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IPC-TM-650
TEST METHODS MANUAL

Number **2.4.41.2**	
Subject **Coefficient of Thermal Expansion—Strain Gage Method**	
Date **8/97**	Revision
Originating Task Group **Rigid Board T.M. Task Group, 7-11d**	

1.0 Scope To describe the strain gage method for determining linear thermal expansion of laminated materials within the temperature range of –55 to +130°C and inorganic substrates (non-laminated) with a range of –55 to +150°C.

1.1 Care should be taken if the higher temperatures are used. The adhesive shown is rated by the manufacturer from less than –200 to greater than +300°C; however, for higher temperature pretesting with the Titanium Silicate Standard or materials of known thermal expansion characteristics is recommended.

2.0 Applicable Documents None

3.0 Test Specimens

3.1 Specimens are normally flat pieces of laminate or printed wiring boards/assemblies that are to be tested non-destructively. Dimensions are to be 50 mm x 50 mm [2.0 in X 2.0 in] minimum by 1.5 mm [0.060 in] minimum thick.

Plated-through holes in the specimen are not desirable, but can be tolerated to a certain extent. If possible, the strain gages are to be located as far from the PTHs as possible and centered with regard to surrounding PTHs. Mounting strain gages over PTHs will result in measurements that may not be representative of the sample material.

For each material or lot tested, a minimum of three determinations shall be made in each of the x and y directions.

4.0 Apparatus

- Silicon carbide paper, 220, 320 and 400 grit
- Cotton tipped applicator
- Tweezers, stainless steel, Style 3C
- Scissors, stainless steel. 2 to 4 inch blades
- Tape, Mylar, transparent, 1/2 inch wide
- Tape, Mylar, transparent 1 inch
- Tape, PFTE, 1 inch wide, no adhesive
- Binder clips, No. 100, large
- Binder clips, No. 20, small
- Silicone gum pad (2.5 mm thick) with metal backup plate
- Test plate constructed of 1.25 mm [0.050 in] thick Alloy 42 plated with 0.025 mm [0.001 in] of copper
- M-Prep Conditioner A or equivalent
- M-Bond 610 Adhesive or equivalent (M-Bond 600 for lower cure temperatures, if applicable)
- M-Prep Neutralizer 5 or equivalent
- M-Coat B, Nitrile rubber coating
- Cleaning solvent, Isopropan OL or equivalent
- Strain gages, Type WK-06-250BG, Measurements Group Inc. (Other strain gages may be selected for customizing for a specific material or temperature range)
- Alloy 42 Holding Fixture (∝30-400°C) = 4.5-5.0 ppm/°C
- Solder terminals, Type CEG-63S, Measurements Group Inc. (Terminal may be integral when using WK series strain gage with option W.)
- Select a solder that will maintain a connection at test temperature;
  Solder Sn-63/Pb-37 Liquidus = 183°C
  Solder Sn-96.5/Ag-3.5 Liquidus = 221°C
  Solder Pb-97.5/Ag-1.5/Sn-1 Liquidus = 309°C
- Solder Flux, Type RMA or equivalent
- Soldering Iron, 15 to 25 watt
- M-line Rosin Solvent, Measurements Group Inc.
- Oven for Curing M-Bond Adhesive with heat rise of 3 to 11°C/min.
- Gauze Sponge
- Thermal cycling chamber for thermal cycling with a heat rise capability of 2 to 30°C/min, and equipped with a programmable temperature control system
- Thermocouple Type J (Type may be used where applicable)
- Titanium Silicate Standard
  Corning Glass Works Code 7971ULE, or
  Measurements Group Inc. #TSB-1
- Wheatstone Bridge

*See 6.1 for source of materials.

5.0 Strain Gage Mounting Procedure The procedure for mounting the strain gages to the PWB material and titanium silicate or other standards as appropriate, includes the preparation of the adhesive and specimen bonding surfaces, application of the adhesive, attachment of the strain gages, and the assembly of the Alloy 42 holding fixture. (The Alloy 42 fixture may not be required, depending on specimen type and application.)

5.1 Adhesive Preparation The strain gages are to be mounted using adhesive M-Bond 610 or equivalent. The M-bond 610 is a two-component system that is mixed as follows:

5.1.1 The resin and curing agent bottle are to be at room temperature before opening.

5.1.2 Using the disposable plastic funnel, empty contents of bottle labeled 'Curing Agent' into the bottle of resin labeled 'Adhesive' (discard funnel).

5.1.3 After tightening the brush cap (included separately), thoroughly mix contents of the 'Adhesive' bottle by shaking for 10 seconds.

5.1.4 Identify the 'Adhesive' bottle by writing the date on the label. Allow the freshly mixed adhesive to stand for a minimum of one hour before using.

5.2 Sample Preparation Two strain gages are applied to one side of the PWB board test specimen at right angles to one another and to the titanium silicate reference standard using the following procedure:

5.2.1 Mark reference lines perpendicular to each other on the test specimen and the titanium silicate standard. For most printed board material this is easily accomplished by making a burnish mark with the wooden end of a cotton-tipped swab applicator.

5.2.2 Thoroughly degrease the gaging areas with cleaning solution.

5.2.3 Dry abrade the area to be bonded with 220 or 320 grit silicon carbide paper, and follow with a final with a final abrading with 320 or 400 grit paper on the areas thoroughly wetted with M-prep Conditioner A. Scrub the gaging areas with repeated applications of Conditioner A using a cotton tipped swab and until a clean cotton swab or lint free pad is no longer discolored. Remove all residues and Conditioner A by wiping thoroughly with a gauze sponge. Do not allow to dry while cleaning before use of the sponge to prevent the contaminating films.

5.2.4 Apply a liberal amount of M-Prep Neutralizer 5 and scrub with a cotton-tipped applicator or lint free pad. Using a single slow wiping motion with gauze sponge, carefully dry the surface. Do not wipe with a back and forth motion as this may allow contaminants to be redeposited.

5.3 Strain Gage Installation Apply the strain gages to the previously cleaned areas of the PWB specimen and the titanium silicate standard using the following procedure:

5.3.1 Remove the gage from the acetate envelope with tweezers; do not bend the gages. Place the gage bond side down onto the cleaned area of the specimen. If a solder terminal is to be incorporated, position it next to the gage. Place a short length of Mylar tape over about half of the gage tabs and entirely over the terminals.

5.3.2 Peel back one end of the taped assembly (by lifting at a small angle) so as to raise both gage and terminal. By curling the Mylar tape back upon itself, it will remain in position to be accurately relaid following the application of the adhesive.

5.3.3 Apply the M-Bond 610 adhesive with a cap brush over the gage surface to form a thin uniform coating. Repeat the application technique to the specimen gage area. Do not allow adhesive to come in contact with the tape adhesive.

5.3.4 Air dry the assemblies for 30 to 40 minutes at 24 ± 2°C [75 ± 4°F] and 40 to 55% relative humidity.

5.3.5 Place the gage/terminal assemblies in their original position over the reference lines, using only enough pressure to allow the assemblies to be tacked down. Overlay the gage/terminal area with thin pieces of PTFE tape, and anchor them in position with pieces of Mylar tape across the ends.

5.3.6 Cut the silicone gum pads to size slightly larger than the gage/terminal areas, carefully centering them in position. Larger pads may restrict proper spreading of the adhesive and entrap residual solvents during the curing process.

5.3.7 Use spring clamps or dead weights to apply pressure (275 to 350 kN/m^2 [40 to 50 psi]) and place in the curing oven which is to be at room temperature.

5.3.8 Raise the temperature to 100 ± 3°C [212 ± 6°F] (use 79°C if using M-Bond 600) at a rate of 3 to 11°C/min, and cure for 4 1/2 to 5 hours. Air bubble entrapped in the adhesive, uneven glue lines, and high adhesive stresses often result from starting with a hot oven.

5.3.9 Remove the specimens after allowing the oven to cool below 55°C, remove clamps and Mylar tape, and clean the entire surface with isopropyl alcohol to remove residual tape adhesive. Wipe dry with a gauze sponge.

5.3.10 Post cure for 2 to 2 1/2 hours at 40°C [72°F] (30°C if using M-Bond 600) above the test upper limit temperature. Care must be taken, if base materials having low T_g values (FR-4) are to be tested.

5.3.11 Bond the solder tabs 6.4 mm [0.25 in] from the strain gages. The gage leads are to looped slightly prior to soldering to prevent inducement of strain resistance changes. Solder tabs may be attached in the same step as the strain gages.

5.4 Specimen Fixture Preparation (If required, Fig. 1)

5.4.1 The PWB and titanium silicate standards, once assembled with the strain gages, are fixtured to prevent bending or warping by the straps labeled PL in Figure 1 during the temperature cycle test. The fixture used for the specimens will not interfere with the thermal expansion of the specimens being tested.

The fixture is constructed of 1.25 mm [0.050 in] thick Alloy 42 plated with 0.025 mm [0.001 in] of copper. This material was chosen because of its thermal expansion properties that are close to that of the test specimens. Plated Alloy 42 straps are used to gently hold the specimen flat to the fixture. Other materials that may closely match the CTE of the test specimen may be used.

5.5 Test Configuration Connect two strain gages, one to the test specimen and one to the to the titanium silicate standard, in adjacent arms forming a half bridge; the remaining half of the Wheatstone bridge being completed with the Wheatstone bridge instrument (see Figure 2). Repeat for the remaining two strain gages, one on the test specimen and one on the titanium silicate standard with a second Wheatstone bridge instrument in the circuit.

Attach (tape) thermocouple to the sample within a 6.0 mm [0.25 in] of the measurement area.

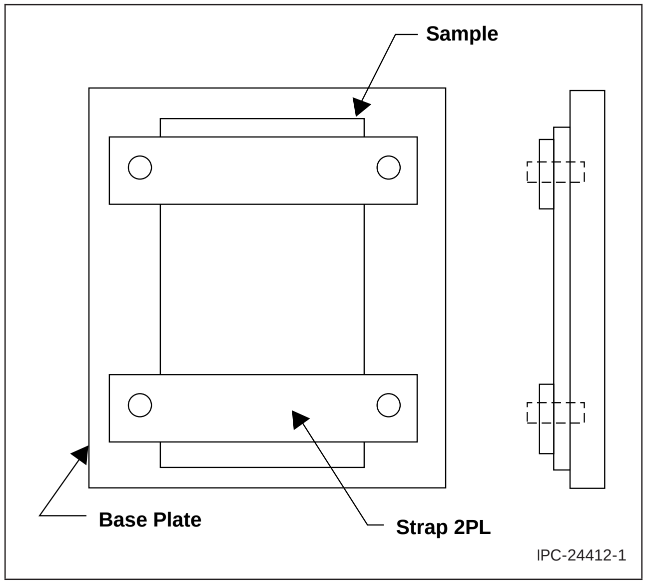

Figure 1 Test Fixture Configuration

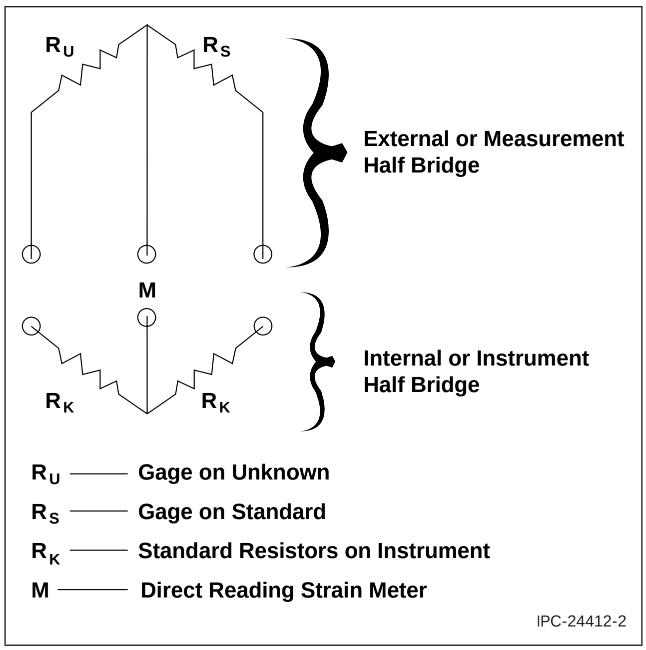

Figure 2 Wheatstone Bridge instrumentation hookup

5.6 Specimen Conditioning/Thermal Cycling Clean the specimens by immersing in M-Line solvent with agitation for 15-20 seconds. Allow to dry for 1 to 1 1/2 hours at 40 ± 5°C [105 ± 9°F].

5.6.1 Place the specimens and the reference standards in the thermal cycling chamber (with programmable temperature control) set at 20°C [68°F] and allow to stabilize for 30 to 40 minutes or as required to relieve strain gage attachment stresses.

5.6.2 Increase temperature at a rate of 2°C/min up to 130°C or other test temperature designated, allowing the specimens to stabilize for 10 minutes or longer, if required. Decrease the temperature to –55°C [–67°F] or other temperature designated and allow to stabilize for 10 minutes or until no further changes are noted on the meter. Increase the temperatures to 25°C [77°F] at the same rate and allow the specimens to stabilize.

5.6.3 Throughout the thermal cycle, the temperature and change in resistance as noted on the meter(strain) should be recorded at the desired time and temperature (two minute intervals).

5.7 Calculation of CTE Plot the gage resistance versus the temperature. Measure the slope of the line between the temperatures of interest and record.

The equation for calculating the Coefficient of Thermal Expansion, $\propto$, are:

$$\propto \; = \; \Delta R/R(GF)\Delta T$$

Where $\propto$ = the coefficient of thermal expansion R = gage resistance reading

ΔR = the change in resistance reading
ΔT = the change in temperature
GF = the Gage Factor of a particular gage and gage configuration and is furnished by the strain gagemanufacturer. The GF for the WK gage is near 2.1

Example:

Resistance reading at 20°C = 352.39
Resistance reading at 170°C = 353.40
GF as furnished by manufacturer = 2.11

$$\propto \; = \; \frac{(353.40 - 352.39)}{(353.40 \;\mathrm{X}\; 2.11 \;\mathrm{X}\; 150)} \; = \; 9.03\ \mathrm{ppm/°C}$$

Note: The graph plot of $\Delta R/\Delta T$ will allow selection of any temperature point.

All strain and temperature data should be recorded on a disk. Software packages are available that the raw data (resistance changes and temperature) to strain and temperature. The software compensates for gage factor with temperature, apparent strain of the gage, and the bridge configuration in reducing the data. The software also uses the data from the titanium silicate standard to adjust the reduced data of the test specimen.

6.0 *Notes*

6.1 Suggested Sources of Materials

6.1.1 Source of Adhesive System
Micro-Measurements Division
Measurements Group Inc.
P. O. Box 27777
Raleigh, NC 27611
Phone: (919) 365-3800

6.1.2 Information Bulletin
Micro-Measurements Division
Measurement Group Inc.
P.O. Box 27777
Raleigh, NC 27611
Phone (919) 365-3800
Bulletin # B130-10

6.1.3 Titanium Silicate Standard
Corning Glass works
Corning, NY 14831
Micro-Measurements Division
Measurement Group Inc.
P.O. Box 27777
Raleigh, NC 27611
Phone (919) 365-3800