organic solvent to immerse a specimen in the oil and keep the temperature at 20 °C ± 15 °C.
2) Specimen: specimen shall be prepared as described in 9.1.2).
3) Test: characteristics of a specimen specified in detailed specification shall be measured first. The specimen shall then be held in the chambers at a temperature selected from Table 5 according to the condition specified in detailed specification for step 1 to step 4 for the cycles specified in detailed specification. The number of cycles shall be 5 when the number is not specified in detailed specification. The specimen shall be left for a sufficient time to bring it to a stable state and then perform following specified tests.

Table 5 – Test condition

Step		Temperature, °C	Time, min	Immerse in
Cycle	1	260 +5/-0	3 to 5	silicone oil
	2	20 ± 15	≦15	transfer
	3	20 ± 15	20	organic solvent
	4	20 ± 15	≦15	transfer

9.4 Resistance to humidity (temperature/humidity cycle) (see JIS C 60068-2-78)

1) Equipment: equipment shall satisfy the following conditions.
   a) A container shall be able to realize the temperature/humidity cycles illustrated in Figure A.6.
   b) The resistance of water shall be larger than 500 Ω·m in case the water is directly sprayed to humidify the chamber.
   c) Water condensated on the wall or ceiling of the chamber shall not drop on or near the specimen.
2) Specimen: specimen shall be a product or coupon with the test pattern (Figures A.1, A.2 E, Figure A.2.1 J).
3) Test: characteristics of a specimen specified in detailed specification shall be measured first. The specimen shall then be held in the chambers for the humidity exposure cycles specified in detailed specification. The number of cycles shall be 10 when the number is not specified

in detailed specification. The specimen shall be left for a sufficient time to bring it to a stable state and then perform following specified tests.

Subject the specimen for 24 h with the procedure step *a* to *g* given in Figure A.6 as one cycle. Procedure at the final cycle, *g*, (measurement at high temperature, measurement right after taking the specimen out of the chamber, and measurement after drying) shall be as stated in detailed specification. The specimen shall be used for the test(s) specified in detailed specification.

The damaged specimen in this test such as mechanical damage, flush over, spark over or breakdown shall be used in other test.

9.5 Resistance to humidity (steady state) (see JIS C 60068-2-78)

1) Equipment: equipment shall satisfy the following conditions.
   a) A container shall be able to keep its temperature and relative humidity in the chamber to 40 °C ± 2 °C and 90 % to 95 %.
   b) The resistance of water shall be larger than 500 Ω·m in case the water is directly sprayed to humidify the chamber.
   c) Water condensated on the wall or ceiling of the chamber shall not drop on or near the specimen.
2) Specimen: specimen shall be prepared as described in 9.4.2).
3) Test: characteristics of a specimen specified in detailed specification shall be measured first. The specimen shall then be held in the chamber at 40 °C ± 2 °C and 90 % to 95 %. It is desirable to preheat the specimen before setting it in the chamber so as not to condensate water vapour on the specimen. The specimen shall be left for a specified time in detailed specification. The time shall be 240 h unless it is not specified in detailed specification. The specimen shall be taken out of the chamber and measure the items specified in detailed specification. Care shall be made to wipe water vapour on the specimen if there is any. The damaged specimen in this test such as mechanical damage, flush over, spark over or breakdown shall be used in other test.

10 Other tests

10.1 Flammability

1) Equipment: equipment shall satisfy the following conditions.
   a) A stand with a holding arm.
   b) A burner with the length of the tube of 100 mm ± 10 mm with opening diameter of Ø = 9,5 mm ± 0,3 mm using methane gas or natural gas with heat capacity of approximately 38 MJ/m^3.
   c) A stop-watch or a timer.
   d) Cotton.
   e) Desiccator with dry potassium chloride.
   f) A test chamber capable of realizing 23 °C ± 2 °C and 50 % ± 5 %.
   g) A test chamber capable of realizing 70 °C ± 2 °C.
2) Specimen: specimen shall be a test board without conductor to be cut to a length of 125 mm ± 0,5 mm and width of 13 mm ± 0,5 mm and the cut surfaces are smoothly made.
3) Number of specimen: the number of specimen used in the test shall be 20.
4) Pre-conditioning: specimens are to be treated according to (a) and (b) below for pre-conditioning.
   a) Leave 5 specimens in a test chamber at 23 °C ± 2 °C and 50 % ± 5 % for 48 h.
   b) Five specimens are heated to 70 °C ± 2 °C die 168 h and then cool them more than 4 h in a desiccator with dry potassium chloride.

5) Test: a specimen shall be clamped vertically to the holder at 6 mm from the top, in a room without air flow, and place a burner with the tip of the upper end of the burner 10 mm ± 1 mm below the lower end of the specimen. Place a cotton pad 300 mm ± 10 mm below the specimen and light the burner to the blue flame with the flame height at 20 mm ± 2 mm. Burn the specimen with the burner flame for 10 s ± 0,5 s. Leave the burner more than 150 mm from the specimen and measure the flaming time of the specimen (time the specimen burns with flame). After the flaming of the specimen, the burner is again brought to the same position of the specimen for 10 s ± 0,5 s. Leave the burner more than 150 mm from the specimen and measure the flaming time and the glowing time (time the specimen is in red but not flaming) of the specimen. Observe if there is any fire in the cotton below caused by anything hot falling from the specimen.

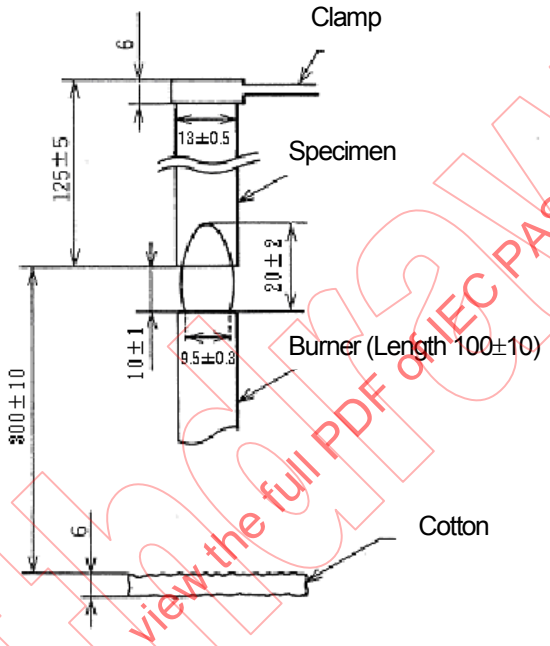


Figure 11 – Flammability test (mm)

10.2 Resistance to chemical solvent

1) Equipment: equipment shall be a container, is solvent resistant and can be heated to a specified temperature with protection from over heating.
2) Specimen: specimen shall be an electronic circuit board with solder resist and/or symbol mark.
3) Pre-conditioning: pre-conditioning shall be as specified in Clause 5.
4) Test: dip the specimen into boiling solvent for 1 min. Check if there is any damage tp the specimen by naked eyes. Confirm there is no peeling of solder resist or symbol mark with the test as described in 8.6 by naked eyes.

10.3 Solderability

1) Equipment: equipment shall be a soldering equipment which is capable of either dip soldering, flow soldering or swing type soldering and can keep its temperature to 235 $^{\circ}$C $^{+5}_{0}$ $^{\circ}$C.

NOTE Swing type instrument described in JIS C 60068-2-20, 6 Specimen

2) Solder: unless otherwise specified in detailed specification, the solder to be used in the test shall be H 60A or H 63A specified in JIS Z 3283.
3) Specimen: unless otherwise specified in detailed specification, specimen shall be a test coupon or a coupon with the test pattern (see Figures A.1 and A.2, A or H).

4) Pre-conditioning: pre-conditioning shall be as specified in Clause 5.

5) Test: coat soldering flux to the surface of a specimen. Flux shall be one of (1) to (3) specified below unless specified in detailed specification. Remove flux after soldering at the temperature and time specified in detailed specification. If not specified in detailed specification, soldering shall be made at 235 $^{+5}_{0}$ °C for 3 $^{+1}_{0}$ s.

Flux (1) Mixture of 25 % rosin (JIS K 5902) in weight and 75 % propyl alcohol （JIS K 8839） or ethyl alcohol (JIS K 8101).

Flux (2) Flux (1) with added diethyl ammonium chloride to a chlorine content of 0,2 % weight % (as free chlorine to rosin content).

Flux (3) Flux with chlorine content of 0,5 % as specified in flux (2).

Check the soldered surface using a magnifying glass under sufficient illumination:

a) Solder wetting and gloss.

b) Repel and pin-holes.

c) Filling of solder in through-hole and wetting.

10.4 Resistance to soldering heat

10.4.1 Solder float method

1) Equipment: equipment shall be a soldering bath which is heated by electric heater and can keep it to a specified temperature.

2) Solder: unless otherwise specified in detailed specification, the solder is specified in 10.3.2).

3) Specimen: use specimen specified in detailed specification. Unless otherwise specified, specimen shall be as illustrated in Figure A.7.

4) Pre-conditioning: pre-conditioning shall be as specified in Clause 5.

5) Test: coat soldering flux to the surface of a specimen. Flux shall be a mixture of 25 % rosin (JIS K 5902) in weight and 75 % propyl alcohol （JIS K 8839） or ethyl alcohol (JIS K 8101) unless otherwise specified in detailed specification. Float the specimen on the molten solder and then take out of the bath and check for swelling or peel. The temperature and time for this test shall be 260 °C $^{+5}_{0}$ °C for 10 s $^{+1}_{0}$ s unless otherwise specified in detailed specification. Use the micro-sectioning specified in 6.2 to check peeling inside of a specimen.

10.4.2 Reflow soldering

1) Equipment: use the equipment specified in detailed specification.

2) Specimen: use specimen specified in detailed specification. Unless otherwise specified, specimen shall be as illustrated in Figure A.7.

3) Pre-conditioning: pre-conditioning shall be as specified in Clause 5.

4) Test: reflow solder the specimen with the temperature profile specified in detailed specification for 1 to 3 times. If the temperature profile is not specified in detailed specification, use the temperature profile given in Figure A.8. Check for swelling or peel after reflow soldering by naked eyes. Use the micro-sectioning specified in 6.2 to check peeling inside of a specimen.

10.5 Resistance to heat of solder resist and symbol mark

10.5.1 Solder floating method

1) Equipment: use the equipment specified in 10.4.1 (1).

2) Specimen: use specimen specified in detailed specification. Unless otherwise specified, specimen shall be as illustrated in Figure A.7.

3) Pre-conditioning: pre-conditioning shall be as specified in Clause 5.

4) Test: float the specimen on the molten solder and then take out of the bath and check for swelling, peel or colour change of symbol mark by naked eyes. The temperature and time for this test shall be 260 °C $^{+5}_{0}$ °C for 10 s $^{+1}_{0}$ s unless otherwise specified in detailed specification. Check if there is any peeling by performing the test specified in 8.6 as a peeling.

10.5.2 Reflow soldering method

1) Equipment: use the equipment specified in 10.4.1 (1).
2) Specimen: use specimen specified in detailed specification. Unless otherwise specified, specimen shall be as illustrated in Figure A.7.
3) Pre-conditioning: pre-conditioning shall be as specified in Clause 5.
4) Test: process the specimen with the temperature profile given in 10.4.2 (4), then float the specimen on the molten solder and then take out of the bath and check for swelling, peel or colour change of symbol mark by naked eyes. Check if there is any peeling by performing the test specified in 8.6 as a peeling.

10.6 Thermal conductivity

10.6.1 Measurement of thermal resistance on the plane

1) Equipment: use the equipment specified in EIA/JEDEC STD 51-2 (Integrated Circuits Thermal Test Method – Environment Conditions – Natural convection (still air)), or an equivalent. The equipment shall have a set of a specimen and a thermo-couple at the center of a cubic chamber with a side length of 30 cm. Schematic diagram of the equipment is shown in Figure A.1.
2) Specimen: use specimen specified in detailed specification. Unless otherwise specified, specimen shall be as illustrated in Figure A.2. A heater of a size of 5 mm x 5 mm with a temperature measuring sensor is used as a heat source and wire bonded to specimen board.
3) Pre-conditioning: pre-conditioning shall be as specified in Clause 5.
4) Test: specimen shall be fixed in the chamber that is equipped with a heater with a temperature measuring sensor whose temperature coefficient has already been obtained. Heat a heater with a temperature sensor, with a heat of W. Electricity is supplied in this standard by connecting the power supply directly to the specimen, with electricity supplied using a card-edge connector specified in EIA/JEDEC STD 51-2. Hold the specimen horizontally in the chamber with the board and the supporting jig being thermally isolated. The heat, W, from the heater with temperature sensor depending on the thermal resistance, R_p, on the plane shall be selected from Table 6. Measure the temperature of the temperature sensor, T_s, and the temperature of the air in the chamber, T_a, after the temperature of the sensor reached a stable state. The thermal resistance on the plane, R_p, shall be calculated from the following equation.

$$R_p = (T_s - T_a)/W \quad \text{(K/W)}$$

Hear transfer parameter, *he,* shall be calculated from the following equation using R_p.

$$he = \frac{1}{R_p \times 0{,}025}$$

Table 6 – Heating of specimen

Load heat (*W*)	Thermal resistance Range of R_p(K/W)
0,1	3000<*R*
0,2	200<*R*<300
0,3	150<*R*<200
0,4	100<*R*<150
0,75	60<*R*<100
1,0	30<*R*<60
2,0	20<*R*<30
3,0	15<*R*<20
5,0	5<*R*<15
10,0	*R*<5

10.6.2 Thermal conductivity in the direction of thickness

1) Equipment: equipment shall consist of a metal block (aluminum or copper) which can hold the specimen specified in 10.6.1 (2) and a cooling system to keep the temperature of the metal block. An illustration of the equipment is shown in Figure A.11.
2) Specimen: specimen shall be as specified in 10.6.1 (2).
3) Pre-conditioning: pre-conditioning shall be as specified in Clause 5.
4) Test: specimen with a heater with a temperature measuring sensor whose temperature coefficient has already been obtained shall be fixed to the metal block with screws. Thermal conductive material such as thermal grease shall be inserted between the specimen and block to reduce thermal resistivity between them. Cut a groove of a depth larger than 1 mm to the block to install a thermocouple on the top plane of the block touching to the specimen. The tip of the thermocouple when buried in the block shall be at the center of the back surface of the heater.

   The metal block is fixed to the cooling system. The cooling system shall be water-cooled as illustrated in Figure A.11 and keep the water temperature constant. Heat to the heater, *W*, shall be selected from Table 7 depending on the thermal resistance to the direction of the thickness, R_t. Measure the temperature of the temperature sensor, T_s, and the temperature of the air in the chamber, T_a, after the temperature of the sensor reached a stable state. Thermal resistance on the thickness, R_t, shall be calculated from the following equation.

$$R_t = (T_s - T_a)/W \text{ (K/W)}$$

   The thermal conductivity parameter, *ke*, shall be calculated from the following equation using R_t.

$$Ke = \frac{t}{R_t \times 2{,}5 \times 10^{-5}} \text{ (W/mK)}$$

where *t* is the thickness; and

$2{,}5 \times 10^{-5}$ is the area of temperature measuring sensor.

Table 7 – Heating of specimen

Load heat (*W*)	Thermal resistance Range of R_p(K/W)
0,1	300<*R*
0,2	200<*R*<300
0,3	150<*R*<200
0,4	100<*R*<150
0,75	60<*R*<100
1,0	30<*R*<60
2,0	20<*R*<30
3,0	15<*R*<20
5,0	5<*R*<15
10,0	*R*<5

10.7 Reflectivity

The test method of reflectivity shall be agreed between user and supplier. An example of a test method is described in Annex B of this document for information.

10.8 Wire bond strength

The test method of wire bond strength shall be agreed between user and supplier. An example of a test method is described in Annex C of this document for information.

11 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EIA/JEDEC STD 51-2, *Integrated circuits thermal test method - Environment condition – natural convection (still air)*

JIS B 7502, *Micrometer*

JIS B 7507, *Slide Caliper*

JIS B 7517, *Height Gauge*

JIS B 7524, *Gap Gauge*

JIS C 0025, *Environmental test – Electricity and electronics – Temperature variation*

JIS C 60068-1, *Environmental testing – Part 1: General and guidance*

JIS C 60068-2-78, *Environmental test – Electricity and electronics – 2-78 High temperature/high humidity test (steady state)*

JIS C 1302, *Insulation resistance meter*

JIS C 2110-2, *Solid electric insulation materials – Test method of insulation breakdown – Part 2: Applying d.c. voltage*

JIS C 5603, *Terms and definitions for printed circuits*

JIS K 5600-5-4, *Paint – Test methods – Part 5: Mechanical strength of painted film – Scratch test (pencil)*

JIS K 5600-5-6, *Paint – Test methods – Part 5: Mechanical strength of painted film – Scratch test (cross-cut)*

JIS K 5902, *Rosin*

JIS K 8101, *Ethyl alcohol*

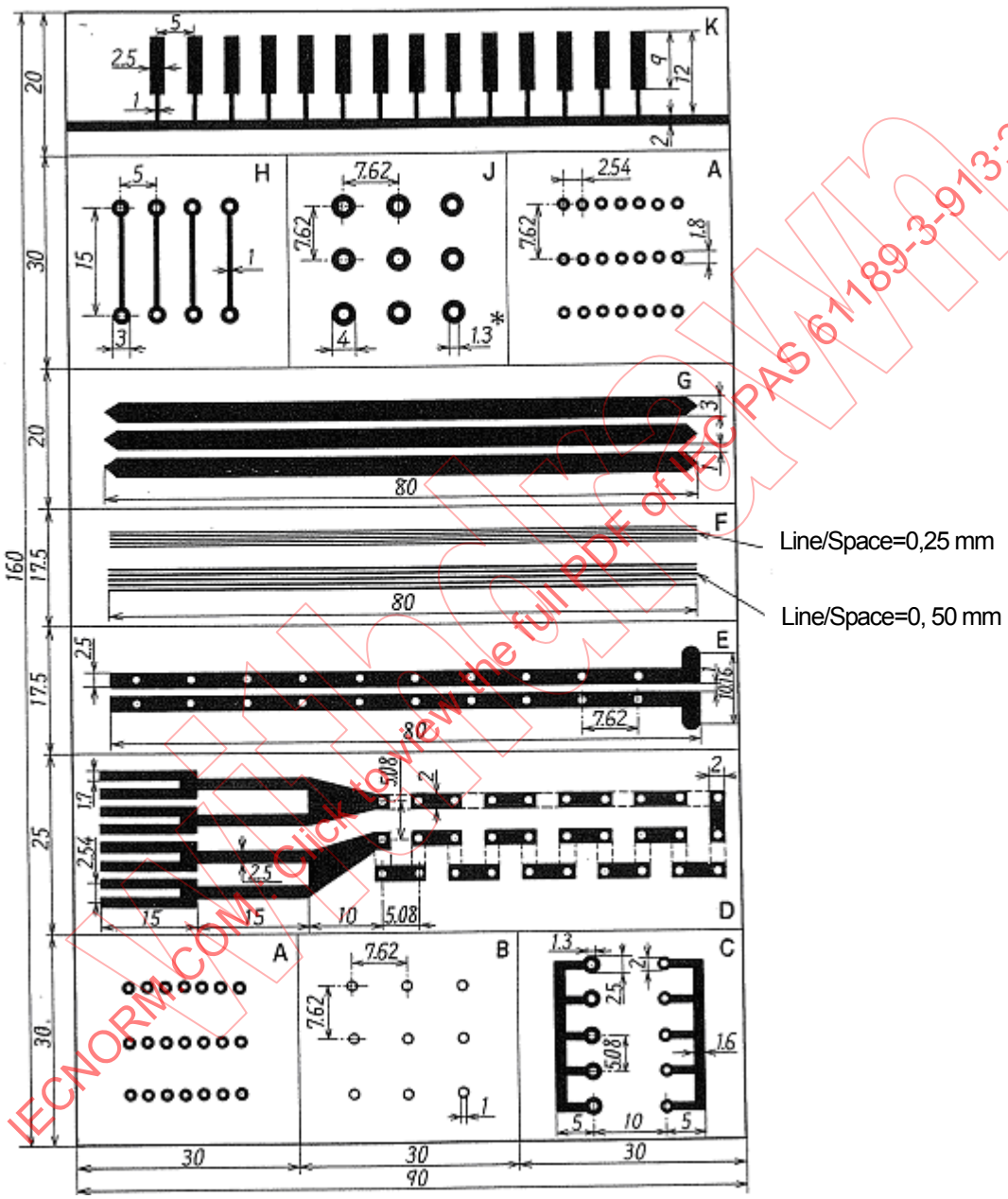
JIS K 8839, *2-propyl alcohol*

JIS Z 1522, *Cellophane adhesive tape*

JPCA-TD01, *Terms and definitions for printed circuits*

Annex A
(informative)

Figures

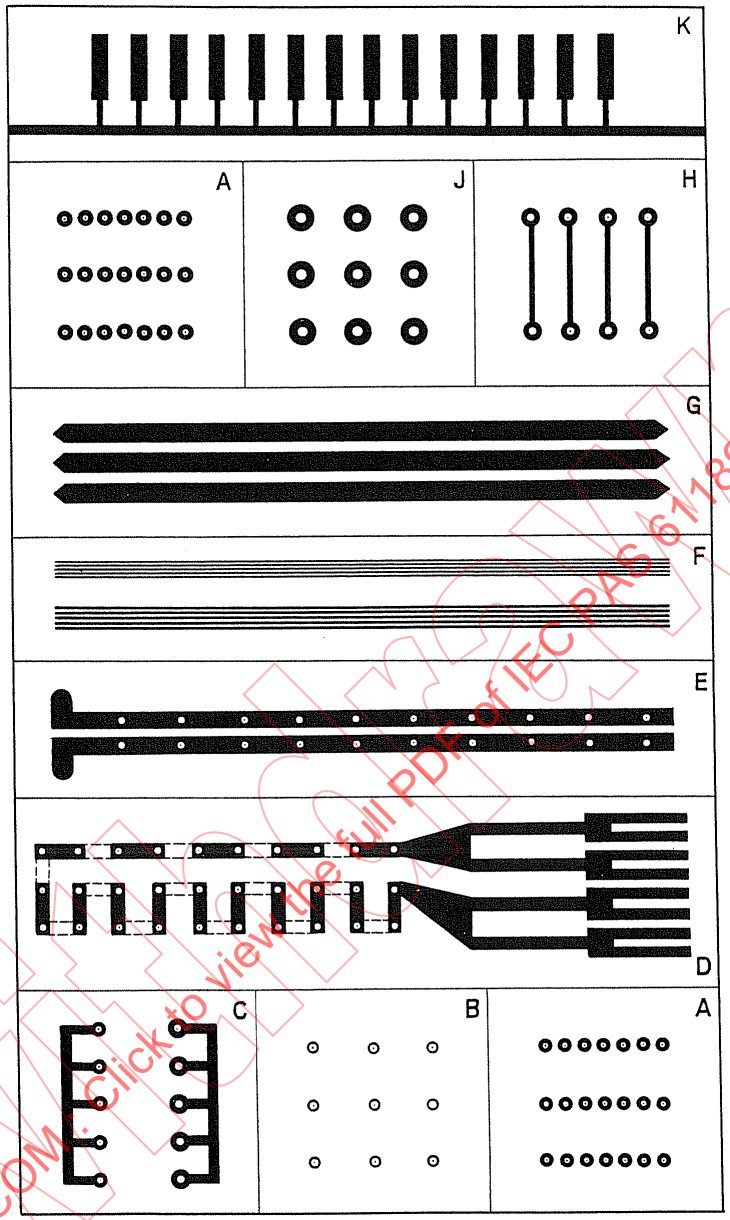


* Not plated holes

NOTE Specimens B, C, and D are not used for single-sided boards.

Specimen	Applicable test	Test item
A	Solderability (plated through-hole and land)	10.3
B	Pulling strength of plated though-hole)	8.3
C	Thickness of plated copper of plated through-hole	6.2
D	Conductance of plated through-hole	7.12, 9.1, 9.2, 9.3
E	Surface breakdown voltage and insulation resistance	7.4, 7.6, 9.1 to 9.5
F	Conductor width, spacing, nick, extraneous copper	6.3.5, 6.3,6
G	Peeling strength of conductor	8.1
H	Solderability (conductor surface)	10.3
J	Pulling strength of un-plated land	8.2
K	Adhesivity of plated film	8.5

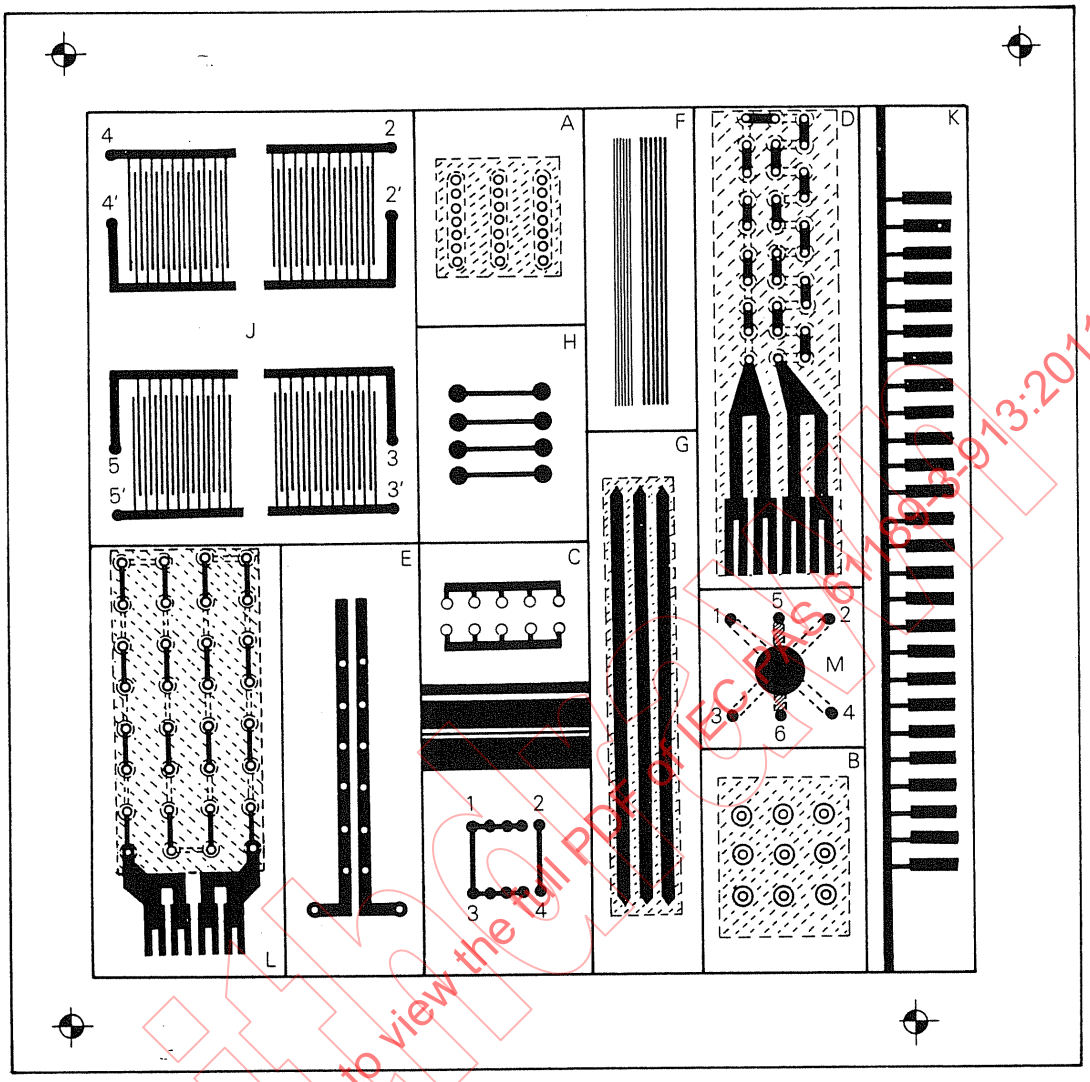
Figure A.1a – Composite test pattern for single- and double-sided electronic board (front surface)



NOTE See Figure A.1 a for dimensions.

Figure A.1b – Composite test pattern for double-sided electronic board (back surface)

Figure A.1 – Composite test pattern



NOTE This figure shows arrangement test patterns in a complex test pattern and does not show the arrangement in the first layer. The meshed parts show the arrangement in X-th layer of specimens A, B, D, G and L. See Figure A.2.2c for the arrangement in X-th layer for specimens C and M.

Specimen	Test item	Nominal hole diameter mm	Nominal land diameter mm	Applicable section
A	Solderability (plated through-hole and land)	0,8	1,8	10.3
B	Pulling strength of plated through-hole	1,0	—	8.3
C	Adhesivity of plated film, micro-section and internal shorts	1,3	2,5	8.5, 6.2
		0,8	2,0	
D	Conductivity of plated through-hole	0,8	2	7.1.2
E	Surface withstanding voltage, surface insulation resistance	0,8	2,5	7.4, 7.6
F	Conductor width, space, nick, extraneous copper	—	—	6.3.5, 6.3.6
G	Peeling strength of conductor, inter-layer peeling	—	—	8.1
H	Solderability (conductor surface)	—	3	10.3
J	Insulation resistance of inner layer	0,8	2	7.7, 9.4, 9.5
K	Adhesivity of plated film	—	—	8.5
L	Interconnection resistance of inner layers	0,8	1,8	7.1.3, 9.1, 9.2, 9.3
M	Interlayer withstanding voltage, and insulation resistance	0,8	2	7.5, 7.8

Figure A.2.1 – Complex test patterns of multi-layer electronics board (perspective)

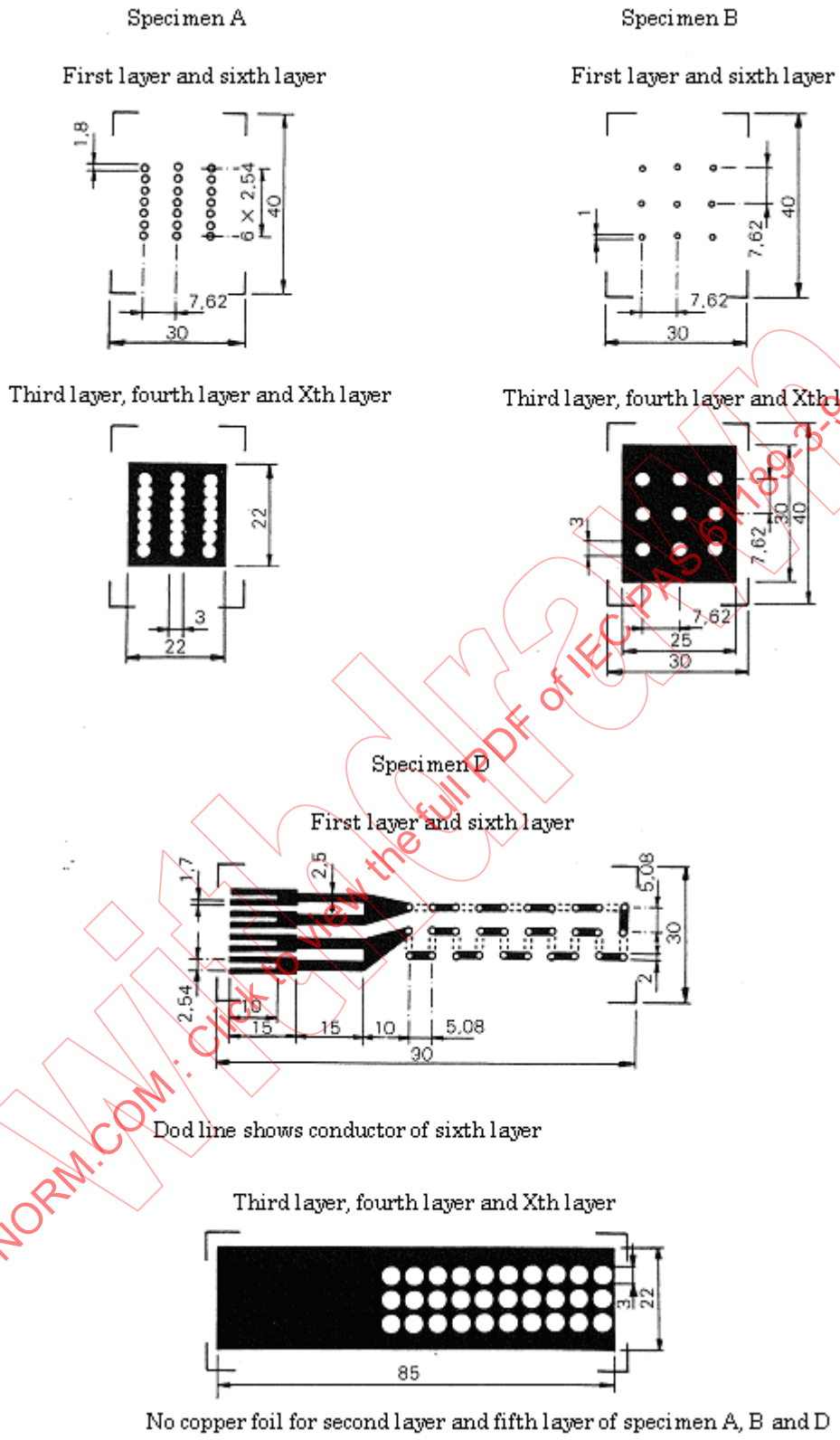


Figure A.2.2a – Electrode patterns of each specimen (Part 1)

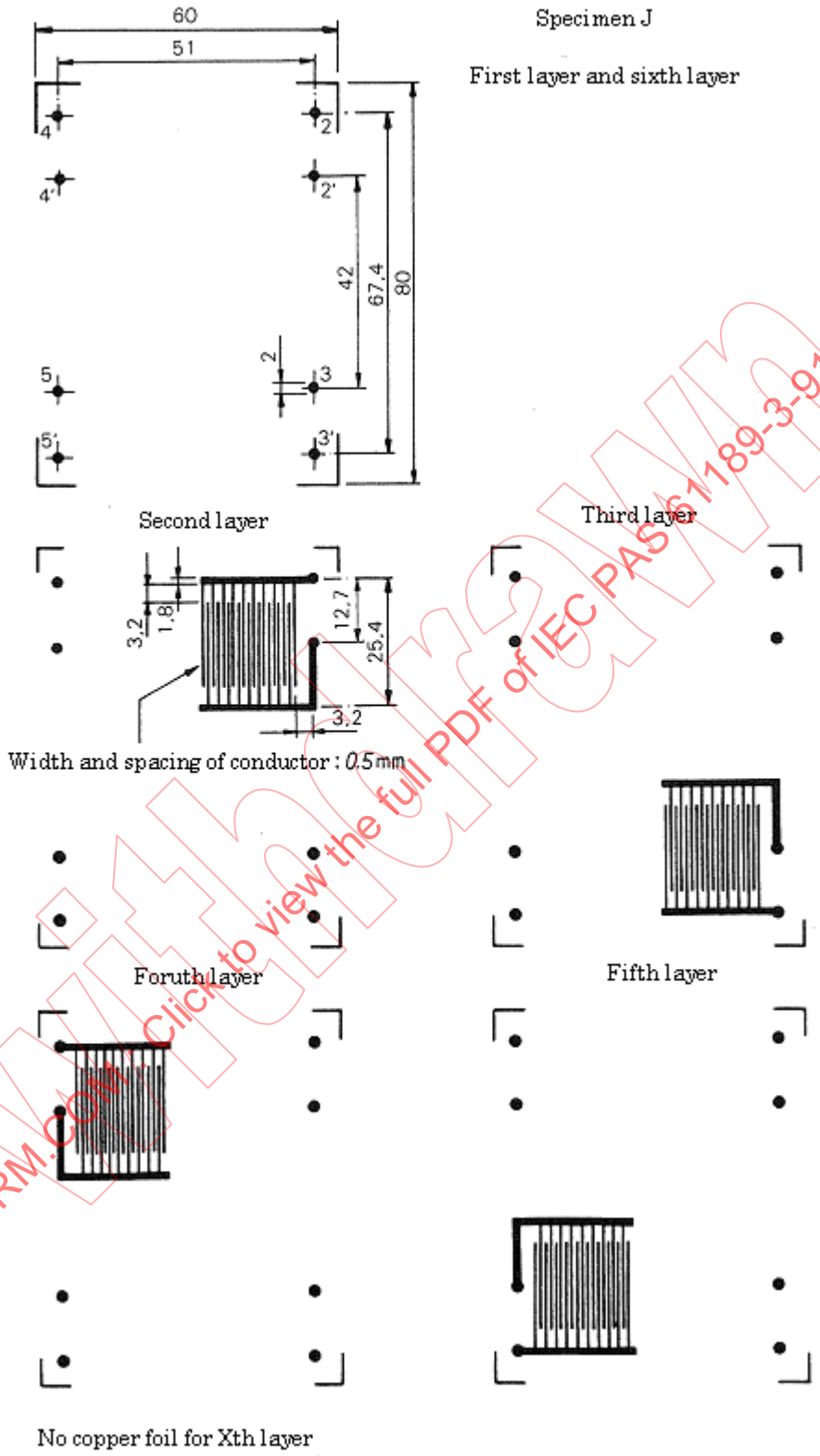


Figure A.2.2b – Electrode patterns of each specimen (Part 2)

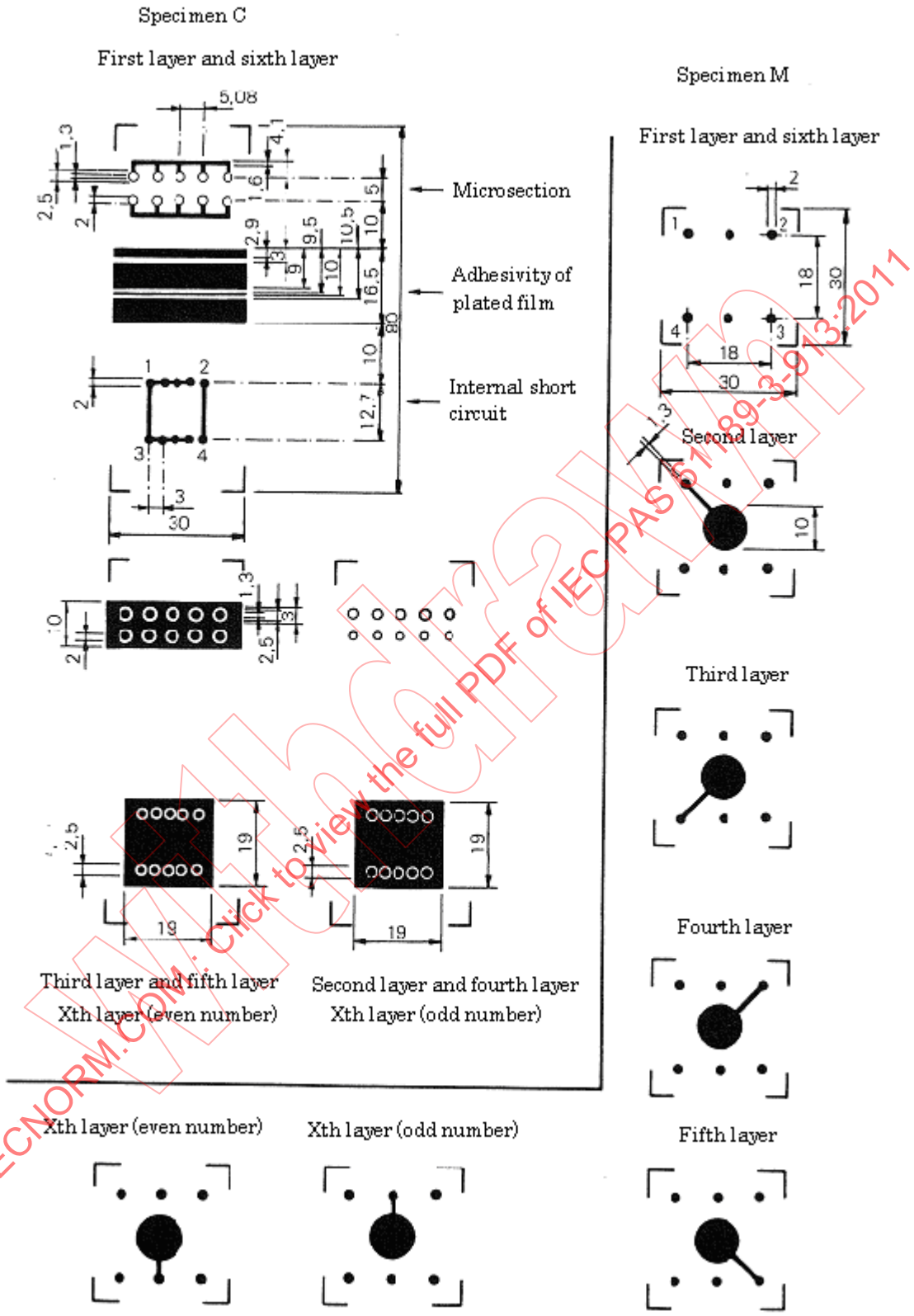


Figure A.2.2c – Electrode patterns of each specimen (Part 3)

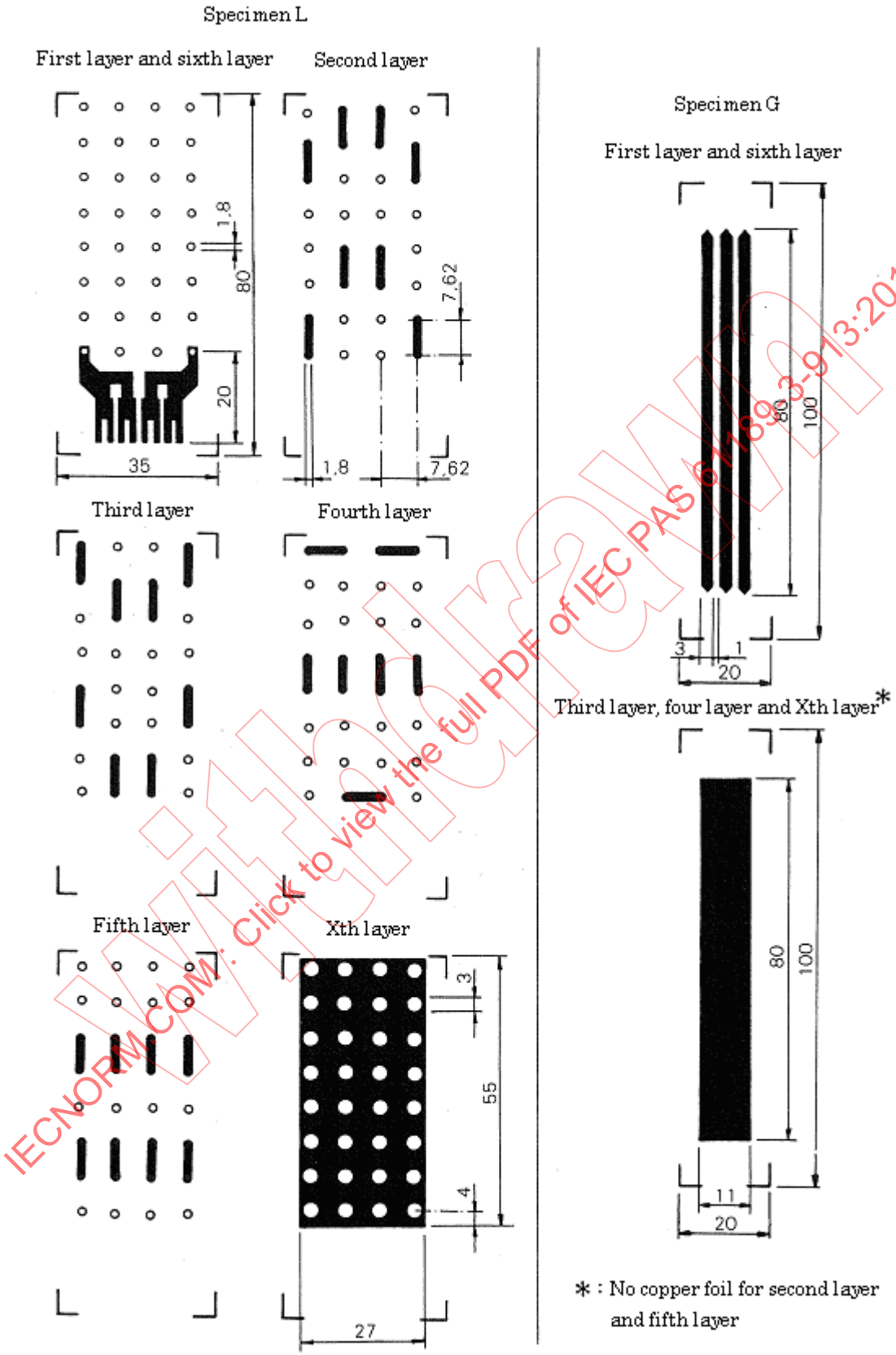
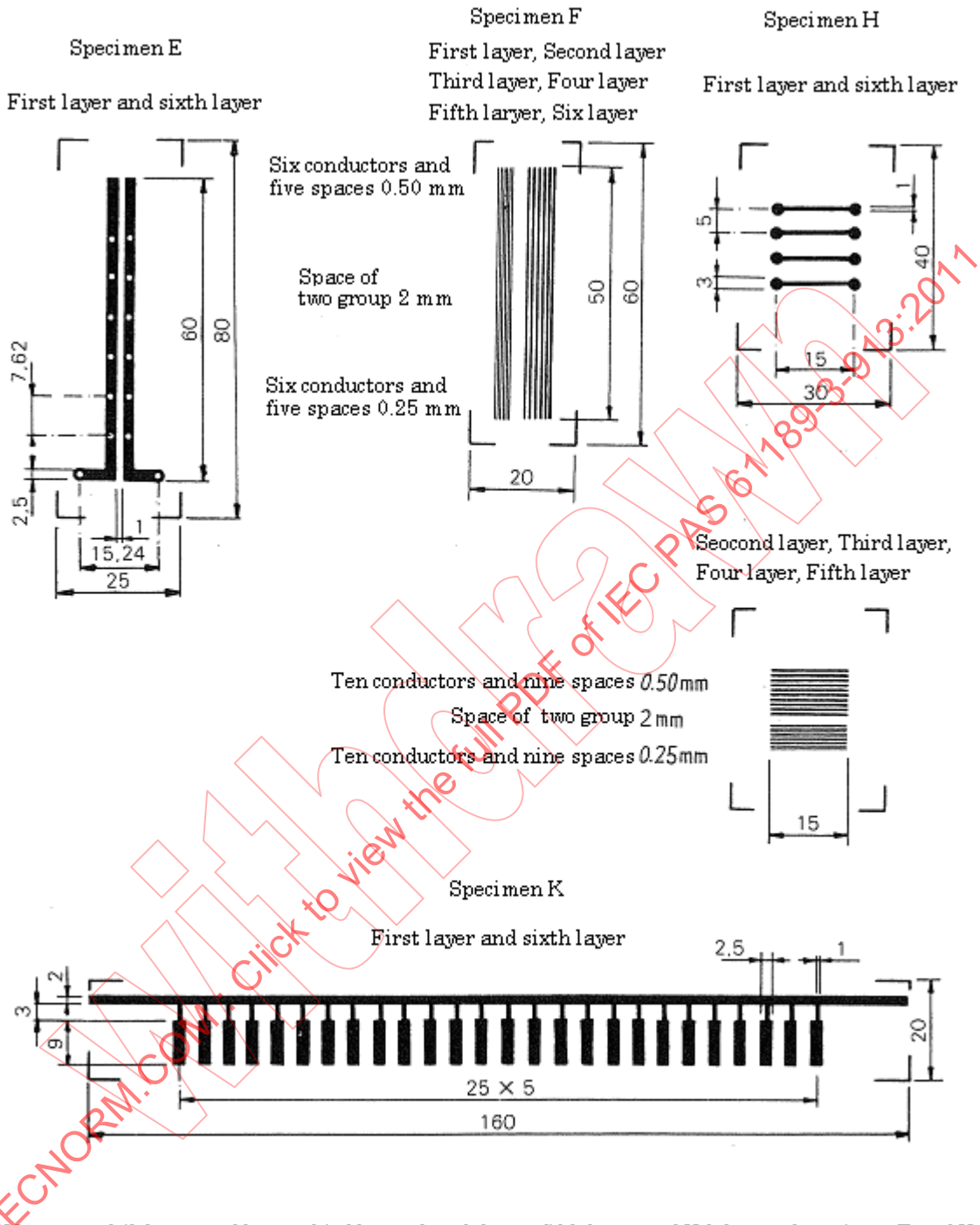


Figure A.2.2d – Electrode patterns of each specimen (Part 4)



No copper foil for second layer, third layer, fourth layer, fifth layer and Xth layer of specimen E and X

No copper foil for Xth layer of specimen F and H

Figure A.2.2e – Electrode patterns of each specimen (Part 5)

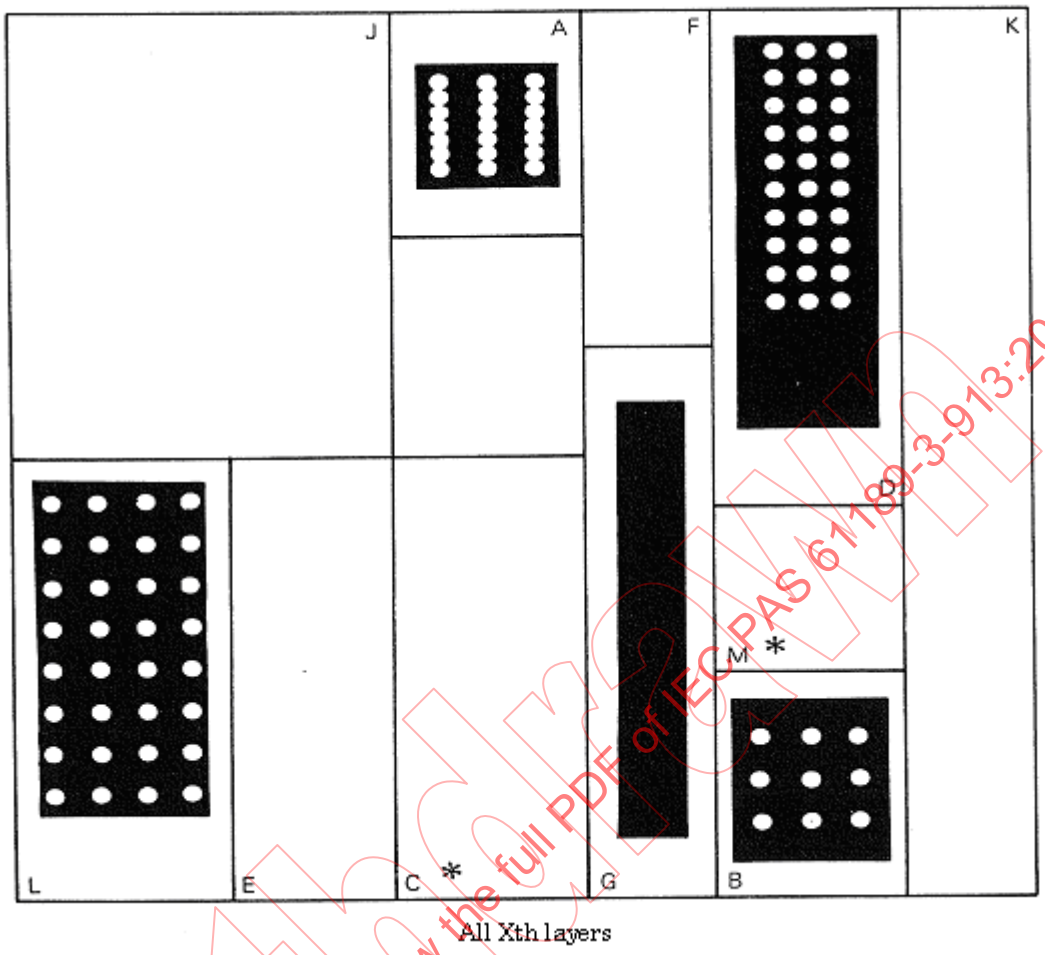


Figure A.2.2f – Electrode patterns of each specimen (Part 6)

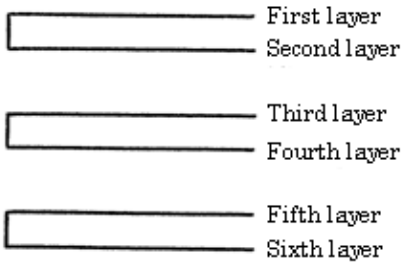
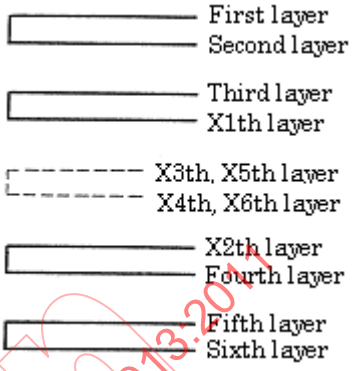
		6th layer	Exceeding 7 layers
Construction			
Number of layers		6	8-10-12-14-16-18-20-22, etc (Number of underlined layers are recommended)
Total layer thickness		1,6 ± 0,2 mm	Depends on detailed specification
Stacked later	Thicknesss	0,2 mm	
	Copper foil	Copper 35 µm for both sides	
Insulation layer	Thicknesss	Minimum 0,1 mm	
	Number of pre-preg	Minimum 2	
Hole		Plate all through-holes	
Surface finish		Specified in detailed specification	
Notes F		These patterns shall be properly arranged according to the specified arrangement. The odd number layer such as X1, X3, X5 and even number layers such as X2, X4, X6 shall be arranged as shown for construction of layers above 7 layers. A sufficient space shall be formed outside of a pattern for fiducial purpose.	

Figure A.2.2g – Electrode patterns of each specimen (Part 7)

Figure A.2.2 – Electrode pattern of each specimen

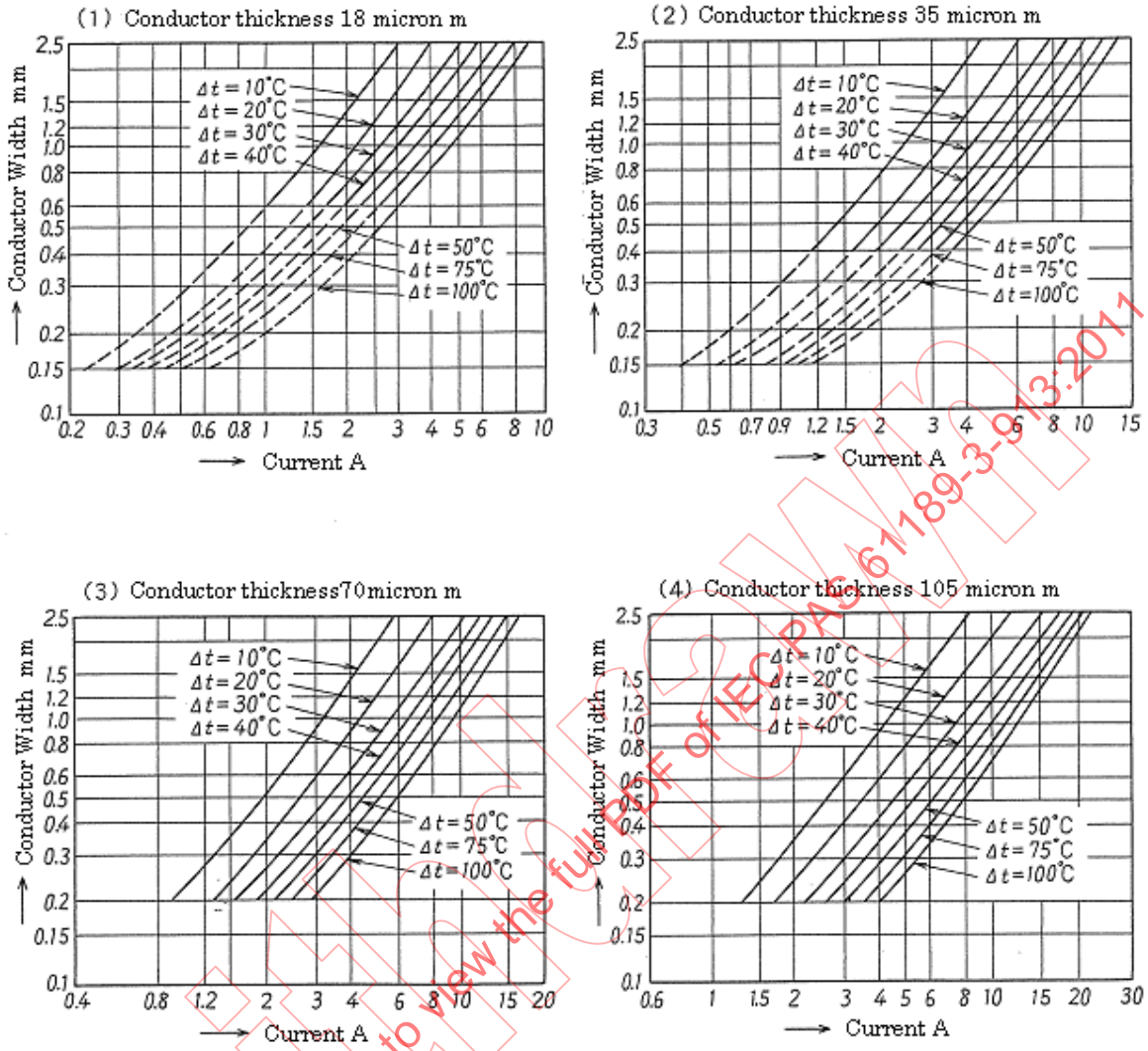


Figure A.3 – Temperature rise according to conductor thickness, width and current

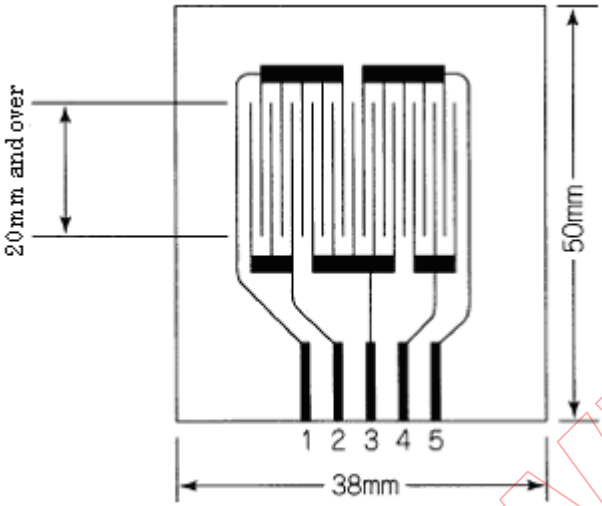


Figure A.4a – Insulation resistance
(normal, resistance to humidity-temperature/humidity cycle and steady state)

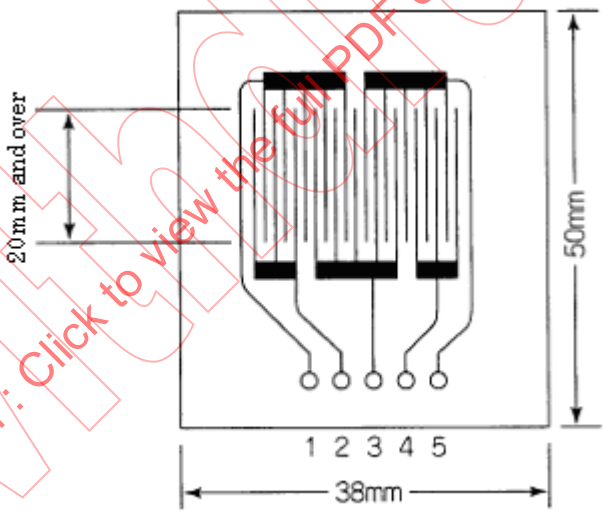


Figure A.4b – Insulation resistance of inner layers
(normal, resistance to humidity-temperature/humidity cycle and steady state)

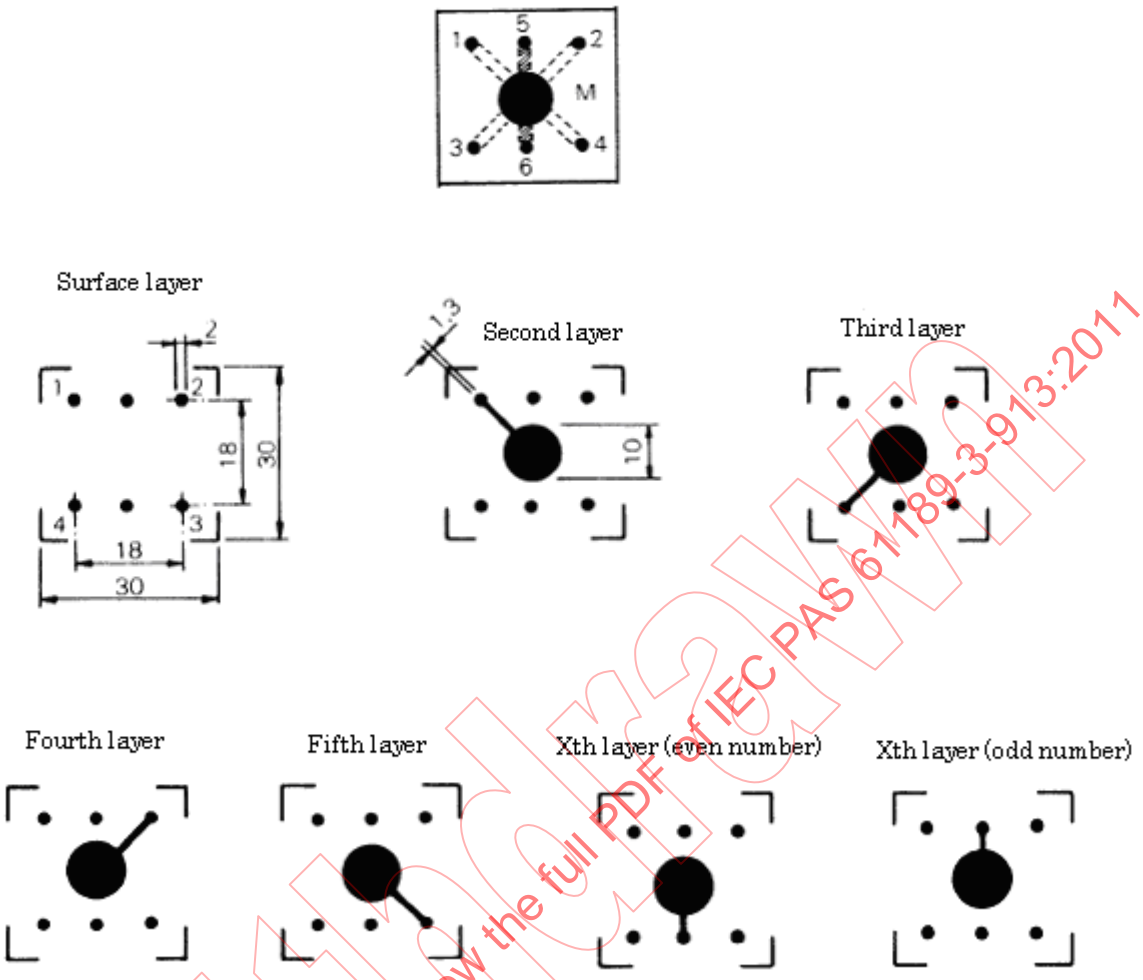


Figure A.4c – Insulation resistance between inner layers (normal, resistance to humidity-temperature/humidity cycle and steady state)

Figure A.4 – Insulation resistance

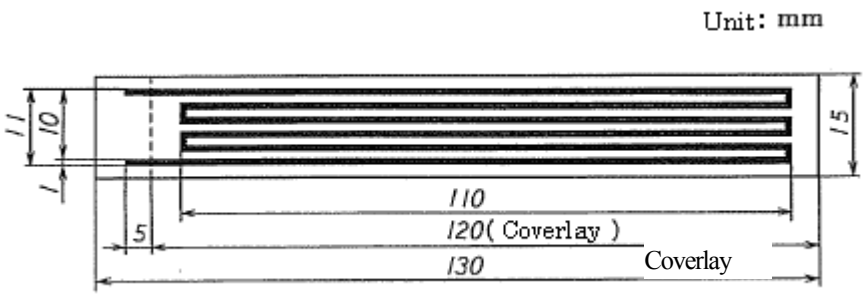


Figure A.5 – Specimen for resistance to bending test