The Institute for Interconnecting and Packaging Electronic Circuits
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IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.3.1	
Subject	
Flexural Fatigue and Ductility, Flexible Printed Wiring	
Date	Revision
3/91	**C**
Originating Task Group	
N/A	

1.0 Scope With this test method the flexural fatigue life for any given bend radius, the flexural fatigue behavior and the ductility of the conductor metal in percent deformation after tensile failure can be determined.

Note: The indirect determination of conductor ductility by using a fatigue test is made necessary by the geometry and dimensions of foil samples which make tensile elongation and rupture tests inadequate for ductility determination.

2.0 Applicable Documents

IPC-TM-650 Method 2.1.1, Microsectioning

IPC-TM-650 Method 2.4.18, Tensil Strength and Elongation, Copper Foil

IPC-D-330 IPC Design Guide

3.0 Test Specimen

3.1 The test coupon shown in Figure 1 is the recommended standard test specimen pattern for either single- or double-sided flexible printed wiring.

3.2 The conductor width of the standard test pattern (Figure 1) can be changed to determine line width effects.

Note: Narrow conductor width will result in reduced flex lives due to an increased flaw size/conductor width ratio. Wide conductors result in increased flex lives due to longer crack propagation times and the possibility of strain relief due to cracks propagating in close proximity from opposite conductor edges.

3.3 Actual flexible printed wiring product, whole or sections thereof, can be used if the circuit geometry is such that the long dimension is at least 63.2 mm [2.5 inches], the wide dimension no more than 38.1 mm [1.5 inches], and the conductors in the long direction can be electrically connected in series to give a pattern similar to the standard test pattern (see Figure 1).

4.0 Apparatus

4.1 Ductility Flex Tester, Universal Mfg., Model FDF or 2FDF or equivalent (see 6.4 and Figure 2).

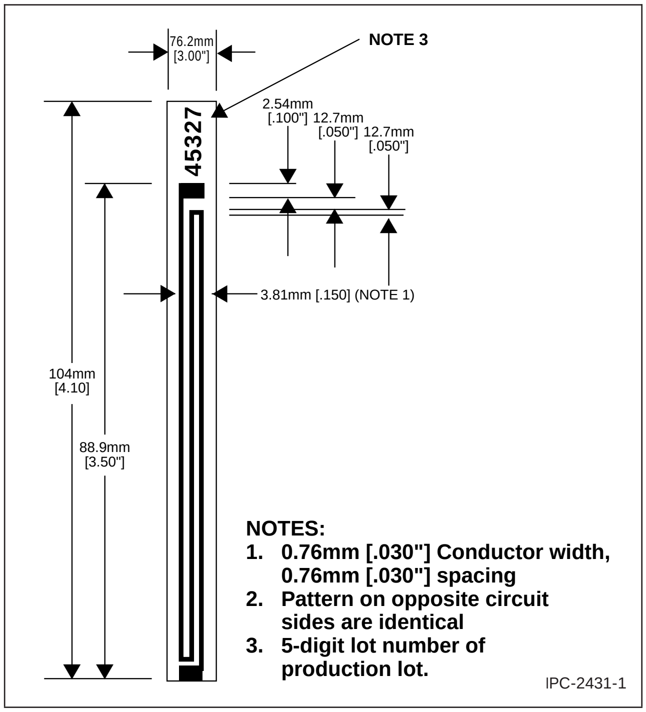

Figure 1 Test coupon configuration (recommended)

4.2 Sample cutter, punch or tensile cut router. Note 6.3.2.

4.3 Micrometer tool capable of measuring 0.0025 mm [0.0001 inch].

4.4 Hewlett-Packard, HP-67, Programmable Calculator or equivalent.

4.5 Sample holders, 203.2 x 12.7 mm [8 x 1/2 inch] of very flexible material, e.g., epoxy-impregnated glass cloth, paper, etc.

4.6 Microscope

5.0 Procedure

5.1 Preparation of Samples

5.1.1 Use the sample cutter to cut the 3.2 mm [1/8 inch] wide test specimen. Examine each specimen for nicks, cuts, or curled edges. Discard any specimen with defects.

5.1.2 Use the micrometer to determine the specimen thickness, t, at the test region of the specimens to the nearest 0.0025 mm [0.0001 inch]. In the case of single-sided or cover-coated specimens, core thickness, t_M, has to be determined also (see Figure 2).

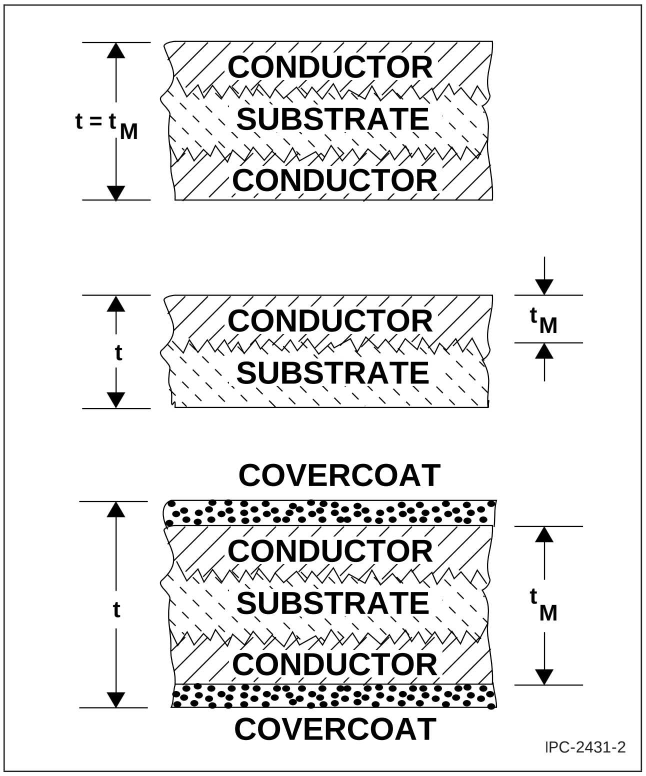

Figure 2 Minimum core thickness

Note: Thickness is a critical parameter in the determination of fatigue ductility. A 10% error in t_M results in a 14% error in D_f.

Note: For asymmetric configuration (2nd configuration in Figure 2) the core thickness, t_M, is preferably determined as a fraction of the specimen thickness, t, from a microsection prepared per IPC-TM-650, Method 2.1.1, and measured with a metallurgical microscope at 200X minimum with a suitable filar eyepiece or reticle. The measurement is to be made from the valley of the rough surface to the smooth surface or valley to valley where both surfaces are rough. The t_M is to be made once on a batch or lot basis, and this fractional value of t_M/t is then multiplied by all other micrometer, t, values to achieve core values for all samples. This applies only to the second and third configuration in Figure 2, where t_M cannot be determined by a micrometer.

5.1.3 For standard test coupons, connect the meander patterns on opposite circuit sides in series and attach thin relay leads to the free ends of the meander patterns. For nonstandard test specimens, connect all conductors to be tested and monitored in series and attach thin relay leads to the two free ends.

5.1.4 Attach test specimen to the ends of 2 sample holders with adhesive tape and clamp 224 grams [8 ounces] circuit weight to free ends of sample holders to form a loop (see Figure 3).

Figure 3 Fatigue ductility flex tester

Note: For flexural fatigue tests lasting in excess of 1000 cycles, the adhesive tape attachment needs to be substantial enough to prevent relative sliding of specimen and sample holder as a result of the cyclic flexure movements.

5.2 Test Procedure

5.2.1 Mount mandrels to flex tester, adjust the support roller positions for a clearance of 1.27 mm [0.05 inches] (shim provided) between rollers and mandrels.

Note: For the ductility test, it is important that the specimens fail between 30 and 500 cycles. Suggested mandrel diameters are 19.05 mm [0.750 inch] for double-sided circuitry and 6.35 mm [0.250 inch] for single-sided circuitry, but for some samples, mandrel diameters different from these diameters may be necessary. Larger mandrel diameters result in longer cyclic life and smaller diameters in shorter life.

5.2.2 Mount test specimen between mandrels, plug relay leads into relay jacks, set counter to zero, and start flex tester.

5.2.3 Electrical discontinuity constitutes failure and the flex tester stops automatically.

5.2.4 Record cycles-to-failure indicated on counter.

5.3 Evaluation

5.3.1 Ductility Test

5.3.1.1 Calculate the ductility for each specimen by iteratively solving the formula below:

$$N_f^{-0.6} D_f^{0.75} + 0.9\,\frac{S_u}{E}\left[\frac{\exp(D_f)}{0.36}\right]^{(0.1785 \log \frac{10^5}{N_f})} - \frac{2t_M}{2_{\rho}+t} = 0$$

where:

D_f = fatigue ductility, inch/inch (x100,%)

N_f = cycles-to-failure

S_u = ultimate tensile strength, psi

E = modulus of elasticity, psi

t_M = core thickness, inch

t = specimen micrometer thickness, inch

ρ = mandrel radius of curvature, within 0.005 mm [0.0002 inch]

Note: This formula is exact only for symmetric cross sections. In the case of nonsymmetrical single-sided laminate, the uncertainty of the location of the neutral axis introduces some error. The error in D, is kept below 20% if

$$\left[\frac{t}{t_M} - 1\right]^2 \frac{E_{substrate}}{E} \leq 0.1$$

IPC Design Guide, IPC-D-330, Section 6, ''Flexibility Considerations in Design of Flexible Printed Wiring,'' gives more detailed information for the accurate determination of the location of the neutral axis and the cyclic strains.

Note: Determine S_u as per IPC-TM-650, Method 2.4.18. Determine E during the test for S_u by unloading and reloading after about 2% elongation and measuring the slope of the reloading curve.

Note: The calculator program described in paragraph 6.2 solves the ductility formula and conveniently prompts for all necessary input parameters.

5.3.1.2 Report the average product ductility from at least three specimens.

5.3.2 Fatigue Test The number of cycles-to-failure, is the flexural fatigue life in fully reversed bending for the bend radius corresponding to the radius (1/2 diameter) of the test mandrel used. An average flexural life from at least three specimens should be reported.

5.3.3 Fatigue Behavior The fatigue behavior of a sample can be obtained by determining the flexural fatigue life with a number of different diameter mandrels. Plotting the results in a strain range versus fatigue life Manson-Coffin plot log $\Delta\varepsilon$ = $[2t_M/(2t\rho + t)]$ versus log N_f) allows intra- and extrapolation to other bend radii or fatigue lives.

5.3.4 The flexural fatigue life at bend radii other than the mandrel radius can also be obtained by evaluating the ductility formula for the flex life in cycles-to-failure using the product ductility determined in 5.3.1.2 and the desired bend radius.

6.0 ***Notes*** For further technical details, reference the material shown below.

6.1 Document in paragraph 2.0.

6.2 Engelmaier, W., ''Fatigue Ductility for Foils and Flexible Printed Wiring.'' Program No. 1883D HP-67/97 User's Library, Hewlett Packard Co., Corvallis, Oregon, 1978.

6.3 Engelmaier, W., ''Fatigue Ductility Flex Tester,'' Drawing L520163, Bell Telephone Laboratories, Inc., Whippany, New Jersey, 1978.

6.4 Test Equipment Sources The equipment sources described below represent those currently known to the industry. Users of this test method are urged to submit additional source names as they become available, so that this list can be kept as current as possible.

6.4.1 Fatigue Ductility Flex Tester, Universal Mfg. Co., Inc., 1168 Grove St., Irvington, NJ 07111; 201-374-9800.

6.4.2 JDC Precision Sample Cutter Model JDC 125-N or equal.