Introduction

This manual establishes uniform methods for testing electronic and electrical parts including basic environmental, physical and electrical tests. These tests were developed to support IPC standards and specifications.

The tests described herein are not to be interpreted as an exact and conclusive representation of actual service operation in any one geographic location, since it is known that the only true test for operation in a specific location is an actual service test at that point. The specified test conditions for a test method are those, which are obtainable in the laboratory and result in reproducible results.

No attempt has been made to include pass/fail criteria in the test methods. This information is found in the individual specifications and standards that reference the specific test method.
All equipment used for performing or supporting the tests shall be calibrated before being put into service. The test facility shall have an established program and procedure for the regular calibration of its equipment.

A calibration program should include a system for selecting, using, calibrating, checking, controlling and maintaining measurement standards, reference materials used as measurement standards and measuring and test equipment used to perform tests described in this manual.
Three main elements must be considered in planning how to obtain test data at room ambient conditions. These are:

1. The set-up for supporting and operating the test equipment.
2. The instrumentation for measuring the data from the tests.
3. The instrumentation for measuring and recording room conditions at the time of the test.

This last factor is important when comparing test data obtained at different times or facilities. In most cases, this step consists of simply recording the barometric pressure, relative humidity and temperature at the time of the test. If other conditions are found to have a significant impact on the test data, these conditions should be recorded as well.

Unless otherwise specified in the applicable test method, individual standard or specification, all laboratory ambient tests shall be made under the following conditions:

1. Temperature: 15 °C to 35 °C [59 °F to 95 °F]
2. Relative Humidity: 35 % to 75 %

Whenever these conditions must be closely controlled to obtain reproducible results or for referee purposes, tests shall be conducted under the following conditions:

1. Temperature: 22 °C ± 3 °C [72 °F ± 5 °F]
2. Relative Humidity: 50 % ± 10 %
The recognition of the effect of the test procedure on the test results must be carried into the examination of the data obtained from the test. The meaning of the data must be analyzed against the background of the procedure for obtaining it. In addition, some general considerations apply in examining the data.

The extent to which usable data can be selected from the test results is influenced by how well the log of the test has been kept. The original data sheet should be marked at all questionable data points. If the reason for questioning a data point can be determined, it should be noted in the test log. Causes for questioning a data point can include changing the operator or observer, exceeding the range on an indicator, replacing test leads that shook loose, or any other incident constituting a deviation from the planned test procedure.

Of equal importance to the test results and much more difficult to detect are questionable data points unaccompanied by a notation in the test log. Additionally, it is often useful to perform all calculations soon after conducting the test. When results are suspect, it is almost always easier to perform a root cause analysis during or immediately after the test. The problem is to distinguish between a divergent point caused by the specimen being tested and one caused by improper use of the test method. Only by an intensive re-examination of the test set up can this problem be answered. Some of the potential causes of divergence are:

- Instruments subjected to an environment for which they are not calibrated
- Thermocouple opening
- Instruments operated without sufficient warm up
- Incorrect sequencing of the test circuit
- Hook ups to the wrong circuit
- Operator error
A concise and detailed test report is essential to convey the necessary elements of the test. The most important consideration in writing the test report is a realization of the minimum requirements of content, regardless of what form is required. It must be borne in mind that the purpose of the test report is to tell someone the following facts:

a. what was tested
b. what information was sought about this item under test
c. what means and procedures were used to obtain the information
d. what data was obtained
e. what conclusions were reached from the information obtained

The intended distribution of the report may be a factor in the determination of not only the extent but also the manner of presentation. For reports intended only for internal use, a description of the facilities, instruments, or calibration procedures used may be made by reference to laboratory equipment identification numbers or to procedure numbers. On the other hand, for reports intended for wide external distribution, complete descriptions are necessary so the test can be duplicated, if desired.

The following paragraphs contain a description of the elements which, depending on the intended audience and type of testing requested, may be necessary in a test report:

**Subject**
The subject of the report is a statement of what the report is about. Example: High Temperature Tests of Flexible Cables.

**Results**
This section of the report includes the results of the testing, the analysis of the results (including any explanations of discrepancies or errors) and the logical development of the conclusions.

It is of primary importance that a reader can look only at the Results section of a report and be able to see what was found and what was concluded.

**Reference**
This section should list the applicable test method and/or specification.

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**Test Specimen**
The test specimen is thoroughly identified in the report name, part number, manufacturer and/or vendor. Operational characteristics and function or design features are briefly explained. Any remarks as to material, special dimensions etc., that may be pertinent to the test or test results are included.

**Test Equipment**
The facility used for imposing the environment, including controls and location of instrumentation, is described in this section of the report. The manufacturer’s name, model and serial number are stated, as well as any modifications incorporated in the facility.

Every measuring instrument employed in the test is identified in the report and its expected or determined (from calibration) accuracy and limits of operation are stated. The date of last calibration and the next calibration due date are listed. Specific characteristics, which are pertinent to the test are indicated.

**Test Setup**
The combination of test specimen, test facility and instrumentation must be thoroughly described in this section of the report. Sketches or drawing of the mounting, loading or actuating fixtures are included and discussed in the description.

Careful consideration must be given to photographs of the test setup in order that maximum detail can be shown. Schematic drawings and sketches showing critical dimensions and locations of instruments may be used to supplement photographs, since scaling of distances as obtained from photographs may not be accurate.

**Test Procedure**
The step-by-step procedure of obtaining the data from the employment of the setup and instrumentation in testing is described sequentially and in detail in this section. The test log used in performing the test, including such modifications as were necessitated during the test, provides the information for writing the procedure.
The following guidelines should be used for numerical reporting:

1. Follow the IPC policy for the use of metric and English units.

In an effort to prepare the industry for a full change to complete metric measurements in IPC standards and specifications, the Technical Activities Executive Committee (TAEC) voted on a new way for both to be included. Through this new metric conversion policy, IPC documents will have hard metric numbers and parenthetical soft imperial numbers with appropriate units.

The hard metric numbers will represent accuracy of the numerical values as decided by the working committee/task group according to their respective contexts.

For example:
The working committee/task group will decide whether a hard metric number should be represented as:

- 1.3 mm (any value within the range of 1.25 mm to 1.34 mm is acceptable), or
- 1.30 mm (any value within the range of 1.295 mm to 1.304 mm is acceptable).

The soft imperial numbers will have one significant digit more than the metric numbers to capture the accuracy represented by the metric numbers.

For example:

- 3 m (one significant digit) converts to 118.1102 in, which will be documented as 3 m [120 in] (two significant digits because the zeros are placeholders used to locate the decimal point).
- 66 µm (two significant digits) converts to 0.002598425 in, which will be documented as 66 µm [2.60 mil] (three significant digits because the non-truncated zero is not a placeholder).
- 725 µm (three significant digits) converts to 0.02854331 in, which will be documented as 725 µm [28.54 mil] or [0.02854 in] (appropriate units are determined by the context of numerical values and both have four significant digits).
- 3.8 \( \times 10^{-6} \) m converts to 1.496063 \( \times 10^{-4} \) in, which will be documented as 3.8 \( \times 10^{-6} \) m [1.50 \( \times 10^{-4} \) in] (if scientific numerical format is appropriate).

2. Spell out numbers one through ten, except in use with measurement and time.
3. Spell out any numbers at the beginning of a sentence.
4. When reporting numbers less than a whole number, place a zero to the left of the decimal point.
5. Report average results to the same amount of significant figures as the numbers being averaged.
6. When readings reach maximum of test equipment or maximum of practical values, precede the number with “greater than” or “>” and explain the reason for not going to the limit.
7. Always report results in the same unit of measurement as that of the requirement.
8. In reporting ranges use the preposition “to,” not a hyphen as: 3 cm to 9 cm.
10. Mark a failed result in such a way as it will stand out to the reader. Later state what this marking signifies.
11. When tabulating, use clearly defined headings.
12. Clarify when more than one set of numbers is in a tabulation of statement.
In interpreting test results, it is essential that all values are known to be valid. Usually the values are placed in one of the three following categories and evaluated to ultimately arrive at a sound decision:

a. Results are declared valid. A decision can be made immediately.

b. Results obviously must be discarded. Specimens that break or otherwise fail because of some obvious flaw, or that do not behave in the same general manner as the other specimens, should be discarded. Retests should be performed on new specimens.

c. Results deviate from the mean value. All test data obtained from properly performed tests must be included in determining mean and standard deviation unless there is an assignable cause not to do so.

The above information is to be used if not found in an individual test method.
1 Scope  Tests performed on presumably identical samples under seemingly identical conditions do not always yield identical results. This is due to errors inherent in every measurement or evaluation. During the development of a new test procedure or use of an existing test procedure, this variability must be understood and precautions taken to ensure that it is controlled to within necessary limits. Performance of this test method will help to estimate measurement error and troubleshoot causes of measurement variability. Use of this test method will provide some evidence that a new test procedure is suitable for use when submitted for review, or an existing test procedure is capable of measuring the applicable parameter.

This method provides a standard procedure for determining the precision of a test method involving binary data or tests that result in two outcomes. These include evaluations where the results are recorded as pass/fail or go/no-go. Examples include solderability tests and visual inspections. This method helps to estimate how often the disposition is performed correctly.

This method is not useful for measurements which result in variables data, or where more than three repeated measurements or more than ten testers are used. These situations are covered under other methods (see 6.1).

1.1 Definitions

**Accuracy** – The difference between an observed measurement and the true (but perhaps unknown) value being measured.

**Precision** – The closeness to each other of repeated measurements of the same quantity.

**Binary Data** – Inspections or tests in which parts are placed in one of two classes. This includes pass/fail, go/no-go tests and inspections.

3 Applicable Documents  The test procedure under evaluation.

3 Test Specimens  The test specimens used will be as specified in the test procedure under investigation.

The number and types of test materials to be used will depend on the range of levels in the class of materials to be tested. If it is known that precision is worse at one end of the range, evaluation could be limited to that end of the range. In general, evaluations are generally advisable for all combinations of materials, levels, set-ups, and conditions. If resources are limited, begin the study with those combinations deemed to be the most critical, or where measurement error is likely to be greatest.

The number of samples will also depend on the difficulty involved in obtaining, processing, and distributing the test specimens, the difficulty, length of time required for, and expense of performing the test, and other prior known information.

This test method will assume that evaluations can be repeated on the same samples. For situations where this is not possible or the sample is consumed during the test, other methods may be better suited (see 6.1).

4 Apparatus  The apparatus used will be as specified by the test procedure under investigation.

5 Procedure

5.1 Planning Evaluation  Keep the evaluation as simple as possible to obtain data that is free of unintended secondary effects.

Prepare a procedure that is complete and describes the test parameters as well as recommended techniques for assessing the outcome. Include known best practices and draw extensively on the experience of test users.

The method used in this procedure allows for up to 10 test conditions. Solicit participants from among the community of facilities with the proper equipment, competent operators and familiarity with the test. In order to obtain representative precision estimates, do not select only from a small group of users who are considered exceptionally qualified. Be sure to specify any special calibration procedures or material preparation requirements.

The analysis method used in this procedure allows for up to 10 repeated evaluations per sample. Carefully evaluate the materials to determine the appropriate classification or disposition before the study. Choose material representing a likely range of conditions normally encountered during routine tests or inspections. Randomize the samples prior to dividing into
test groups. Prepare more than the material required to ensure an adequate amount is available for the study in case of lost or damaged specimens, errors, test set-up, etc.

Carefully package and label the material. Assign serial numbers, if possible. Identify the version of the test procedure. Specify care and handling procedures. Provide a data sheet, and describe any documentation required. Require a test log, and insist that observations of any unusual events be recorded.

5.2 Conducting the Evaluation Ensure the samples are inspected on receipt. Send replacement material if damaged or tests are performed improperly.

Inspect the data sheets when returned. Review the test logs for unusual events. Review the results. Question unusual dispositions or comments. Incorrect dispositions and typos must be fixed prior to analysis.

5.3 Analyzing the Data Analysis may be performed on the data sheet or on the Excel spreadsheet (see 6.2).

The basic techniques involve beginning with a set of parts or materials for which the classification has been previously determined. Several inspectors or testers then examine and classify the parts and the results are compared with the known standard classification.

The effectiveness of the test is the number of correct determinations divided by the total number of classification opportunities (number of parts times the number of inspectors).

\[
E = \frac{\text{Number of correct dispositions}}{\text{Number of parts} \times \text{Number of testers}} \quad (1)
\]

The probability of a false reject and the probability of a false accept can be defined as follows:

\[
P(\text{FR}) = \frac{\text{Number of dispositions where good parts were rejected}}{\text{Number of good parts} \times \text{Number of testers}} \quad (2)
\]

\[
P(\text{FA}) = \frac{\text{Number of dispositions where bad parts were accepted}}{\text{Number of bad parts} \times \text{Number of testers}} \quad (3)
\]

5.4 Preparing Analysis Conclusions Goals for measurement precision should be established before the study begins. The goals should be established using knowledge of the anticipated levels of product variability (or process capability), specifications, customer needs and the possible impact of dispositioning test samples improperly. As a rule of thumb, the guidelines shown in Table 1 have been extensively applied.

If the test effectiveness is inadequate, then steps should be taken to diagnose and improve the causes of the deficiency. The probabilities of false acceptance and false rejection should help in this diagnosis. Marginal tests should also be improved.

An acceptable test effectiveness rating (E) indicates that the test method dispositions the products with reasonable correctness.

The results of this evaluation should be compared to the test efficiency goals for this inspection. The rules of thumb noted above have been found to be useful. These goals could be amended, depending on the criticality of the inspection, and the impact of incorrect disposition.

6 Notes

6.1 Methods for Analyzing Repeatability and Reproducibility This test method covers situations where the measurements result in binary data, such as go and no-go, or pass and fail tests. The precision of the test is determined by calculating the consistency and correctness of the sample dispositions.

Measurements that result in variables data can be analyzed using IPC Test Method IPC-TM-1.9.

In some cases, the measurement cannot be repeated more than once on the same sample. This is common where the sample is consumed during the test, such as chemical analysis, or changed during testing, such as solderability evaluations. In these cases, the analysis using a modified average and range method is possible. This method is under development.

6.2 References

a. ISO 5725-1 Accuracy (trueness and precision) of measurement methods and results (parts 1 to 6), 1998(E), International Organization for Standardization, Geneva, Switzerland (www.iso.org).

### 6.3 Software

Measurement precision studies are greatly facilitated by use of software to perform the calculations. Below are just a few of the many software packages which can be used for this purpose. Reference (a) is an Excel spreadsheet written to perform the calculations in this procedure.

- **c. SPC XL**, Air Academy Press, 1155 Kelly Johnson Blvd, Colorado Springs, CO 80920 ([www.airacad.com](http://www.airacad.com)).
- **d. Minitab**, Minitab. Inc., 3081 Enterprise Dr, State College, PA 16801 ([www.minitab.com](http://www.minitab.com)).
- **e. Interlaboratory Data Analysis Software for E691**, ASTM, 100 Barr Harbor Dr, West Conshohocken, PA 19428 ([www.astm.org](http://www.astm.org)).
Measurement Precision Study – Binary Data

Table 1: Data Entry Form
Enter test results into the table below.

<table>
<thead>
<tr>
<th>Tester</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Standard</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>2</td>
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</table>

Calculations

Table 2: Samples Dispositioned Correctly
Score a “1” where disposition in Table 1 above matched the true standard.
Score a “0” where disposition did not match the true standard.
Note these scores for each of the testers in the table below.

<table>
<thead>
<tr>
<th>Tester</th>
<th>Samples</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Standard</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>1</td>
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</tbody>
</table>
Table 3: Good Parts That Were Rejected
Score a “1” where good parts were rejected in Table 1 above.
Score a “0” everywhere else.
Note the scores for each tester in the table below.

<table>
<thead>
<tr>
<th>Tester</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>True Standard</td>
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</table>

Table 4: Bad Parts That Were Accepted
Score a “1” where bad parts were accepted in Table 1 above.
Score a “0” everywhere else.

<table>
<thead>
<tr>
<th>Tester</th>
<th>1</th>
<th>2</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>10</th>
<th>Total</th>
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<tbody>
<tr>
<td>True Standard</td>
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Table 5: Measurement System Scorecard

<table>
<thead>
<tr>
<th>Results</th>
<th>Tester 1</th>
<th>Tester 2</th>
<th>Tester 3</th>
<th>Tester 4</th>
<th>Tester 5</th>
<th>Tester 6</th>
<th>Tester 7</th>
<th>Tester 8</th>
<th>Tester 9</th>
<th>Tester 10</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Disposed correctly</td>
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<td>Good and rejected</td>
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<td>Bad and accepted</td>
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<td>Total tests</td>
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<tr>
<td>Acceptable parts</td>
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<tr>
<td>Rejectable parts</td>
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</tr>
<tr>
<td># of testers</td>
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</tbody>
</table>

Total tests = Number of testers times the number of parts.
Acceptable parts = Count acceptable parts in the True Standard line of the data input table.
Rejectable parts = Count rejectable parts in the True Standard line of the data input table.
# of testers = Count the number of participants.

Table 6: Measurement System Effectiveness

<table>
<thead>
<tr>
<th>Metric</th>
<th>Calculation</th>
<th>Result</th>
<th>Acceptable</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test effectiveness (%)</td>
<td>( \frac{\text{Total parts dispositioned correctly}}{\text{Total parts tested}} \times 100 )</td>
<td>&gt;90</td>
<td>&lt;80</td>
<td></td>
</tr>
<tr>
<td>Probability of false rejects (%)</td>
<td>( \frac{\text{Total good and rejected parts}}{(\text{No. of testers}) \times (\text{Good parts})} \times 100 )</td>
<td>&lt;5</td>
<td>&gt;10</td>
<td></td>
</tr>
<tr>
<td>Probability of false acceptance (%)</td>
<td>( \frac{\text{Total bad and accepted parts}}{(\text{No. of testers}) \times (\text{Bad parts})} \times 100 )</td>
<td>&lt;2</td>
<td>&gt;5</td>
<td></td>
</tr>
</tbody>
</table>
Recommendations

If applicable and if possible, this section is used to recommend needed corrections or to indicate discrepancies in the design of the specimen, which was tested. Care should be taken to limit the recommendations to those things indicated by the test, and not go into design problems, which are the responsibility of the designer.
1 Scope  Tests performed on presumably identical samples under seemingly identical conditions do not always yield identical results. This is due in part to errors inherent in every measurement. During the development of a new test procedure or use of an existing test procedure, this variability must be understood and precautions taken to ensure that it is controlled to within necessary limits. Performance of this test method will help to estimate measurement error and troubleshoot possible causes. It can provide evidence that a new test procedure is suitable for use when submitted for review, or an existing test procedure is capable of measuring the applicable parameter.

This method provides a simple, easy to use, standard procedure for determining the precision of a test method using the average and range method. It can be used on tests that involve measurements that yield continuous data. The calculations shown in this procedure are streamlined versions; useful for situations where up to five repeated readings are taken on each of up to 10 samples by up to 10 test laboratories, operators or test conditions.

This procedure is not useful for measurements which result in binary data, such as pass-fail or go-no go results, or where more than five repeated measurements or more than ten laboratories or conditions are used. These situations are covered under other methods. (see 6.3)

1.1 Definitions

Accuracy (Bias) – The difference between an observed measurement and the true (but perhaps unknown) value being measured (see Figure 1).

Continuous Data – Numerical data that can take any conceivable value within an observed range and forms a distribution about a mean value.

Precision – The closeness to each other of repeated measurements of the same quantity.

Repeatability – Variation of a measurement system that is obtained by repeating measurements on the same sample(s) by the same procedure under the same measurement conditions (see Figure 1).

Reproducibility – Variation among the averages of measurements made under different measurement conditions such as different operators, equipment, and/or locations (see Figure 1).

Resolution – The size of the smallest increment on the measurement instrument under examination. This value is frequently used in the advertising literature to classify the instrument.

Figure 1  Measurement Repeatability and Reproducibility
2 Applicable Documents  The applicable document will be the test procedure under evaluation.

3 Test Specimens  The test specimens used will be as specified in the test procedure under investigation.

The number and types of test materials to be used will depend on the range of levels in the class of materials to be tested. If it is known that precision is worse at one end of the range, evaluations could be limited to that end of the range. In general, evaluations should be performed on all combinations of materials, levels, test set-ups, and test conditions. If resources are limited, begin the study with those combinations deemed to be the most critical, or where measurement error is likely to be greatest.

The number of samples will also depend on the difficulty involved in obtaining, processing, and distributing the test specimens, the difficulty, length of time required for, and expense of performing the test, and other prior known information.

This test method will assume that measurements can be repeated on the same sample. For situations where this is not possible or the sample is consumed during the test, see 6.3.

4 Apparatus  The apparatus used will be as specified by the test procedure under investigation.

The resolution of the measurement apparatus should be sufficient to achieve the desired accuracy of the measurement. For example, if you were to measure mass, and expect to measure it to 1 gm, the balance should be able to measure to at least 0.1 gm.

5 Procedure

5.1 Planning the Evaluation  Keep the evaluation as simple as possible to obtain estimates of within and between tester variability that are free of unintended secondary effects. A particular test condition could be different combinations of laboratories, operators, equipment, etc.

Be sure the procedure under evaluation is complete and describes the test parameters as well as recommended techniques for controlling variability. Include known best practices and draw extensively on the experience of test users.

The method used in this procedure allows for up to ten test conditions. Solicit participants from among the community of facilities with the proper test equipment, competent operators and familiarity with the test. In order to obtain representative precision estimates, do not select only from a small group of users who are considered exceptionally qualified. Be sure to specify any special calibration procedures or material preparation requirements.

The analysis method used in this procedure allows up to five repeated measurements per sample. The test samples should be carefully prepared in order to be as consistent and homogeneous as possible. Try to limit the lots of raw materials and processing facilities used. Randomize the samples prior to dividing into test groups. Prepare more than the material required to ensure adequate amount is available for the study in case of lost or damaged specimens, errors, test set-up, etc.

Carefully package and label the samples. Assign serial numbers, if possible. Identify the version of the test procedure and specify care and handling procedures. Provide a data sheet, and describe any documentation required. Require a test log, and insist that all observations of any unusual events be recorded.

5.2 Conducting the Evaluation  Ensure the samples are inspected on receipt. Send replacement units if damaged or tests are performed improperly. Follow the documented test procedure carefully to ensure no unusual variation is introduced.

Inspect the data sheets when returned. Review the test logs for unusual events. Review the measurements for level and consistency. Question unusual data points. Incorrect readings and typographical errors must be corrected prior to analysis.

5.3 Analyzing the Data  Analysis may be performed on the Measurement Precision data sheet or on other applicable software. A Measurement Precision Calculator has been prepared to perform the calculations using the equations shown below (see 6.5).

This evaluation technique is called the Average and Range Method and partitions the total measurement precision (S_tot) into two portions: the within test condition variation, called repeatability (S_r) and between test condition variation, called reproducibility (S_m). The method does this by calculating an estimate of the standard deviation of the measurement repeatability by using the range of the repeated measurements within each test condition, and by calculating an estimate of the standard deviation of the reproducibility by using the range between different test condition averages.

For normally distributed parameters, these two standard deviations are combined to estimate the total measurement precision by taking the square root of the sum of the squares.
This method is summarized by equations (1) through (3) below.

\[
S_{R\&R} = \left( S_R^2 + S_P^2 \right)^{1/2} \tag{1}
\]

where,

\[
S_R = R \times K_1 / 5.15
\]

\[
S_R = \left[ (R_x \times K_2)^2 - \left( \frac{28.1 \times S_P^2}{n \times k} \right) \right]^{1/2} / 5.15 \tag{2}
\]

and where

\[
R = \sum_{i=1}^{m} \sum_{j=1}^{n} R_{ij} / m \times n \tag{3}
\]

\[ R_{ij} = \text{Range of repeated readings for test condition } i \text{ and sample } j \]

\[ m = \text{number of test conditions} \]

\[ n = \text{number of samples} \]

\[ R_x = \text{Range of operator averages - the maximum Test condition average, minus the minimum test condition average.} \]

\[ k = \text{number of repeated readings} \]

The K factors, K_1, K_2, and K_3 are noted in Table 1 below.

### Table 1 K Factors

<table>
<thead>
<tr>
<th>K Factors</th>
<th>Readings</th>
<th>Conditions</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>3.65</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.70</td>
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<tr>
<td></td>
<td>10</td>
<td>1.62</td>
<td>10</td>
</tr>
</tbody>
</table>

5.4 Evaluating Process Capability of Measurement System

The estimated standard deviation of the total measurement precision, \( S_{R\&R} \), can be used to evaluate the capability of the measurement process. This capability assessment is performed by comparing the estimated measurement precision to the specification tolerances and to total product variation.

5.4.1 Capability Assessment 1 – Gage Repeatability and Reproducibility (GRR)

The precision-to-tolerance ratio, GRR, shows what percent of the specification window is consumed by measurement uncertainty, and is defined as:

\[
\text{GRR} = \frac{5.15 \times S_{R\&R}}{\text{USL} - \text{LSL}} \times 100 \tag{4}
\]

where,

\[ \text{USL} = \text{upper specification limit} \]

\[ \text{LSL} = \text{lower specification limit} \]

This equation is defined for situations where both specification limits exist. It would not be evaluated where only an upper or lower limit exists. A factor of 5.15 is used to calculate the 99% confidence interval on the total measurement precision. Another commonly used factor is 6 used to represent a 99.975% confidence interval.

5.4.2 Capability Assessment 2 – Precision to Variation Ratio (PV)

The precision-to-variation ratio shows what percentage of the total observed product variation can be attributed to measurement uncertainty. It is calculated as follows:

\[
\text{PV} = \frac{S_{R\&R}^2}{S_P^2} \times 100 \tag{5}
\]

Where

\[ S_P^2 = S_{R\&R}^2 + S_P^2 \tag{6} \]

And where

\[ S_P = \text{Range between the maximum and minimum part measurement averages.} \]

\[ K_3 = \text{noted in Table 1, above.} \]

5.4.3 Measurement Tolerance

The measurement tolerance defines a confidence half interval around the measured value using the estimated measurement precision.

\[
\text{TOL} = 2.57 \times S_{R\&R} \tag{8}
\]

The factor 2.57 is used to give the 99% confidence half interval. Thus there is a 99% chance that the true (but unknown) value of the parameter being measured will fall within ± TOL of the measured value.

5.5 Preparing Analysis Conclusions

Goals for measurement precision should be established before the study begins. The goals should be established using knowledge of the anticipated levels of product variability (or process capability), specifications, customer needs and the possible impact of dispositioning test samples improperly (see 6.4).
As a rule of thumb, the guidelines shown in Table 2 have been extensively applied.

<table>
<thead>
<tr>
<th>GRR and PV</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;30</td>
<td>Needs improvement</td>
</tr>
<tr>
<td>10 to 30</td>
<td>Marginal</td>
</tr>
<tr>
<td>&lt;10</td>
<td>Acceptable</td>
</tr>
</tbody>
</table>

In this table, test measurement precision would be acceptable if it is less than 10% of the specification width and less than 10% of the total product variation. A test precision that is more than 30% of the specification width, or more than 30% of the total product variation, would need improvement. A test precision more than 10% but less than 30% of specification width or total product variation would represent marginal measurement precision, and should be improved. An illustration of the relationship between specification limits and measurement uncertainty is shown in Figure 2.

If measurement precision is judged to be marginal or worse, for either GRR or PV, steps should be taken to reduce the measurement variability. The repeatability and reproducibility estimates can be examined to determine the largest contributor to total measurement uncertainty. If the largest component of variation is repeatability, the cause of variability is within a given test condition. Probable causes include problems with calibration, lack of operator controls, excessive within part variation or equipment problems. If the largest component of variation is reproducibility, the cause of variability is between test conditions. The probable causes include difference in test procedural problems test methods, or equipment calibration.

An acceptable GRR or PV value indicates that the test method precision is adequate and should yield data with reasonable certainty.

6 Notes

6.1 Measurement System Properties  An ideal measurement system would have a number of properties including the following:

a. The measurement system would have adequate resolution.

b. The measurement system would be in statistical control, the variation in the measurements would be due to common or random causes only, with all special or definable causes removed.

c. The variability of the measurement error would be small when compared to the manufacturing product variability.

d. The variability of the measurement error would be small when compared with the specification limits.

6.2 Sources of Measurement Variation  A measurement system may exhibit several types of variation, including the following:

a. Accuracy (or bias) – The difference between an observed measurement and the true (but perhaps unknown) value being measured.

b. Precision – The closeness to each other of repeated measurements of the same quantity. Precision can be separated into two components:

   Repeatability – Variation of a measurement system that is obtained by repeating measurements on the same sample(s) by the same procedure under the same measurement conditions including the same operator.

   Reproducibility – Variation among the averages of measurements made under different measurement conditions such as different operators, equipment, and/or locations.

c. Stability (or drift) – The variation observed when repeating measurements on the same device and the same test setup, over an extended period of time.

d. Linearity – The difference in bias values through the expected operating range of the measurement instrument.

This test method has addressed item 6.2.b above. The other sources of variation are addressed in the references (see 6.4).
6.3 Methods for Analyzing Repeatability and Reproducibility

There are several methods for calculating the measurement precision from the data obtained during the measurement precision study. Two of the most commonly applied techniques are applied to measurements that result in variables data, and are called the Average and Range, and ANOVA methods.

a. **Average and Range Method** – This method is covered in this test method and provides an estimate of the standard deviation of the repeatability and reproducibility using the ranges between the highest and lowest measurements in a subgroup. This method allows measurement variability to be decomposed into two components, repeatability and reproducibility. It does not estimate the interaction effects.

b. **The ANOVA (Analysis of Variance)** – This method uses a components of variance technique to decompose the measurement variability into various categories, such as, parts, operators, test equipment, etc. It can calculate the interaction between any of these components. It is more flexible, but is more challenging to calculate. This method generally requires a computer and a certain degree of expertise to interpret. The analysis method is described in the references, see 6.4.

Measurements which result in binary data, such as go and no-go, or pass and fail tests, can be analyzed for consistency and correctness of disposition, see IPC Test Method IPC-TM 1.8.

In some cases, the measurement cannot be repeated more than once on the same sample. This is common where the sample is consumed during the test, such as chemical analysis, or changed during testing, such as solderability evaluations. In these cases, the analysis using a modified average and range method is possible. This method is currently under development.

6.4 References

a. ISO 5725-1 Accuracy (trueness and precision) of measurement methods and results (parts 1 to 6), 1998(E), International Organization for Standardization, Geneva, Switzerland (www.iso.org).


e. Statistical Process Control Guidelines, Texas Instruments, Dallas, TX


h. “Is 100% Test 100% Effective,” W. Russell, 1998 IPC EXPO, San Jose, CA (gives methods for calculating the likely outcomes on product test for differing levels of measurement precision.)

6.5 Software

Measurement precision studies are greatly facilitated by use of software to perform the calculations. Below are just a few of the many software packages that can be used for this purpose. Reference (a) is an Excel spreadsheet written to perform the calculations in this procedure.


e. Interlaboratory Data Analysis Software for E691, ASTM, 100 Barr Harbor Dr, West Conshohocken, PA 19428 (www.astm.org).
### Measurement Precision Study - Data Sheet

<table>
<thead>
<tr>
<th>Condition A</th>
<th>Reading</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
<th>Sample 6</th>
<th>Sample 7</th>
<th>Sample 8</th>
<th>Sample 9</th>
<th>Sample 10</th>
<th>Average</th>
</tr>
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<tr>
<td></td>
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<td>2</td>
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</tbody>
</table>

\[
\bar{X}_A = \frac{\sum X_A}{n}
\]

\[
R_A = \text{Range}
\]

<table>
<thead>
<tr>
<th>Condition B</th>
<th>Reading</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
<th>Sample 6</th>
<th>Sample 7</th>
<th>Sample 8</th>
<th>Sample 9</th>
<th>Sample 10</th>
<th>Average</th>
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</table>

\[
\bar{X}_B = \frac{\sum X_B}{n}
\]

\[
R_B = \text{Range}
\]
# Measurement Precision Study - Data Sheet (continued)

## Condition C Reading

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\[ \bar{X}_C = \]  
\[ R_C = \]

## Condition D Reading

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\[ \bar{X}_D = \]  
\[ R_D = \]

## Condition E Reading

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\[ \bar{X}_E = \]  
\[ R_E = \]

## Condition F Reading

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\[ \bar{X}_F = \]  
\[ R_F = \]
### Measurement Precision Study - Data Sheet (continued)

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<th>Reading</th>
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<th>Average</th>
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</tr>
<tr>
<td></td>
<td>Average</td>
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<td>$\bar{x}_G =$</td>
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<td>$R_G =$</td>
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### Measurement Precision Study – Calculation Sheet

#### Sample Data

| Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average Part Average
|--------|---|---|---|---|---|---|---|---|---|----|---------------------|
|        |   |   |   |   |   |   |   |   |   |    | X = \[
| Max Part Avg | \[
| Min Part Avg | \[
| Range of Part Avgs | \[

#### Condition Data

| Condition | A | B | C | D | E | F | G | H | I | J | Average Condition Range
|-----------|---|---|---|---|---|---|---|---|---|---|---------------------|
| Average   |   |   |   |   |   |   |   |   |   |    | R = \[
| Average Range |   |   |   |   |   |   |   |   |   |    | \[
| Max Condition Avg | \[
| Min Condition Avg | \[
| Range of Condition Avgs | \[

#### Variability Calculations

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<td>Repeatability</td>
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<td>Reproducibility</td>
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<td>Total R&amp;r</td>
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### Comparisons to Specifications (Used when both specifications exist)

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<tr>
<th>Topic</th>
<th>Equation</th>
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<th>Answer</th>
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<tbody>
<tr>
<td>% Repeatability</td>
<td>$5.15 \times \frac{S_r}{USL - LSL}$</td>
<td>$\times 100$</td>
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<tr>
<td>% Reproducibility</td>
<td>$5.15 \times \frac{S_R}{USL - LSL}$</td>
<td>$\times 100$</td>
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<tr>
<td>% Measurement R&amp;r</td>
<td>$5.15 \times \frac{S_{R&amp;R}}{USL - LSL}$</td>
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### Comparisons to Total Variation

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<tr>
<td>% Repeatability</td>
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<td>$S_t^2 \times 100$</td>
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</tr>
<tr>
<td>% Reproducibility</td>
<td>$S_R^2$</td>
<td>$S_t^2 \times 100$</td>
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</tr>
<tr>
<td>% Measurement R&amp;r</td>
<td>$S_{R&amp;R}^2$</td>
<td>$S_t^2 \times 100$</td>
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### Measurement Tolerance

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<th>Equation</th>
<th>Calculation</th>
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<tbody>
<tr>
<td>Tolerance</td>
<td>$\pm 2.57 \times S_{R&amp;R}$</td>
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</table>
1.0 Scope  This procedure is to be used for preparing a metallographic specimen of printed wiring products. The finished microsection is used for evaluating the quality of the laminate system and the plated-through holes (PTHs). The PTHs can be evaluated for characteristics of the copper foils, plating, and/or coatings to determine compliance with applicable specification requirements. The same basic procedures may be used for mounting and examination of other areas. Because manual metallographic sample preparation is regarded by many as essentially an art, this method describes those techniques that have been found to be generally acceptable. It does not attempt to be so specific as to allow no acceptable variations that can differentiate metallographers. Furthermore, the success of these techniques remains highly dependent upon the skill of the individual metallographer.

2.0 Applicable Documents

IPC-MS-810  Guidelines for High Volume Microsectioning
ASTM E 3  Standard Methods of Preparation of Metallographic Specimens

3.0 Test Specimens  Cut the required specimens from a printed board or test coupon. Allow sufficient clearance to prevent damage to the area to be examined. The recommended minimum clearance is 2.54 mm. Abrasive cut-off wheels can cut closer to the area of examination without causing damage. Some commonly used methods include sawing using a jeweler's saw, miniature band saw, or abrasive cut-off wheel; routing using a small milling machine; or punching using a sharp, hollow die (not recommended for brittle materials, i.e., polyimide and some modified epoxy resin systems). See IPC-MS-810. It is recommended that a minimum of one microsection containing at least three of the smallest diameter PTHs shall be made for each specimen tested. When microsectioning multilayer production printed boards designed without nonfunctional lands on all layers, care needs to be exercised in choosing the test location such that internal lands are connected to the selected PTHs. This is so that a complete quality evaluation can be made.

4.0 Apparatus or Material

4.1 Sample removal method (see IPC-MS-810 for the best method to meet your needs).
4.2 Mount molds
4.3 Smooth, flat mounting surface
4.4 Release agent (optional)
4.5 Sample supports (optional)
4.6 Metallographic rotary grinding/polishing system
4.7 Belt sander (optional)
4.8 Metallographic microscope capable of 100X to 200X magnification
4.9 Vacuum pump and vacuum desiccator (optional)
4.10 Room temperature curing potting material (recommended maximum cure temperature 93°C)
4.11 Abrasive paper (USA CAMI Grade grit numbers 180, 240, 320, 400, and 600. See Figure 1 for conversion from American to European grit sizes).
4.12 Cloths for polishing wheels: a hard, low, or no nap cloth for rough and intermediate polishing and a soft, woven, or medium nap cloth for final polishing.
4.13 Oxide or colloidal silica polishing suspension (final polish, 0.3 to 0.04 micron)
4.14 Diamond polishing abrasive (six to 0.1 micron)
4.15 Polishing lubricant
4.16 Specimen etching solution (see 6.4)
4.17 Cotton balls and swabs for cleaning and etchant application

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4.18 Isopropyl alcohol, 25% methanol aqueous solution, or other suitable solvent (check for reaction with the encapsulation media and marking system)

4.19 Specimen marking system

4.20 Ultrasonic cleaner (optional)

5.0 Procedure

5.1 Preparation of Specimen Grind the sample sequentially on 180, 240, 320 grit wheel to within approximately 1.27 mm of final polish depth. Deburr all edges prior to mounting.

5.2 Mounting Metallographic Sample

5.2.1 Clean mounting surface and dry thoroughly, then apply release agent to the plate and mounting rings.

5.2.2 Thoroughly clean the sample using a suitable solvent such as isopropyl or ethyl alcohol. This is especially important when microsectioning “thermally stressed” (solder floated) specimens. Residual flux may result in poor adhesion of the encapsulation media causing gaps between the specimen and the media. These gaps make proper metallographic sample preparation extremely difficult, if not impossible.

5.2.3 Stand specimen in mount ring, perpendicular to the base using sample supports, clips, or with the use of double-sided adhesive tape.

5.2.4 The surface to be examined should face the mounting surface.

5.2.5 Fill the mounting ring carefully with potting material, by pouring from one side to ensure complete PTH filling. Some potting materials may require dilution as recommended by the material manufacturer to reduce the viscosity in order to fill small diameter PTHs. Hand protection is recommended to prevent skin sensitization.

5.2.6 The sample must remain upright and the holes filled with encapsulating material.

5.2.7 Epoxy potting materials may require vacuum degassing in order to achieve complete hole filling.

5.2.8 Allow specimen to cure and remove hardened mount from ring. The minimum qualities the mount should exhibit are:

- No gaps between the potting material and the sample
- The PTHs filled with material
- No bubbles in the potting material

The presence of these deficiencies will result in sample preparation difficulties, as noted in 5.2.2. Identify the specimen by a permanent method. The selected marking system should remain unaffected by solvent and lubricant exposure.

5.2.9 For finite plating thickness measurements, such as gold and nickel thickness on edge board contacts, the overplated specimen may be placed at a 30° angle. This will provide viewing at twice the actual thickness. The measured thickness is then divided by two to arrive at the true thickness. For a more thorough discussion of the techniques of taper sectioning, refer to the references in 6.5.

5.3 Grinding And Polishing
5.3.1 Using the metallographic equipment, rough grind the mount on 180 grit abrasive paper no closer than to the edge of the PTH barrel walls.

**Note:** Copious water flow must be used to prevent overheating and damage to the specimen and removal of grinding debris.

5.3.2 Fine grind specimen, using copious water flow, to center of the PTHs utilizing 240, 320, 400, and 600 grit discs, in that order. The final paper (600 grit) should finish at the axial centerline of the PTHs. Wheel speeds of 200 to 300 rpm are generally used during fine grinding. Rotate the specimen 90° between each successive grit size and grind for twice to three times the time it takes to remove the scratches from the previous step. The scratch removal can be verified by microscopic inspection between steps. It is of great importance that the ground surface of the microsection is in a single plane. The purpose of rotating the microsection 90° between successive grit sizes is to facilitate inspection. If scratches are observed to be perpendicular to those made during the last step performed, it is a good indication that the surface is not flat and the microsection requires additional grinding. If the surface of the microsection is not flat upon completion of the grinding operations, it may not be possible to remove all of the grinding operations, and grinding scratches during rough polishing. The metallographer should recognize the fact that the coarser grit sizes (180, 240, and 320) induce a larger depth of deformed and fragmented material. Since the depth of deformation decreases sharply below a particle size of about 30 microns (400 grit), it is better practice to spend longer times on 400 grit and especially 600 grit to achieve the final plane sectioning, rather than on the coarser grit sizes.

5.3.3 Rinse sample with running tap water and blow dry with filtered air. Ultrasonically clean, if desired, between each step.

**Note:** Ultrasonic cleaning is highly recommended, especially between the finer grinding steps, prior to rough polishing and between all polishing steps. It is the nature of printed board specimens, especially those with epoxy base material following thermal exposures, to contain voids that can trap grinding and polishing residues that are not removed during simple rinsing. Care needs to be exercised not to damage the specimen surface with excessive ultrasonic cleaning. Ultrasonic cleaning for as little as one minute can damage a polished surface.

5.3.4 Rough polish the specimen with six micron diamond abrasive on a hard, low, or no nap cloth. Following rough polishing, microscopically examine the specimen to verify removal of all 600 grit scratches. Ultrasonically clean the specimen, if desired. Continue polishing with one to three micron diamond abrasive again using a hard, low, or no nap cloth and microscopically examine the specimen to verify the removal of all the six micron diamond scratches. Ultrasonically clean the specimen, if desired. Generally, polishing a few minutes using medium pressure during the above steps is sufficient if the microsection has been ground correctly. Wheel speeds of 200 to 300 rpm are generally used during rough and intermediate polishing. Final polishing is accomplished using a soft, woven, or medium nap cloth using a one to 0.1 micron diamond, 0.05 micron alumina or other oxide, or a colloidal silica polishing suspension. This final step is only performed for 10-20 seconds using light to medium pressure when using oxide or silica polishing compounds. When using diamond compounds on soft woven cloths, final polishing may extend several minutes (see 5.3.5). Reduced wheel speeds of 100 to 150 rpm are generally used during final polishing due to increased drag on the microsection. Typically, six micron followed by one micron diamond and a 0.04 micron colloidal silica or 0.05 micron alumina have been used successfully. However, other variations such as six micron, three micron, and 0.25 micron diamond have also been used successfully. Some have even used 1.0 and 0.3 micron alumina on napless cloths followed by 0.05 micron alumina on a soft, medium napped cloth. This procedure can be used successfully, depending upon the skill of the metallographer, but will generally result in poorer edge retention and more relief effects than the diamond compounds (see 6.5, Reference 1).

5.3.5 Warning The use of napped cloths can result in poor edge retention (rounding) and relief between constituents since it exacerbates the varying rates of material removal (i.e., tin-lead alloy and the softer encapsulation media are removed at a faster rate than the copper or glass fibers in the base material). The higher the nap, the more the effect. The user needs to minimize the polishing time and use ample lubricant and light pressure during final polishing.

5.3.6 Rinse in mild soap and warm water or solvent and blow dry.

5.3.7 Examine and repolish, beginning with six micron diamond, if necessary, until:

1. There are no scratches larger than those induced by the final polishing abrasive.
2. The specimen is not higher or lower than the mounting material.

3. There is no smearing of the copper plating into the PTH or base material.

4. The plane of microsectioning is at the centerline of the hole as defined by the governing specification. If the grinding depth is insufficient, additional grinding and repolishing may be required.

5. There is little, if any, visible preparation induced damage to the glass fibers of the base material.

See IPC-MS-810 for photomicrographs illustrating some of the above qualities. When the required microsection quality has been achieved, examine the microsection of multilayer printed boards in the “as-polished” condition as specified in 5.4.1 to identify suspect areas of internal layer separation that appear as dark lines or partial dark lines. These areas should be verified after metallographic etching. There may not be a one-to-one correlation of all separations noted “as-polished” versus those noted after etching, when examined at the specified magnifications.

5.3.8 Swab specimen with suitable etching solution (see 6.4) typically applied for two to three seconds, repeat two to three second swabbings if necessary, to reveal the plating interfaces.

**Caution:** Over etching may totally obscure the demarcation line between the copper foil and electroplate copper, preventing accurate inspection.

5.3.9 Rinse in running tap or deionized water to remove etchant.

5.3.10 Rinse in solvent and blow dry.

5.4 Evaluation

5.4.1 Set the magnification at 100X and measure all characteristics required by the standard or specification using a metallograph set for bright field illumination. Referee at 200X, unless otherwise specified.

5.4.2 Measure the plating thickness in at least three PTHs. Total surface copper thickness can also be determined on the same specimen cross-section. Record the plating thickness determinations and quality of the plating. Plating thickness determinations should not be made at nodules, voids, or cracks.

5.4.3 Quality observations may include the following: blisters, laminate voids, cracks, resin recession, hole wall pull-away, plating uniformity, burrs and nodules, plating voids, and wicking. In addition, plating quality for multilayer printed boards may include: innerplane bond to PTH, resin smear, glass fiber protrusion, and resin etchback. Some of the plating conditions may be observed on the polished specimen prior to etching.

6.0 Notes

6.1 Overplating the specimen per ASTM E 3 with a layer of copper or other plating with a hardness similar to the specimen, prior to encapsulation, provides better edge retention, thereby providing more accurate thickness measurements.

6.2 For a more accurate evaluation of possible internal layer separations, the procedures covered in 6.2.1 and 6.2.2 are recommended.

6.2.1 Re grind Procedure

6.2.1.1 After polishing and examining with a metallographic microscope, turn power off at the final grinding wheel.

6.2.1.2 Gently regrind the specimen using copious amounts of water and 600 grit paper with the wheel in a stationary position parallel to the PTH barrels. Six to eight double strokes should be sufficient. This action will remove any copper metal smear that may have occurred over the interconnection separation during rotary polishing.

6.2.1.3 Rinse and dry specimen and repolish per 5.3.3 through 5.3.7, then reexamine under the metallograph to determine if interconnection separation exists.

6.2.1.4 After examination in the “as-polished” condition (and taking photomicrographs, if desired), etch the specimens with the mild etchant described in 6.4, and reexamine the specimen again for interconnection separation and all other characteristics. There may not be a one-to-one correlation of all separations noted “as polished.”

6.2.2 Mechanical/Chemical Preparation (Attack Polishing) Another useful technique is a simultaneous mechanical/chemical polish at the final polishing step. Use a mixture of 95% colloidal silica and 5% by volume hydrogen peroxide (30% concentration) and polish on a chemically resistant cloth. This results in a simultaneous mechanical and chemical
abrasion of the specimen. The metallographer must be careful to balance the mechanical abrasion with the chemical abrasion. Too much mechanical abrasion will result in fine scratches; too much chemical polishing will result in etching of the specimen. Neither of these conditions is desirable. Experimentation will be required to develop the optimal balance.

6.3 In order to develop more insight into detected interconnection separations, regrind and repolish the specimen in the horizontal plan (perpendicular to the original vertical plane), and examine the semicircumferential interface. This method has a low success rate when the separation affects less than 50% of the internal layer thickness (as noted on the vertical microsection).

6.4 The following is the recommended solution for specimen etching.

25 ml ammonium hydroxide (25-30%)
25 ml-35 ml of 3-5% by volume stabilized hydrogen peroxide

The addition of 25 ml of water (distilled or reverse osmosis) will dilute the solution, resulting in longer etching times, which may be desirable in certain situations.

Wait five minutes before using. Prepare fresh every few hours.

6.4.1 There are other etchant solutions that have been used or that may be developed for etching copper. Care must be exercised in their selection and use because of the sensitive nature of the electrolytic, electroless, and foil etching characteristics as well as possible galvanic effects in the presence of tin-lead. See 6.5, Reference 2 and IPC-MS-810.

6.4.2 When studying tin-lead solders, it is sometimes helpful to use etchants specifically designed to reveal those alloy’s microstructures (see 6.5, Reference 2).

6.5 Additional references on metallographic laboratory practice.

1.0 Scope  This procedure describes the preparation of metallographic specimens containing ceramic components mounted on printed wiring boards or ceramic substrates. This procedure must be carefully followed to minimize ceramic chunking and to maintain a flat surface.

2.0 Applicable Documents  None

3.0 Apparatus  The following is a suggested list of equipment and supplies.

- Low speed diamond saw
- Vacuum impregnation equipment
- Metallographic polisher
- Epoxy resin potting compound. Selection of an epoxy resin with a low exothermic reaction is critical when mounting solder joint specimens to prevent microstructural changes induced by resin cure.
- Specimen mounting plate
- Molding rings
- Metal bonded diamond discs: 0.70 micron, 0.45 micron, 0.30 micron
- Diamond paste lubricant
- Diamond paste 3 micron
- 0.5 micron aluminum oxide powder
- Texmet cloth (or equal)
- Micro cloth
- Ultrasonic bath system

4.0 Test

4.1 Preparation of Specimen

4.1.1 Cut specimen close to desired area of observation using a low speed diamond saw.

4.1.2 After cutting specimen, clean using chloroethene.

4.1.3 Mount the specimen on a flat plate in conjunction with a bakelite ring.

4.1.4 Mix the epoxy resin according to manufacturer’s instructions.

4.1.5 Evacuate the epoxy resin to remove air induced by mixing.

4.1.6 Pour just enough epoxy resin in bakelite ring to cover specimen. Evacuate for 3 to 5 minutes to assure sufficient fill and adhesion.

4.1.7 Fill sample ring to top with epoxy resin and cure per manufacturer’s instructions.

4.2 Micropolishing

4.2.1 Rough grind the specimen to within 1.3 mm [0.05 inch] of desired location using a 70 micron diamond wheel with water lubricant at low speed (550 rpm).

4.2.2 Ultrasonic clean the specimen using detergent and water.

4.2.3 Grind to desired location using a 45 micron diamond wheel with water lubricant at low speed (550 rpm).

4.2.4 Ultrasonic clean the specimen using detergent and water.

4.2.5 Grind for 1-2 minutes using a 30 micron diamond wheel with a water lubricant at low speed (550 rpm).

4.2.6 Ultrasonic clean the specimen using detergent and water.

4.2.7 Rough polish the specimen using a metallographic polisher in conjunction with Texmet (or equal) cloth and 3 micron diamond paste lubricated with an oil base fluid. Polish for 30-40 minutes using heavy pressure and fast speed setting.

4.2.8 Final polish on metallographic polisher using 0.5 micron aluminum oxide in conjunction with microcloth lubricated with water. Polish for approximately 2 minutes using light pressure and medium speed setting.
4.2.9 Ultrasonic clean sample in water. Wipe sample with a water soaked cotton ball and dry.

5.0 Evaluation

5.1 Set the magnification at 100 x minimum and perform visual and plating thickness of at least three plated-through hole sections.

5.2 Total surface copper thickness can also be determined on the same specimen cross-section. Plating thickness determination shall not be determined at nodules, voids, cracks, or irregular and thin platings.

5.3 Record average plating thickness determinations and quality of the plating.

6.0 Note: Metallographic equipment and supplies vary, therefore it is recommended that variations to this procedure should be agreed on between supplier and user.
1.0 Scope
This procedure is an alternate method for preparing multiple metallographic specimen(s) using microsection equipment. The specimen(s) is(are) for evaluation of quality of the laminate system, plated-through holes (PTHs), the copper foils, platings, and/or coatings. The same basic procedure may be used for examination of other areas on the product.

Note: This microsection technique is a process and not a test method.

Note: SAFETY The use of the materials listed in Section 4.0 may be limited or forbidden in some environments. Please review the Material Safety Data Sheet (MSDS) for the materials being used.

2.0 Applicable Documents
- IPC-MS-810 Guidelines for Semi-Automatic Microsection
- IPC-RB-276 Qualification and Performance Specification for Rigid Printed Boards

3.0 Test Specimens
Remove the required specimen(s) from the product to be tested. Allow sufficient clearance to prevent damage to the area and PTHs to be examined. The recommended clearance from the pad edge to the cut surface is 2.54 mm [0.100 in]. Abrasive cut-off wheels can cut closer to the sample without damaging the area to be examined.

4.0 Apparatus
- sample removal method (see IPC-MS-810 for best method)
- sample alignment tools
- mount molds
- mounting surface
- vacuum/pressure system (optional)
- release agent (optional)
- potting material (recommended maximum cure temperature is 200°F)
- explosion proof fume hood for mounting material
- microsection equipment (see IPC-MS-810 for purchasing guidelines)
- metricated abrasive paper P100–P1200 (American grit range: 100–600)
- polishing cloths
- diamond abrasive (1–9 micron) or oxide abrasive (3–0.1 micron)
- polishing lubricant
- micro-etch solution
- micro-etch applicator (optional)
- engraver (optional)

5.0 Procedure and Evaluation

5.1 Procedure
5.1.1 The semi or automatic microsection technique is a process and not a test method. Microsectioning needs to be viewed as a process with quality criteria as each major step is completed. This procedure specifies the quality criteria that must be met to make microsections that can consistently find the defects (or anomalies) of concern. The customer should not specify the process steps and materials but the quality criteria for surface preparation of the specimen.

5.1.2 Preparation of Specimen(s) Remove the specimen from the PWB or panel such that the tooling pin holes or target PTHs are not damaged. Complete any thermal testing required by the customer.

5.1.3 Inspect Tooling Pin System Inspect the tooling pin holes or slots to verify they are not plugged or damaged. Clear plugged tooling pin holes with a tool that will not change its dimensional location or enlarge the hole. A drill bit of the same hole diameter is recommended.

Inspect the tooling pins for foreign material adhering to them. Clean the pin surface as required. Discard any pins that are bent or the surface scarred.

5.1.4 Load Specimen On Tooling Pins The pins align the target PTHs on a common plane. This common plane assures all the PTHs will grind to the center of the hole at the same instance.

Push the tooling pins into the tooling holes or slots. The pins must fit snugly.

5.1.5 Potting the Specimen(s) The potting material must have a low shrink rate, and the cure temperature must be less...
than 93°C [200°F] at the center of the mount to prevent false failures. Mold release may be applied to the mount to permit easy removal of the cured mounting material (optional). Thoroughly mix the potting material without trapping air and pour into the mold. Assure the tooling pins do not shift position or rise up while pouring and/or curing of the potting material. If necessary to avoid voids in the finished mount and to insure adequate hole filling, evacuate the mount before cure using a vacuum system. Allow the potting material to cure and return to ambient temperature before removing from the mount. Remove the hardened mounts from their molds (as applicable).

5.1.6 Traceability The mount/specimen must be permanently marked in such a manner to ensure traceability back to the PWB or panel. If the mounts are cured within the mount holder, traceability is not required until the mounts are removed from the holder.

5.1.7 Mount Quality The minimum qualities the mount must exhibit are no gaps between the potting material and the specimen, the PTHs filled with material, and no bubbles in the potting material in the areas of examination.

5.1.8 Grind Process Set-Up.

5.1.8.1 Tooling Stops The mount holder has tooling stops to allow the equipment to grind a set distance. These stops must be calibrated for each abrasive paper grit to assure the scratches from the previous step are removed. See IPC-MS-810 for a detailed discussion and examples.

5.1.8.2 Grind Pressure The equipment’s pressure setting is the direct force on a load cell. To determine the pressure on each mount, divide the pressure setting by the surface area of the mounts being processed. See IPC-MS-810 for a detailed discussion and examples.

The recommended pressure setting for 6 mounts at 38.1 mm [1.5 in] diameter is 351.5 g/sq. cm (5.0 psi) with the wheel RPMs between 300–600.

5.1.8.3 Other Variables Recommended variables to be familiar with are length of time the abrasive paper removes material efficiently, scratch size the abrasive paper causes on the specimen(s) surface, and water quality (undissolved particles that can cause scratches; i.e. calcium deposits).

5.1.9 Grind the Mounts Be liberal with the amount of water used to promote efficient removal of material by the abrasive paper. The hardness of the specimen will dictate the number of rough and fine grind steps needed to reach near the center of the hole. The rough grind grits P180-P240 (American 180-240) are used to enter the edge of the PTH, and the fine grind grits P800-P1200 (American 400-600) are used to grind near the center of the hole. The distance to stop short of the center is determined by the scratch size of the last grind step used.

A recommended grinding process from which to start development is:

<table>
<thead>
<tr>
<th>Step</th>
<th>Abrasive grit size</th>
<th>RPM</th>
<th>Pressure (g/sq.cm)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>P180</td>
<td>200–300</td>
<td>351.5</td>
<td>15 seconds after the stops touch</td>
</tr>
<tr>
<td>Step 2</td>
<td>P400(opt)</td>
<td>200–300</td>
<td>351.5</td>
<td></td>
</tr>
<tr>
<td>Step 3</td>
<td>P1000</td>
<td>200–300</td>
<td>351.5</td>
<td></td>
</tr>
</tbody>
</table>

5.1.9.1 Clean the Mounts Clean the mount surface with a mild hand soap to remove the abrasive grit. This is especially important when the same mount holder is used for grinding and polishing. Be careful not to scratch the surfaces to be evaluated while cleaning.

5.1.10 Grind Quality The minimum qualities the mount must exhibit are:

1) The target PTHs are ground to the center of the PTHs as defined by the customer’s specification.
2) Only fine grind scratches apparent on the mount when viewed at 100X magnification.
3) No gap between the potting material and the specimen(s).
4) No residual abrasive paper grit material on the mount surface.
5) The ground surface has only one plane of material removal. If the mount has several planes of material removal, portions of the sample will not polish since the odd surface never touches the polishing cloth.

5.1.11 Polish Process Setup The tooling stops are recessed or removed from the mount holder during polishing. The reason is the polish process removes a negligible amount of material and will not change the flatness of the surface. The number of polish steps is determined by the hardness of the specimen(s), distance to the center of the hole, and scratch size of the last fine grind step. There may be multiple intermediate polish steps but only one final polish step.
5.1.12 Intermediate Polish Steps  The intermediate steps must remove the fine grind scratches and prepare the surface for the final polish step. The recommended process settings for 6 mounts at 38.1 mm [1.5 in] diameter is less than 351.5 g/sq. cm (5.0 psi), a medium to hard polish cloth, short nap surface, and low wheel RPM (100–200). Additional variables that must be considered are volume of lubricant, lubricant types, abrasive size, abrasive type (diamond or oxide), and process time.

A recommended polish process from which to start development is:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of cloth</td>
<td>Napless</td>
<td>Napless</td>
</tr>
<tr>
<td>Type of polish abrasive</td>
<td>Diamond</td>
<td>Diamond</td>
</tr>
<tr>
<td>Polish abrasive size</td>
<td>6 micron</td>
<td>1 micron</td>
</tr>
<tr>
<td>Time</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Pressure (g/sq. cm)</td>
<td>351.5 or less</td>
<td>351.5 or less</td>
</tr>
</tbody>
</table>

5.1.12.1 Clean the Mount(s)  The mounts must be cleaned between each polish step. The reason is to prevent contaminating the next polish step with the current grit size. If the polish step is contaminated, the step will produce undesirable scratches. Clean the mounts with mild hand soap, rinse with water, and dry. Do not scratch the surface to be evaluated when cleaning.

5.1.13 Final Polish the Mounts  The final polish step removes the scratches from intermediate polishing and prepares the surface for evaluation. The recommended process setting for the same surface areas as 5.1.12 are a medium to soft polish cloth, low wheel RPM (100-200), and low pressure setting 351.5 g/sq. cm (5.0 psi) or less. Additional variables that must be considered are volume of lubricant, type of nap surface on polish cloth, and process times. The type of abrasive used must be diamond (maximum rated size: 1.0 micron) or colloidal silica.

Warning

If a high nap polish cloth is used too long in the final polish, the inspectors ability to see defects can be hampered. This step must be engineered for short process times (30 seconds or less) with a careful balance of lubricant to prevent copper rounding.

5.1.13.1 Clean the Mount  This last clean step must remove all the contaminants as described in 5.1.12.1 and the polish lubricant. The lubricant film will prevent even microetching of the specimen(s).

5.1.14 Traceability  If the mounts are cured in the mount holder, remove the mounts. The mount/specimen must be permanently marked in such a manner to ensure traceability back to the PWB or panel.

5.1.15 Polish Quality  The surface qualities of a properly prepared microsection mount are:

1. The target PTHs are ground to the center of the PTH as defined by the customer’s specifications.
2. No scratches larger than 1.0 micron on the metal surface to be examined (i.e. copper).
3. No smear of metals (i.e. copper, tin/lead, nickel) over other metals, board base material, and/or potting material.
4. No rounding of metal surfaces (i.e. copper) in the PTH.
5. No gaps between the specimen(s) and potting material.

Rounding of metal surfaces is apparent as the material edge being out of focus at 100X magnification on the metallograph or shaded a charcoal black color.

5.2 Evaluation Method

5.2.1 Separation Evaluation  Evaluate the PTHs for inner-layer separation prior to microetch. Any observations need to be re-inspected after etch. The separations noted in the unetched and microetched conditions will not necessarily correlate one to one.

5.2.2 Microetch the Specimen  Swab or dip the specimen into a suitable microetching solution and rinse with running water. The recommended etching solutions and formulations are listed in IPC-MS-810. The etch time will vary with the type of etchant chosen to microetch the sample.

5.2.3 Evaluation  Evaluate the average thickness of the plated metals and determine PTH quality per the customer’s specifications.

6.0 Notes

6.1 Diamond Polish  The diamond polish media is preferred over alumina for PWB’s being evaluated to IPC-RB-276
Class 2 and 3 products. Diamond media substantially reduces the risk of metal smear and rounding. Diamonds provide a sharper definition of copper surfaces to evaluate for separation of conductive surfaces.

6.2 Etchants The two most common microetchants for copper are ammonium hydroxide/hydrogen peroxide and sodium dichromate etchant. Both have benefits and drawbacks that must considered when making a choice (See IPC-MS-810).

6.3 Abrasive Paper The abrasive grit size has different designators (Metricated versus American). Figure 1 tabulates the correlation between grades.

6.4 See IPC-MS-810 for photomicrographs illustrating acceptable and unacceptable polish quality.
1.0 Scope This test method identifies the major areas of concern during a visual examination and describes the recommended procedures.

2.0 Application Documents None.

3.0 Test Specimen Any representative clad or unclad sample of printed wiring material.

4.0 Equipment/Apparatus Magnifier or microscope capable of up to 30X magnification, having a reticle capable of measuring to the nearest 0.001 in.

5.0 Procedures

5.1 Pinholes Pinholes are predetermined by visual examination using not less than 10X magnification on the specimen. Copper surfaces should be prepared by cleaning or light etching.

5.2 Pits and Dents The maximum total point count for pits and dents, per square foot of panel inspected is determined as follows:

<table>
<thead>
<tr>
<th>Longest Dimension (inch)</th>
<th>Point Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000 to 0.010 inclusive</td>
<td>1</td>
</tr>
<tr>
<td>0.011 to 0.020 inclusive</td>
<td>2</td>
</tr>
<tr>
<td>0.021 to 0.030 inclusive</td>
<td>4</td>
</tr>
<tr>
<td>0.031 to 0.040 inclusive</td>
<td>7</td>
</tr>
<tr>
<td>over 0.040</td>
<td>30</td>
</tr>
</tbody>
</table>

Pits and dents should be determined visually using not less than 10X magnification on the specimen.

5.3 Scratches Scratches can be measured with the use of a microscope (30X maximum).

5.4 Wrinkles Wrinkles should be viewed by normal or corrected 20/20 vision.

5.5 Inclusions Inclusions should be measured using 18X to 30X magnification.

6.0 Notes

For additional reference see:
IPC-CF-150: Copper Foil
IPC-A-600: Acceptability of Printed Boards
MIL-P-13949: Laminate Materials

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### Table: Test Method Information

<table>
<thead>
<tr>
<th>Number</th>
<th>2.1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>Surface Examination, Unclad and Metal-Clad Material</td>
</tr>
<tr>
<td>Date</td>
<td>12/82</td>
</tr>
<tr>
<td>Revision</td>
<td>A</td>
</tr>
<tr>
<td>Originating Task Group</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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1.0 Scope  This method is designed to determine the thickness of woven glass fabric, such as E-glass, S-glass, and quartz, used as reinforcement in prepreg (resin-impregnated glass fabric, or B-stage). It is applicable for glass fabric inspection before and after impregnation.

2.0 Applicable Documents
FED-STD-191

3.0 Test Specimens
3.1 Size  Specimen size of 101.6 x 101.6 mm [4.0 x 4.0 in] is recommended; specimens used for determination of resin content by Burn Off Method may be used. Specimens shall be of sufficient size to insure that all points of the pressure foot of the thickness gage shall be at least 6.4 mm [0.25 in] from the edge of the specimen.

3.2 Quantity and Sampling  Unless otherwise specified, three pieces of material shall be cut one each from three sample sheets. Specimens shall be cut with the edges on a bias to the orientation of the fabric. Specimens shall be free of folds, creases, knots or other distortions which are not representative of the material surface.

4.0 Apparatus or Material
4.1 Muffle furnace  Muffle furnace that is capable of maintaining 550 +/-50°C [1022 ±90°F].

4.2 Thickness Gage (Dead weight type)  A dead weight type thickness gage equipped with a dial graduated to read with a precision of 0.0025 mm [0.0001 in] shall be used. The pressure foot shall be circular with a diameter of 6.35 ±0.025 mm [0.25 ±0.001 in], and with the moving parts weighted to apply a total load of 173 ±14 kPa (25 ±2 psi) to the specimen. The anvil shall be not less than 6.35 mm [0.250 in] in diameter. The micrometer shall be capable of repeating its readings to 0.0013 mm [0.00005 in] at zero setting or on a steel gage block.

5.0 Procedure
5.1 Preparation of Prepreg Specimens  Place specimens in a muffle furnace at 550±50°C [1022 ±90°F], for a period of time necessary to assure complete removal of the organics (resin). After removal from the muffle furnace, the specimens shall be cooled to room temperature.

5.2 Thickness Determination  The specimen shall be placed on the thickness gauge anvil, and the pressure foot shall be closed onto the specimen at a location outside the area to be measured. The pressure foot shall be backed off to a distance of 0.008 to 0.01 mm [0.0003 to 0.0004 in], the specimen moved to the measurement position, and the pressure foot then released onto the specimen. The pressure foot shall be allowed to rest there for a minimum of 5 seconds. The dial reading shall then be taken to the nearest 0.0025 mm [0.0001 in].

5.3 Evaluation  Record each reading and report the average of three measurements to the nearest 0.025 mm [0.001 in].

6.0 Notes  See Federal Test Method Standard No. 191, Method No. 5050 for additional information and background on this procedure.
1.0 Scope  This method is designed to determine thread count of woven glass fabric used for prepreg (resin-impregnated glass fabric, or B-stage). It is applicable for glass fabric inspection before and after impregnation.

2.0 Applicable Documents  None

3.0 Test Specimens  Unless otherwise specified, three specimens cut to the size convenient to performing the test, with a minimum of 101.6 x 101.6 mm [4.0 x 4.0 in], shall be cut from random locations in a roll or one each from three sample sheets. The warp and fill directions of the fabric shall be noted.

4.0 Apparatus or Material

4.1 Muffle furnace  A muffle furnace that is capable of maintaining 550 ±50°C [1022 ±90°F].

4.2 Magnifier and counting device. Type and model to be determined, or equivalent.

4.3 Gingher Thread Counter, Model G4, or equivalent.

5.0 Procedure

5.1 Method A: Thread Count by Picks per Inch Method

5.1.1 For prepreg, place specimens in a muffle furnace at 550 ±50°C [1022 ±90°F] for a minimum of 15 minutes or until sufficient resin is burned away to be able to clearly see the yarns of the fabric. After removing the specimens from the muffle furnace, allow to cool to room temperature on a flat surface to prevent distortion of the fabric.

5.1.2 Place the specimen as flat as possible, without tension, on a smooth horizontal surface. Use the magnifier and measuring device to count the yarns within a specific distance, 25.4 mm [1.0 in] minimum, in each direction of the cloth.

5.2 Method B: Thread Count by Gingher Thread Counter Method

5.2.1 Lay the Gingher comparator parallel along one grain direction to be counted. Rotate the comparator back and forth out of parallel with the grain by 10 to 15 degrees until an optical parabola is observed. The apex of the parabola is tangent to the thread count per inch.

5.2.2 Repeat 5.2.1 for the other (orthogonal) direction of the cloth yarns.

5.3 If any discrepancies or disagreement between test data is found, Method 5.1 shall be the referee method.

5.4 Report  Average the number of yarns for each direction. Report the individual readings and average results.

6.0 Notes

6.1 Summary  The following details should be specified in the applicable performance specification or product procurement specification.

a. Test Method to be used (see 5.1, and 5.2).

b. Specimen size and number to be tested, if other than specified (see 3.0).

c. Where applicable, any additions or modifications to the specified procedure and criteria.
1 Scope  This method is used to determine warp and fill thread count in materials containing combustible fibers.

2 Applicable Documents  None

3 Test Specimen  The specimen may be of any convenient size greater than 51 mm x 51 mm.

4 Equipment

4.1 Glass pick, ruler, pointer or other suitable form of counting device

4.2 Microscope

5 Procedure

5.1 Yarn Warp  Place the sample as flat as possible, without tension on a smooth horizontal surface. The actual number of warp yarns shall be counted in 25 mm of cloth width.

5.2 Yarn Filling  The number of yarns per 25 mm in the filling direction shall be determined as in 5.1.

5.3 Evaluation of Test  When the warp direction is known, report the number of yarns per 25 mm as "A x B," where A and B are the number of warp and fill yarns per 25 mm respectively. When the warp direction is not known, report the number of yarns per 25 mm as "A:B," where A is the number of yarns per 25 mm in either direction and B is the number of yarns in the perpendicular direction.
1.0 Scope

1.1 This method describes the procedure required to examine materials and/or finished product for workmanship, which is the general quality of the goods other than as specified by the applicable standard.

2.0 Applicable Documents

3.0 Test Specimens

3.1 Any piece of a lot is subject to examination. Generally, those specimens prepared for inspection and/or testing for specific properties may be used to determine workmanship.

4.0 Apparatus or Material

4.1 Referee optical device - 10X magnification.

5.0 Procedure

5.1 Evaluation

5.1.1 At any stage of product handling, sample preparation, or specimen conditioning, the product shall be under scrutiny for detection of any defects, flaws, or unusual characteristics other than those specifically called out in the applicable specification, using unaided or corrected 20/20 vision.

5.1.2 In the case of a questionable evaluation with 20/20 vision, a referee inspection shall be made using the 10X magnification.

5.2 Record and Report

5.2.1 Each incidence of suspect flaw or defect shall be noted and documented. The authorized quality function shall determine whether the reliability, serviceability, or functionality of the product may be affected.

5.2.2 Record and report findings, including photographs of defect, if deemed necessary.

6.0 Notes None
1.0 Scope
To visually locate, and by feel, evaluate surface scratches during visual inspection. If more exacting data is required for referee evaluations of microsectioning per IPC-TM-650, Method 2.1.1 shall be used.

2.0 Applicable Documents
None.

3.0 Test Specimen
Any qualified submitted sheet(s) or cut to size panel(s) or periodic quality conformance specimens.

4.0 Apparatus
Dunlop Tortex guitar pick 1.00 mm thickness or equivalent.

5.0 Procedures
5.1 Test
5.1.1 Locate scratches visually using normal or corrected 20/20 vision.
5.1.2 Scratches which stop the pick when light pressure is applied are unacceptable. Scratches which can be felt by the pick but do not stop it are acceptable.
5.1.3 The referee test shall be by microsection per IPC-TM-650, Method 2.1.1.

5.2 Evaluation
5.2.1 Evaluate in the “working area” of the sheet or panel. Working area excludes a 1 in. border on all four edges. Compare results with inspection represented in the appropriate specification.
1.0 Scope
This inspection method is designed to visually inspect for dicyandiamide, commonly called “dicy,” that is not dissolved in the resin of prepreg materials in which it is used as a curing agent, by means of polarized lighting.

2.0 Applicable Documents
None.

3.0 Test Specimens
Unless otherwise specified, one ply of prepreg cut to 101.6 x 101.6 mm [4.0 x 4.0 in].

4.0 Apparatus or Material
4.1 An incidental light source such as a photographic light box, light table or illuminated microscope base. Light intensity shall be sufficient to detect small features of the specimen under fully polarized conditions, such as a 60 watt light bulb used in a light box.

4.2 A matched pair of polarizing filter lens.

4.3 A microscope capable of magnification at least 30X to 100X.

5.0 Procedure

5.1 Preparation

5.1.1 Place one polarizing filter directly over the light source. Place the specimen over the filter.

5.1.2 Place second polarizing filter over the specimen directly in line with the first filter.

5.1.3 Set microscope to desired magnification between 30X and 100X and position over the approximate center of the filters. For referee purposes, magnification shall be at 100X.

5.1.4 Focus microscope on the specimen through the top filter.

5.1.5 Rotate top filter 90° from bottom filter (see Figure 1).

5.2 Evaluation

5.2.1 Examine for the presence of dicy over the entire specimen, excluding the edges. The dicy (if present) will cause scattering of the polarized light which can then pass through the second filter in sufficient intensity to be visible.

5.2.2 Careful scrutiny must be used to eliminate consideration of dust or cracks in the resin as dicy, because they will also diffuse polarized light. Severe incidence of undissolved dicy may be observed using partially or non-polarized light.

5.3 Report
Presence of dicy shall be noted as per the degrees shown in Appendix A. Appearance as to the form, i.e., crystal, flake, or cluster, shall be reported.

6.0 Notes
6.1 Dicy is a curing agent used with epoxy resin; it is introduced at the resin mixing stage. If the mix is not homogeneous or is improperly done, particles of dicy may not dissolve or may be recrystallized. Dicy may also recrystallize during the treating operation. During lamination of the prepreg, dicy may contribute to the formation of voids or other defects.

6.2 Dicy Flake
A loose mass of crystals, usually in the form of crystals radiating from a center point.

6.3 Dicy Cluster
A concentration of crystals or flakes.

Figure 1 Dicy inspection set-up (expanded view)
Appendix A:  [Photos of dicy in lowest, medium, high, and extreme levels.]

<table>
<thead>
<tr>
<th>Degree 1</th>
<th>Degree 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Image" /></td>
<td><img src="image2.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Degree 2</th>
<th>Degree 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3.jpg" alt="Image" /></td>
<td><img src="image4.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>
DEGREES OF DICYANDIAMIDE (DICY) CRYSTALS

Degree 3

Degree 2

Degree 4

Degree 4

Degree 4

Degree 5
1 Scope  This method describes a procedure for quantifying the presence of inclusions and voids in flexible printed wiring materials.

2 Applicable Documents  None

3 Test Specimen  One specimen, 25 cm x 25 cm (per clad side for metal clad dielectrics).

4 Test Equipment

4.1 Shear for cutting 25 cm x 25 cm test specimen.

4.2 Microscope or optical inspection device capable of up to 30X magnification, having a reticle capable of measuring to the nearest 0.013 mm.

4.3 Etching system capable of removal of metal cladding.

4.4 Chemical etchant capable of metal removal without detrimental effect to either the adhesive or dielectric at 55°C ± 5°C.

5 Procedure

5.1 Sample Preparation

5.1.1 When the sample is metal clad, chemically erode 100% of the metal away, then wash and dry. When the sample is adhesive-coated, remove protective cover sheet. Because of the electrostatic nature of the material, neutralize the static with deionized air or equivalent.

5.1.2 Divide the specimen into 2.5 cm squares.

5.1.3 Randomly choose 10 of the squares to examine.

5.2 Examination

5.2.1 Using 30X magnification, inspect the 10 squares (see 4.2) for inclusions and voids. A void is the absence of the specified material in a localized area, such as a bubble or hole. An inclusion is a foreign particle, metallic or nonmetallic, that is entrapped (cannot be wiped off with a cloth) in the specified material and was not intended as part of the specified material, including gel particles.

5.2.2 Measure the longest dimension of the inclusion/void to the nearest 0.013 mm. Record the size in mm, quantity, and type of inclusion/void found.

5.3 Evaluation

5.3.1 Calculate the parts per million (ppm) of inclusions/voids as follows:

$$\sum \frac{K Y}{0.025} = \text{ppm}$$

where \( K \) is the size of the inclusion/void expressed in mm, \( Y \) is the number of inclusions/voids recorded of a particular size, and \( \text{ppm} \) is the inclusion/void presence. Formula for converting from mm to ppm:

$$\frac{\left(\sum K Y\right)}{0.25} = \text{PPM}$$

(For examination of 10 sites)

NOTE: For the purpose of this test method, an AQL requirement of 1.0% is equivalent to 10,000 ppm.

Where:

\( K = \) Size of inclusion/void in mm

\( Y = \) Number of inclusions/voids of a particular size.

Example

Suppose you examine a sample of 10 sites and record the following inclusions/voids per Table 1:

- Inclusions: 0.0875 mm, 0.0875 mm, 0.125 mm
- Voids: 0.025 mm, 0.025 mm, 0.05 mm, 0.0625 mm

Calculation of inclusions*

$$\frac{\left(\sum K Y\right)}{0.25} = \frac{0.05 (0.0875) + 0.025 (0.125)}{0.125} = 0.03 \text{ PPM}$$

Calculation of Voids*

$$\frac{\left(\sum K Y\right)}{0.25} = \frac{0.05 (0.025) + 0.025 (0.05) + 0.025 (0.0625)}{0.25} = 0.02 \text{ PPM}$$

Table 1 Sample Data Record

<table>
<thead>
<tr>
<th>Type</th>
<th>Number by Size (mm)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.025-0.075</td>
</tr>
<tr>
<td>Conductive</td>
<td></td>
</tr>
<tr>
<td>Non-conductive</td>
<td></td>
</tr>
<tr>
<td>Total Inclusions</td>
<td></td>
</tr>
<tr>
<td>Total Voids</td>
<td></td>
</tr>
</tbody>
</table>

*Note: If there were different sized inclusions/voids on the same sample, then these would be added together before converting to ppm.
1.0 Scope  This method is intended to cover all mechanical dimension inspections typically referenced on a Printed Board drawing. This will cover non-optically enhanced measurement techniques which are not covered by IPC-TM-650, Method 2.2.2.

2.0 Applicable Documents

ANSI NCSL Z540  International Calibration Standards or Physical Constants

3.0 Test Specimens  The test specimen(s) shall be defined in the applicable performance specification or standard.

4.0 Apparatus or Material

4.1 Mechanical measurement gage capable of sufficient accuracy precision and resolution to accomplish the necessary measurement (i.e., calipers, micrometers, pin gages, templates, etc.).

4.2 All mechanical measurement gages shall be calibrated in accordance with ANSI NCSL Z540, International Calibration Standards or Physical Constants.

5.0 Procedure

5.1 Gages which use an origin based system (i.e., calipers, micrometers) shall be initialized at the origin.

5.2 Operate the gage in a manner consistent to obtain the accuracy, repeatability, and precision required.

5.3 If the attribute to be measured can vary across the printed board, multiple measurements must be made to characterize the variation within the sampled area (i.e., hole sizes, thickness).

5.4 Read and record the dimensions for the attribute(s) measured using the same number of significant digits specified by the drawing, standard, or specification as a minimum or maximum limiting value.

6.0 Notes

The following items can affect the test results.

Tool wear & maintenance
Environment effects
Delicacy of gages – proper storage
Improper calibration

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1.0 Scope  
This method is intended to describe optically enhanced measurement techniques for dimensions of 3 mm or less, typically referenced on a Printed Board drawing. This method will not cover mechanical dimensional verification which is covered by IPC-TM-650, Method 2.2.1. This method is intended to supersede IPC-TM-650, Method 2.2.3.

2.0 Applicable Documents

IPC-OI-645  Standard for Visual Optical Inspection Aids
IPC-A-600E  Acceptability of Printed Boards

3.0 Test Specimens

3.1 The test specimen(s) shall be defined in the applicable performance specification or standard.

4.0 Apparatus or Material

4.1 Optical inspection aid capable of a magnification where the feature(s) to be measured occupies at least 20% of the field of view. (See IPC-OI-645 for detailed description.)

4.2 Reticle or Filar Micrometer attachment to Optical Inspection Aid that contains gradations or a scale, which will provide a minimum measurement resolution of 50% of the last significant digit of the referenced dimensional requirement. The Reticle or Filar Micrometer should be calibrated at the given magnification to ascertain the distance in mm (inches) between each division.

5.0 Procedure

5.1 Select an optical aid which allows for clear viewing of the area(s) containing the attributes to be measured.

5.2 Adjust the optical aid so that both the feature(s) to be measured and the reticle or filar micrometer attachment are in focus.

5.3 Align the reticle or filar micrometer so that the measurement scale is visible and aligned with the edges of the feature(s) to be measured.

5.4 Read the reticle or filar micrometer to obtain the number of divisions between feature edges.

5.5 To obtain the actual dimensions of the feature, multiply the number of divisions read by the calibration data previously obtained for the reticle or filar micrometer in (µm/division) (inches/division) at the given magnification.

5.6 Record the dimensions for the attribute(s) measured using the same number of significant digits specified by the drawing, standard, or specification as a minimum or maximum limiting value.

6.0 Notes

6.1 For a thorough description of the requirements, definitions, and certification provisions for optical inspection aids, see IPC-OI-645.

6.2 IPC-A-600 contains figures and diagrams which depict measurement techniques for certain attributed.
1 Scope  This test method is used to establish and define the procedures for determining thermal gradient dimensional changes of a plastic dielectric, metal clad or unclad. This method may also be used to determine dimensional changes after metal removal of a clad.

2 Applicable Documents  None

3 Test Specimen  The test specimen shall be at least 27 cm x 29 cm of unclad or metal clad dielectric material cut and punched per Figure 1.

4 Test Equipment
- Shear — for cutting 27 cm x 29 cm test specimens.
- Micro-Rule — with dial indicator reading to 0.0125 mm or less or an equivalent optical system.
- Hole Punch — 0.889 mm minimum diameter.
- Oven — mechanical convection type capable of maintaining a temperature of 150°C ± 2°C.
- Etcher — capable of maintaining test specimens a 43°C ± 5°C during the metal removal.
- Line Scribe — capable of producing a line 0.125 mm wide maximum.
- Chemical Etchant — capable of metal removal without detrimental effect to either the adhesive or dielectric.

5 Procedure

5.1 Sample Preparation  Scribe 0.125 mm wide lines or punch holes at positions A through D in specimen at locations shown in Figure 1. Allow specimen to stabilize at 23°C ± 2°C and 50% ± 5% relative humidity (RH) and measure separation of holes/lines between corresponding positions (center of hole or center of line). For example, the distance between hole centers A-B and C-D, also A-C and B-D. Record as initial measurement (1). Stabilization times may be reduced if statistically sound evidence has been generated on the specific product line to support shorter stabilization times to reach equilibrium.
Twenty-four hour stabilization is referee method.

5.2 Method A  Dimensional stability of unclad material due to thermal exposure—standard condition.
(1) Place test specimen unconstrained in an oven maintained at 150°C ± 2°C for 30 ± 2 minutes.
(2) Cool specimen to standard conditions of 23°C ± 2°C and 50% ± 5% RH for 24 hours minimum (see 5).
(3) Remeasure separation of holes/lines and record as final measurement after thermal exposure (F_l).

5.3 Method B  Dimensional stability of metal clad dielectrics due to metal removal.
(1) Chemically erode the metal away except for the target areas, which can have up to 13 mm x 13 mm square metal, using an etchant that has no detrimental effect on either the dielectric or adhesive. Wash and dry. The test specimen should be unconstrained during the etching, washing, and drying operation.
(2) Stabilize test specimen for 24 hours at 23°C ± 2°C and 50% ± 5% RH (see 5.1).
(3) Remeasure separation of holes/lines and record as final measurement after etching (F_2).

5.4 Method C  Dimensional stability of dielectric due to thermal exposure and metal removal, using specimens from Method B.
(1) Place unconstrained etched, conditioned, and measured specimen from Method B in an oven maintained at 150°C ± 2°C for 30 ± 2 minutes.
(2) Stabilize specimen at 23°C ± 2°C and 50% ± 5% RH for 24 hours and remeasure separation of holes (see 5.1).
(3) Remeasure separation of holes/lines and record as final after etching and thermal exposure (F_3).

5.5 Calculate the linear dimensional changes as follows:
(Start with initial reading I from 5.1)

\[
\text{M.D.} = \left( \frac{(A-B)_f - (A-B)_i}{(A-B)_i} + \frac{(C-D)_f - (C-D)_i}{(C-D)_i} \right) \times 100 \\
\text{T.D.} = \left( \frac{(A-C)_f - (A-C)_i}{(A-C)_i} + \frac{(B-D)_f - (B-D)_i}{(B-D)_i} \right) \times 100
\]

Where:
M.D. = % change in machine dimension.
T.D. = % change in transverse dimension.
I = Initial Reading.
F = Final Reading (Either F_1, F_2, or F_3).
A-B = Distance Between Points A & B.
A-C = Distance Between Points A & C.
C-D = Distance Between Points C & D.
B-D = Distance Between Points B & D.

6 Notes  The alternate method for marking clad samples allows the use of scribed lines. Caution must be used to protect scribed lines during etch operation.
1.0 Scope  This test method is to describe the procedures to be used for performing dimensional inspections on microsections of printed boards. This method does not apply to measurements less than 1.25 µm (0.00005 in). This method is intended to supersede IPC-TM-650, Methods 2.2.9 and 2.2.11.

2.0 Applicable Documents

IPC-TM-650  Method 2.1.1
IPC-TM-650  Method 2.1.1.2
IPC-A-600  Acceptability of Printed Boards

3.0 Test Specimens  The test specimens are to be microsections of printed boards or the associated quality conformance test circuitry prepared in accordance with IPC-TM-650, Methods 2.1.1 or 2.1.1.2.

4.0 Apparatus or Material

4.1 Metallographic equipment and consumables as described in IPC-TM-650, Methods 2.1.1 or 2.1.1.2.

4.2 In addition, the microscope or metallograph described in Methods 2.1.1 or 2.1.1.2 shall be equipped with a measuring reticle or filar eyepiece.

4.2.1 Reticle or Filar Micrometer attachment to Optical Inspection Aid that contains graduations or a scale, which will provide a minimum measurement resolution of 50% of the last significant digit of the referenced dimensional requirement. The Reticle or Filar Micrometer should be calibrated at the given magnification to ascertain the distance in µm (inches) between each division.

5.0 Procedure

5.1 The dimensional inspections are to be performed on freshly prepared and etched microsections. When oxidation and/or staining are present that would inhibit the clear viewing of the areas to be measured the microsections(s) shall be prepared again beginning with the finest grinding step in the metallographic preparation sequence.

5.2 The microscope’s or metallograph’s measuring reticle or filar eyepiece shall be calibrated in accordance with the manufacturer’s instructions using a stage micrometer. The calibration frequency shall be at a minimum of one (1) year intervals or more frequently, if required, to maintain accuracy of the dimensional inspections.

5.3 Attributes that can be measured using microsections of printed boards include but are not limited to: plating, coating, or solder resist thickness, the size of laminate voids or cracks, the amount of positive or negative etchback, conductor thickness, dielectric spacing, either laterally or vertically, annular ring width, layer-to-layer registration, or the extent of wicking.

5.4 Select a magnification that allows clear viewing of the areas containing the attributes to be measured. For instance, when viewing multilayer printed boards with plated-through holes or vias for layer-to-layer registration, magnifications of 50X to 100X would be used. When measuring plating thicknesses of electrodeposited copper or nickel, a magnification of 200X would be used.

5.5 Read and record the dimensions for the attributes(s) to be measured using the same number of significant digits specified by the drawing, standard, or specification as a minimum or maximum limiting value.

6.0 Notes

6.1 Measurements less than 1.25 µm (0.00005 in) cannot accurately be made using optical techniques. Electronic measurement techniques should be considered for these measurements.

6.2 IPC-A-600 contains figures and diagrams which depict microsectional attributes and measurements.
1.0 Scope  To measure the inside diameter of drilled through-holes in printed wiring boards, either in process or end product.

2.0 Applicable Documents

ICP-D-300 Dimensions and Tolerances, Printed Wiring Boards, Single and Two-Sided Rigid Boards.

ICP-A-600 Acceptability of Printed Wiring Boards.

3.0 Test Specimen  Sample board or production printed wiring board; in either case, the specimen shall have identical drilling or punching characteristics without through-hole punching.

4.0 Apparatus  Stereoscopic Microscope with 10x magnification, micrometer scale eye piece, and illuminator or equal.

5.0 Procedure

5.1 Measurement  Set the microscope on 10x magnification and measure the inside diameter of the hole from one side of the hole to the other side at the widest part of the hole.

5.2 Evaluation of Test  Record measurements of drilling and punching characteristics.
1.0 **Scope**  To measure the inside diameter of plated through holes in printed wiring boards.

2.0 **Applicable documents**  None.

3.0 **Test Specimen**  Production board or test pattern, number and design of holes shall be determined by agreement between vendor and customer or applicable drawings.

4.0 **Apparatus**

4.1 **Stereoscopic microscope**  With 20x magnification micrometer scale eye piece and illuminator.

5.0 **Procedure**

5.1 **Measurement**  Set the microscope on 20x magnification and measure the inside diameter of the hole from one side to the other side at the largest point.

5.2 **Evaluation of test**  Record measurements and note if voids and nodules were present.
1 Scope  To determine hole center line to datum dimensions on PWBs.

2 Applicable Document  None

3 Test Specimen  A PWB obtained at any point of the manufacturing process prior to mounting components.

4 Apparatus  Pocket and optical comparator for dimensions to be measured with a pocket comparator up to 13 mm and an optical comparator for dimensions over 13 mm.

5 Procedure

5.1 Measurement  Place the test specimen on a flat gauging table and measure all holes with respect to the datum.

5.2 Test Evaluation  Report all measurements as an average.
1.0 Scope  This is a nondestructive test that may be used at any time during the preproduction phase of printed wiring board manufacturing.

2.0 Applicable Documents

2.1 IPC-A-600  Acceptability of Printed Wiring Boards

2.2 IPC-D-325  End Product Documentation Specification for Printed Boards

3.0 Test Specimen  Any preproduction or production single-sided, double-sided, multilayer printed wiring board or test coupon. This may also be a discrete wiring board with pads on one or more layers.

4.0 Apparatus  Any optical, opto-mechanical, or mechanical measuring device capable of measuring to 0.001 in. or less. X-ray photographs may be used. All measurements should be made perpendicular to the specimen.

5.0 Procedure

5.1 General  Initially the determination of hole locations is made with respect to the master drawing, then the accuracy of the conductor placement is made as a secondary size control.

5.2 Hole Location  A test specimen is placed on the measuring device. All holes are measured for location accuracy. (Register to master drawing requirements.)

5.3 Double-Sided Boards and Multilayer Surface Layers—Conductor Locations  After locating hole center (paragraph 5.2), center of lands are located and compared to the centers of the respective holes. For variation of the pattern on one side compared to that on the other side, all measurements shall be made to the holes and compared.

5.4 Multilayer Boards—Internal Conductor Location  Multilayer internal registration may be determined using X-ray photography. One shot is taken with the test specimen laying flat. Two additional shots are taken with the specimen positioned at a 30° angle in both the X and the Y.

Proceed to measure the X-ray negatives or photographs using from 10 to 30 power.

6.0 Note  Set up and operating parameters, i.e., Kv, Ma, distance and time, will depend on the board thickness and type of equipment.
1.0 Scope  This method of test covers the procedure for determining weight (average thickness - by weight measurement) of copper foil for printed circuits.

2.0 Applicable Documents  None.

3.0 Test Specimen  Use template described below to cut three samples of copper. Samples should be taken from near the left and right edges and the center across the width of the roll.

4.0 Apparatus

4.1 Balance capable of weighing accurately to ±0.1 grams.

4.2 Knife suitable for cutting copper.

4.3 Template precut to 254 sq. in. (0.164 sq. meters) [12 in ±1/32 in by 21-3/16 in ±1/32 in] (304.8mm by 538.2 +0.079mm).

5.0 Procedure

5.1 Identify the samples (left, center and right); weigh sections singly and record values.

5.2 Evaluation

(1) One ounce copper foil (nominal 0.0014 in.) should weigh 50 grams ±5.

(2) Two ounce copper foil (nominal 0.0028 in.) should weigh 100 grams ±10.

(3) “X” ounce copper foil should weigh 50X grams ±10%.
1.0 Scope  
This method provides a technique for determining the overall thickness of treated or untreated copper foils and for determining the profile factor on foils used for the manufacture of electrical grade laminates and multilayer circuit boards.

The profile factor is the difference between the actual mechanical thickness of the foil and the calculated effective thickness based on the weight and density. This method will define the profile factor to about 0.00025 mm [0.01 mil], however, due to variations within the foil the use of values of increments less than 0.00125 mm [0.05 mil] is seldom necessary on treated foils. This method easily achieves this level of precision.

A. Background: While for a sample with perfectly flat surfaces the theoretical and actual thickness would be equal, in practice virtually all foils used in such applications are manufactured with one rough surface to enhance adhesion to the substrate. Since this irregular surface reduces the effective electrical thickness of the substrate material and may affect other electrical and mechanical properties, it is often useful to quantify the degree of variation from the theoretical thickness. The technique described herein provides a measure of this variation, which on normal foil generally runs from 0.0025 to 0.025 mm [0.1 mil to 1 mil] and may represent over a 50% increase to the foil's theoretical thickness.

B. Applications: The effective minimum electrical thickness of a double-sided laminate may be readily determined by subtracting the overall mechanical thickness of the foil (both sides) from the overall thickness of the laminate at a particular location.

The actual mechanical thickness of the base material may be estimated by subtracting the effective thickness of the copper foil from the overall mechanical laminate thickness.

The Profile Factor may be used to monitor variations of incoming foils of a particular type without time consuming microsectioning. Comparison of different foil types may be made but judgment or performance should be made using the actual criteria of interest.

2.0 Applicable Documents  
None.

3.0 Apparatus

3.1 Paper cutter

3.2 25.4 mm [1 inch] precision cutter, 324 mm [12 inches] long minimum.

3.3 Analytical balance 1 mg. resolution.

3.4 Standard 25.4 mm [1 inch] ratchet micrometer with 0.0025 mm [0.0001 inch] resolution (or better), 25 psi pressure, 6.4 mm [0.25 inch] anvil.

3.5 Parallel jaw pliers.

4.0 Specimen

4.1 Number: 3.

4.2 Form: 324 x 25.4 mm [12.00 x 1.00 inches].

4.3 Location

4.3.1 Roll: Specimens shall cut across the width of the foil from the center and both edges of the roll.

5.0 Procedure

5.1 Test

5.1.1 Fold the specimen around itself into a 10 ply 25.4 mm [1 inch] long sample maintaining the treated side out so that there are no treated side to treated side interfaces.

5.1.2 Weigh the specimen on the analytical balance to the nearest 0.001 gram and record as WI.

5.1.3 Compress the outer 3.2 mm [1/8 inch] of the specimen using a pair of pliers with parallel jaws or equivalent device.

5.1.4 Using the micrometer, measure the thickness of the specimen to the nearest 0.0025 mm [0.0001 inch] or better in four locations around the center at least 3.2 mm [1/8 inch] from the compressed edges. Use three clicks of a properly calibrated ratchet micrometer (providing a force of 25 psi ±5 psi on the sample).
5.2 Calculation

5.2.1 Calculate the effective thickness of the foil in mils by multiplying the weight of the 324 x 25.4 mm [12 x 1 inch] specimen by 0.572 mil/g.

\[ Te \text{ (mil)} = 0.572 \frac{\text{mil}}{\text{g}} \times W \text{ (g)} \]

\[ Te = \text{Thickness Equivalent} \]

Sample calculation:

\[ W = 2.16 \text{ g} \]

\[ Te = 0.572 \text{ mil/g} \times 2.16 \text{ g} = 0.0031 \text{ [1.236 mil]} \]

5.2.2 Calculate the average mechanical thickness micrometer of each 10 ply specimen from the four values taken on each sample.

5.2.3 Calculate the average overall thickness (Tm) for each sample by dividing the average thickness of the specimen by the number of plies.

5.2.4 Calculate the average profile factor of the foil for each specimen by subtracting the effective thickness from the average mechanical thickness.

\[ PF = Tm - Te \]

5.2.5 Average the three values of profile factor.

5.3 Report

5.3.1 Report the average profile factor for the three specimens tested.

5.3.2 Report the average mechanical thickness for the three specimens tested.

6.0 Notes

Thickness of Specimen: The thickness of the specimen used must be at least 100 times the precision of the thickness measuring device. More plies may be required for lighter foil, e.g., 0.5 ounce per square foot foil if the micrometer precision is 0.0025 mm [0.0001 inch] since a minimum of 0.25 mm [10 mils] is required to fulfill the 1% requirement. If a precision 25.4 mm [1 inch] cutter is not available a paper cutter or punch and die set may be used for sample preparation, however, the areas of the sample used for weight determination must be known to 1% or better and the thickness sample must be free from wrinkles or creases.

Precision: A study of various 1 oz./ft copper foils resulted in reproducibility between testers using a hand micrometer with 0.0013 mm [0.00005 inch] resolution.

Comparison to Other Methods: The profile factor determined by this test may vary slightly from the actual profile height as estimated from other methods, such as microsectioning or profilometry. The denser the treatment structure the more this technique will underestimate the true profile height. The precision of this method between testers was about 50% better than microsectioning in determining the amount of profile on low profile treated ED copper using the same number of determinations using a single microsection as the test vehicle. The time required by this method is under 5 minutes.
1.0 Scope  This method of test covers the procedure for determining the weight and/or thickness of releasable carrier copper foils for printed circuits.

2.0 Applicable Documents  None.

3.0 Test Specimen  Use template described below to cut three samples of carrier copper foil. Samples should be taken from near the left and right edges and center across the width of the roll.

4.0 Apparatus

4.1 Balance capable of weighing accuracy to ±0.001 grams.

4.2 Knife suitable for cutting copper.

4.3 Template pre-cut to 0.026 sq. meters [40 sq. in] 100 ±0.1 mm by 250 ±0.1 mm [4 ±1/32 in by 10 ±1/32 in].

4.4 B-Stage (prepreg) material and sufficient laboratory equipment for lamination.

5.0 Procedure

5.1 Test

5.1.1 Cut three specimens 100 x 250 mm [4 by 10 inches] in size across the web of the roll.

5.1.2 Using a balance, weigh three separate specimens to the nearest 0.001 grams. Record the weights for each specimen.

5.1.3 Laminate the three specimens to a B stage (prepreg) material to a total thickness of 1 mm [0.062 in] thick (suggest 8 piles of No. 7628 glass style 0.17 mm [0.0068 in] nominal thickness or equal).

5.1.4 After lamination, remove the carrier substrate. Weigh the carrier on a balance to the nearest 0.001 gram. Record the weights, Subtract the weights recorded from the corresponding weights in 5.1.2.

5.2 Evaluation

5.2.1 To calculate the approximate thickness of the thin copper foil in microns, multiply the weight difference obtained in 5.1.4, by the factor 4.349.

5.2.2 To calculate the area weight in grams per 6451 square mm [254 square inches] of the carrier copper foil, multiply the weight difference obtained in 5.1.4 by the factor 6.35.

5.2.3 To calculate the area weight in ounces per 3657 square mm [square foot] of the carrier copper foil, multiply the weight difference by the factor 0.127.
1.0 Scope  This method of test covers the procedure for determining the weights and/or thickness of etchable carrier copper foils for printed circuits.

2.0 Applicable Documents  None.

3.0 Test Specimen  Use template described below to cut three samples of carrier copper foil. Samples should be taken from near the left and right edges and center across the width of the roll.

4.0 Apparatus

4.1 Balance capable of weighing accuracy to ±0.001 grams.

4.2 Knife suitable for cutting copper.

4.3 Template pre-cut to 0.026 sq. meters [40 sq. in] 100 +0.1 mm by 250 ±0.1 mm [4 ±1/32 in by 10 ±1/32 in].

5.0 Procedure

5.1 Test

5.1.1 Cut three specimens 100 x 250 mm [4 by 10 inches] in size across the web of the roll.

5.1.2 Using a balance, weigh three separate specimens to the nearest 0.001 grams. Record the weights for each specimen.

5.1.3 Remove the copper from the carrier substrate by etching the samples in a 50% nitric acid solution for 30 seconds or a suitable time to remove the copper foil. Rinse and dry.

5.1.4 Reweigh carrier substrate on the balance to the nearest 0.001 gram. Record the weight of each sample. Subtract the weights recorded from the corresponding weights in 5.1.2.

5.2 Calculation

5.2.1 To calculate the approximate thickness of the etchable carrier copper foil in microns, multiply the weight difference obtained in 5.1.4, by the factor 4.349.

5.2.2 To calculate the area weight in grams per 6451 square mm [254 square inches], multiply the weight difference obtained in 5.1.4 by the factor 6.35.

5.2.3 To calculate the area weight of the etchable carrier in ounces per 3657 square mm [square foot], multiply the weight obtained in 5.1.4 by the factor 0.127.
1.0 Scope

1.1 A nondestructive inspection method for determining the quality of plated-through connections in printed wiring boards.

1.2 Theory. Copper will display a resistivity of known value depending upon the geometry of the shell and the conductivity of the copper. If the shell is not uniform, defects such as cracks, voids, or thin spots in the copper will cause the measured resistance to be higher than the theoretical value. This value is computed by using the equation given in Fig. 1.

2.0 Applicable Documents

IPC-TC-500 Specification for copper plated through hole, two-sided boards, rigid.

3.0 Test Specimen

3.1 Description of Specimens. The following types of specimens can be tested using the equipment specified herein:

(1) Printed wiring boards, either two-sided or multilayer, which can fit properly within the neck of the test meter.

NOTE: In testing of plated-through holes in two-sided or multilayer printed wiring boards, the measurement is the resistance of the plating in the hole only and is not related to any interconnected circuit terminating in that hole, unless there is an electrically parallel circuit, i.e., two or more holes located within 0.25” of each other.

(2) Printed wiring boards up to 3/8” in thickness.

(3) Plated-through connections of any diameter which can be spanned conveniently by the probes.

3.2 Specimen Preparation. Insulating materials such as flux, conformal coatings, encapsulating compounds, adhesives, mold release compounds, etc., shall be removed from the terminal areas to allow a positive metal-to-metal contact to be made between the probes and the plated-through hole terminal area. Closely spaced conductors shall be masked to prevent the probes from bridging between the terminal areas and adjacent conductors. Whatever material is used to mask the conductors shall be located in such a manner that the probes are not separated from the hole to be measured.

Figure 1 Resistance Calculation of Plated-Through Connection

\[ R = \frac{0.215348 \times 10^4 (T)}{D \cdot t^2} \]

where:

- \( R \) = resistance (ohms)
- \( T \) = thickness of PWB (inches)
- \( D \) = diameter of drilled hole (inches)
- \( t \) = copper plating thickness in hole (inches)

NOTES:

1. It is assumed that the conductivity of the copper is 100 percent IACS.
2. To compute the value of \( t \) with known values of \( D, T, \) and \( R \), use the following equation:

\[ t = 0.5D - \left[ \frac{0.25D - 0.219T}{R} \right]^{1/2} \]

where

- \( R \) = resistance (microhms) and \( D, T, \) and \( t \) are in inches.
3.3 Operating Conditions. The evaluation of the plated-through holes shall be performed at room temperature (68° to 75° F) and the printed wiring boards to be evaluated shall be stabilized at that temperature for approximately one hour prior to evaluation.

4.0 Apparatus

4.1 Description of Equipment. The microhm resistance meter used in the nondestructive testing employs the standard four-probe technique. The equipment is portable and suitable for bench operation. The equipment consists of two essential parts:

1. the mechanical portion for providing physical attachment with the test specimen and
2. the electrical-electronic portion for providing the microhm readout of the through connection being measured

The probes are tension-suspended to ensure positive interfacial contact with the termination areas over a range of material thicknesses.

4.2 The meter impresses a constant ac current into the through connection, and the voltage that develops across the hole is sensed. This voltage is amplified and observed visually on a suitable meter or a digitized readout. See circuit diagram in Fig. 2A.

5.0 Procedure

5.1 Calibration of Equipment. In order to provide valid resistance measurements, the equipment must be calibrated as specified in the manufacturers’ instruction manual.

5.2 Test Steps. The steps to be performed in evaluating the quality of plated-through holes in printed wiring boards are as follows:

5.2.1 Calibrate the equipment.

5.2.2 Prepare and condition the specimen(s) to be inspected per 3.2.

5.2.3 Position the printed wiring board between the probes as shown in Fig. 2B.

5.2.4 Depress the upper probes until they are locked over the plated-through hole.
NOTE: A steady reading indicates that the probes are making good contact. Trial settings to obtain the minimum resistance value will indicate when the probes are properly located over the interconnection.

5.2.5 If poor electrical contact is evidenced, relocate the probes until a minimum resistance is indicated.

NOTE: During the microscopic inspection (30X) of the edges of the plated-through hole and the adjacent areas on the terminal area, there shall be no detectable damage to the surfaces by contact with the probes during testing. In the absence of such surface defects, the microhm testing can assuredly be considered nondestructive.

5.2.6 Read and record the microhm value.

5.2.7 Compare the microhm value with the plating thickness of the standardization curve as illustrated in Fig. 3. The theoretical curves shown in Fig. 3 indicate to within 0.2-mil thickness the plating in the through connection and for all practical purposes are representative of the resistance-plating thickness relationships encountered in practice.

NOTE: This comparison shall indicate if the plating thickness of the through connection meets the acceptable thickness requirements.

5.2.8 When this method is used, any reading above the specified allowable microhm reading shall be reason for further investigation of the defect for conformance to the requirements of the applicable fabrication specification.

5.2.9 Plating thickness curves shall be generated by the user.

6.0 Resistance Curves

6.1 Curves for the resistances of plated-through holes of three different diameters in 1/16” printed wiring boards are presented in this test method (Fig. 3). Over coatings of gold, tin-lead, etc., can have an effect on the micro-ohm readings depending on the electrical resistance relative to the copper. Resistivity of tin-lead is approximately ten times that of copper, while gold is of the same resistivity.

6.2 To eliminate material and equipment variables, the user should develop thickness-resistance curves for his particular condition based on metallographic cross-section measurements (TM-650 Method 2.2.13). These curves may be used as guides for acceptance of product.
Figure 3  Microhm Meter Calibration Curves
1.0 Scope A method for determining whether or not the powder in a solder paste complies with the relevant powder type. The ASTM B-214 standard screen powder size distribution method has been found to be acceptable.

2.0 Applicable Documents
ASTM E11
BS.410
DIN 4188
ISO 565
ISO 3310

3.0 Test Specimen
Approximately 150 grams of solder paste

4.0 Equipment/Apparatus
Vibratory test sieving machine
Test sieves to BS.410, ASTM E11, DIN 4188, or ISO 565 and ISO 3310 with mesh openings of 150, 75, 45, 38, 25 and 20 micrometers
Sieve bottom receiver and lid
Balance (scale) with an accuracy of 0.01 g
Beaker 400–600 ml
Watch glass
Solvent
Acetone
Spatula

5.0 Procedure

5.1 Preparation
5.1.1 Wait, if necessary, until the solder paste is at room temperature.

5.2 Test
5.2.1 Homogenize the paste by stirring with the spatula.

5.2.2 Weigh paste containing approximately 110 g of solder alloy into the carefully cleaned beaker.

5.2.3 Add approximately 50 ml solvent.

5.2.4 Stir the mixture with the spatula so that the flux in the paste can dissolve in the solvent.

5.2.5 Cover the beaker with the watch glass.

5.2.6 Let the beaker with the watch glass stand until the solder powder settles.

5.2.7 Decant, carefully, as much as possible of the fluid without losing any of the solder powder.

5.2.8 Repeat the extraction procedure five times, using 50 ml solvent for each extraction.

5.2.9 Add approximately 50 ml acetone to the washed solder powder and stir with the spatula to assist in drying.

5.2.10 Let the solder powder settle.

5.2.11 Decant, carefully, as much as possible of the acetone.

5.2.12 Repeat the acetone wash 2 additional times.

5.2.13 Allow the powder to dry at ambient temperature until the weight is constant.

5.2.14 Weigh test sieves, with mesh opening sizes appropriate for the type of powder being tested, and the sieve bottom receiver. Typical sieves required are shown in Table 1.

<table>
<thead>
<tr>
<th>Table 1 Screen Opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
</tr>
<tr>
<td>Type 2</td>
</tr>
<tr>
<td>Type 3</td>
</tr>
<tr>
<td>Type 4</td>
</tr>
</tbody>
</table>
5.2.15 Place the sieves on the receiver with the sieve with the smallest opening on the receiver and processing sequentially upward to the largest opening screen.

5.2.16 Weigh the powder and put this in the top sieve.

5.2.17 Place the lid on the sieve combination and transfer this to the sieving machine.

5.2.18 Run the machine for approximately 40 minutes.

5.2.19 Reweigh the sieves and the receiver.

5.2.20 Subtract the original weights of the sieves and the receiver to obtain the weights of powder with sizes greater than, within, and less than the nominal size range from Table 2A and 2B.

### Table 2A % of Sample by Weight—Nominal Sizes

<table>
<thead>
<tr>
<th>Type</th>
<th>Less Than 1 % Larger Than</th>
<th>80% Minimum Between</th>
<th>10% Maximum Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>150 Microns</td>
<td>150–75 Microns</td>
<td>20 Microns</td>
</tr>
<tr>
<td>Type 2</td>
<td>75 Microns</td>
<td>75–45 Microns</td>
<td>20 Microns</td>
</tr>
<tr>
<td>Type 3</td>
<td>45 Microns</td>
<td>45–25 Microns</td>
<td>20 Microns</td>
</tr>
</tbody>
</table>

### Table 2B % of Sample by Weight—Nominal Sizes

<table>
<thead>
<tr>
<th>Type</th>
<th>Less Than 1 % Larger Than</th>
<th>90% Minimum Between</th>
<th>10% Maximum Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 4</td>
<td>38 Microns</td>
<td>38–20 Microns</td>
<td>20 Microns</td>
</tr>
</tbody>
</table>

5.3 **Evaluation** Express the masses of the powder above, within, and below the nominal size range as percentages of the mass of the original sample. Enter data in Table 3.

### Table 3

<table>
<thead>
<tr>
<th>Type</th>
<th>+150µm</th>
<th>+75 µm</th>
<th>+20 µm</th>
<th>−20 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 2</td>
<td>+ 75 µm</td>
<td>+45 µm</td>
<td>+20 µm</td>
<td>−20 µm</td>
</tr>
<tr>
<td>Type 3</td>
<td>+ 45 µm</td>
<td>+25 µm</td>
<td>+20 µm</td>
<td>−20 µm</td>
</tr>
<tr>
<td>Type 4</td>
<td>+ 38 µm</td>
<td>+20 µm</td>
<td>−20 µm</td>
<td></td>
</tr>
</tbody>
</table>
1.0 Scope   This test specifies a standard procedure for estimating the particle size and the particle shape of solder powder in solder pastes by microscopic methods.

2.0 Applicable Documents   None

3.0 Test Specimen
1 gram of solder paste

4.0 Equipment/Apparatus
Thinner
Spatula
Beaker 30 ml
Microscope, magnification 100 times
Measuring ocular, scale division 10 µm
Microscope slides
Microscope glass cover slips

5.0 Procedure

5.1 Preparation

5.1.1 Wait, if necessary, until the solder paste is at room temperature.

5.2 Test

5.2.1 Homogenize the paste by stirring with the spatula.

5.2.2 Weigh approximately 4 g of thinner.

5.2.3 Add approximately 1 g of the solder paste.

5.2.4 Stir with the spatula until a uniform mixture has been obtained.

5.2.5 Apply a small drop on the microscope slide.

5.2.6 Cover the slide with the cover slip and press gently to spread out the small drop between the glasses.

5.2.7 Measure with the microscope the length and width of the estimated smallest and largest solder powder particles in a viewing area of approximately 50 particles. (Photographs may be used for measuring and/or reference purposes).

5.2.8 Estimate the principle shape of the particles as spherical or non-spherical.

5.3 Evaluation   Express the masses of the powder above, within, and below the nominal size range as percentages of the mass of the original sample. Enter data in Table 1.

<table>
<thead>
<tr>
<th>Type</th>
<th>+150µm</th>
<th>+75 µm</th>
<th>+20 µm</th>
<th>−20 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 2</td>
<td>+ 75 µm</td>
<td>+45 µm</td>
<td>+20 µm</td>
<td>−20 µm</td>
</tr>
<tr>
<td>Type 3</td>
<td>+ 45 µm</td>
<td>+25 µm</td>
<td>+20 µm</td>
<td>−20 µm</td>
</tr>
<tr>
<td>Type 4</td>
<td>+ 38 µm</td>
<td>+20 µm</td>
<td>−20 µm</td>
<td></td>
</tr>
<tr>
<td>Type 5</td>
<td>+ 30 µm</td>
<td>+15 µm</td>
<td>−15 µm</td>
<td></td>
</tr>
<tr>
<td>Type 6</td>
<td>+ 15 µm</td>
<td>+ 5 µm</td>
<td>− 5 µm</td>
<td></td>
</tr>
</tbody>
</table>
1.0 **Scope**  This test method is designed to determine powder particle size distribution in creams by image analysis.

2.0 **Applicable Documents**  None

3.0 **Test Specimen**  10 grams of solder paste

4.0 **Equipment/Apparatus**  Thinner

5.0 **Procedure**

5.1 **Preparation**

5.1.1 Stencil some solder cream onto a glass slide using a 5 or 6 mm diameter, 0.1 mm thick stencil.

5.1.2 Apply a little thinner to the solder paste and gently disperse the paste over an area about 20 mm diameter, using a glass rod. Cover with a 22 mm diameter cover glass and gently press to give a monolayer dispersion of powder particles under the cover glass.

It is important to get a good dispersion without a lot of bubbles or particle agglomerates. If the paste you are examining has a high metal content, remove some of the stencilled paste before dispersing it. The standard stencils are suitable for 85–86% metal paste.

5.1.3 Label the glass slide with the powder batch number.

5.2 **Images for Analysis**  The next step is to put 10 or 15 images from each sample into an image directory.

5.2.1 Start up the image analyzer.

5.2.2 Set up the microscope illumination for X10 and select the X10 objective.

5.2.3 Put the slide on the microscope, focus, swing the binocular eyepiece to the left sending the light to the TV camera, and refocus on the screen.

5.2.4 Ensure that there are no agglomerations or badly out-of-focus particles and then capture the image.

5.2.5 Capture 10 images covering the slide in a systematic way without consciously selecting areas (other than avoiding agglomerations and areas of very low particle density).

5.2.6 Record the number of the slide and remove from the microscope.

5.2.7 Put the next slide on the microscope and repeat the process.

5.2.8 When all the samples have been recovered, swing the eyepiece back and switch off the microscope.

5.2.9 Comments

– Do not change the illumination between samples.

– Record a series of samples at the same magnification.

5.3 **Image Analysis**

5.3.1 When images from the required number of samples have been entered, select ‘Multi Sample Size’ on the menu (or ‘One Sample Size’ for a single sample). An image in red and blue will then come up on the screen.

5.3.2 Using the left and center buttons on the mouse, adjust the thresholds until the red areas correspond to the particles to be measured. Selecting the right hand button allows you to vary the line on the screen where the intensity plot is measured. Adjust the top threshold so that it is about halfway down the intensity minima. Press center and right buttons on the mouse simultaneously.

5.3.3 You should now see a green rectangle on a grey image. If there is no rectangle, press the left hand button until one appears.

5.3.4 A particle is measured if the top of the particle lies within the rectangle, so the size and position of the rectangle must be adjusted so that the sides are half a particle diameter from the sides of the screen, and the base of the rectangle a whole particle diameter from the bottom of the screen. The top of the rectangle should lie along the top of the screen. The
middle button on the mouse swaps between ‘moving’ and ‘growing’ the rectangle. When the rectangle is set, press the right hand button on the mouse to proceed.

5.3.5 On the keyboard that now comes up on the screen, select the number of samples being processed.

5.3.6 On the next keyboard select the number of particles to be measured (200 for type 1-4 and 400 for type 5-6 is suggested).

5.3 Evaluation Express the masses of the powder above, within, and below the nominal size range as percentages of the mass of the original sample. Enter data in Table 1.

| Table 1 |
|---------|---------|---------|---------|---------|
| Type 1  | +150μm  | +75 μm  | +20 μm  | −20 μm  |
| Type 2  | + 75 μm | +45 μm  | +20 μm  | −20 μm  |
| Type 3  | + 45 μm | +25 μm  | +20 μm  | −20 μm  |
| Type 4  | + 38 μm | +20 μm  | −20 μm  |         |
| Type 5  | + 30 μm | +15 μm  | −15 μm  |         |
| Type 6  | + 15 μm | + 5 μm  | − 5 μm  |         |
1.0 Scope  This test method is designed to determine the maximum (average) solder particle size in a solder paste using a fineness of grind gauge.

2.0 Applicable Documents
ASTM D-1210-79  Fineness of Dispersion of Pigment-Vehicle Systems

3.0 Test Specimen  At least 100 grams of uniformly mixed solder paste.

4.0 Equipment/Apparatus  
Gauge-Hegman Type CMA 185*, or equivalent, in accordance with ASTM D1210-79. A hardened steel, stainless steel, or chrome-plated steel block approximately 175 mm in length, 65 mm in width, and 13 mm thick.

The top surface of the block shall be ground smooth and flat and shall contain one or two grooves 140 mm in calibrated length and 12.5 mm wide parallel to the longer sides of the block.

Each groove shall be tapered uniformly in depth lengthwise from a suitable depth (for example 50 to 100 micrometers) at 10 mm from one end to zero depth at the other with intermediate calibrations in accordance with the depth at these points.

Scraper—A single- or double-edged hardened steel, stainless steel, or chrome-plated steel blade 90 mm long, 38 mm wide, and 6.4 mm thick. The edge or edges on the long sides shall be straight and rounded to a radius of approximately 0.38 mm.

5.1 Test
5.1.1 Using a fineness of grind gauge (Hegman) Type CMA 185 or equivalent in accordance with ASTM D-1210 determine the maximum and average particle size of the powder.

5.2 Evaluation  Acceptance of each type of powder shall be based on the specifications listed in Table 1. Enter the results in Table 2 "Test Report on Solder Paste."

*Source: Precision Gage & Tool Co. 28 Volkenand Ave., Dayton, Ohio 45410 513/254-8404

Table 1

<table>
<thead>
<tr>
<th>Type</th>
<th>1st</th>
<th>4th</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>160µm</td>
<td>150 µm</td>
<td>140 µm</td>
</tr>
<tr>
<td>Type 2</td>
<td>80µm</td>
<td>75 µm</td>
<td>65 µm</td>
</tr>
<tr>
<td>Type 3</td>
<td>50µm</td>
<td>45 µm</td>
<td>40 µm</td>
</tr>
<tr>
<td>Type 4</td>
<td>40µm</td>
<td>38 µm</td>
<td>35 µm</td>
</tr>
<tr>
<td>Type 5</td>
<td>30µm</td>
<td>25 µm</td>
<td>23 µm</td>
</tr>
<tr>
<td>Type 6</td>
<td>20µm</td>
<td>15 µm</td>
<td>15 µm</td>
</tr>
</tbody>
</table>
Table 2 Test Report on Solder Paste

Enter appropriate information in top portion of report and complete report by entering the test results or checkmarks in the appropriate spaces.

Inspection Purpose:

- Qualification
- Quality Conformance A
- Quality Conformance B
- Shelf-Life Extension
- Performance

QPL I.D. Number: __________
Manufacturer’s Identification: ________________________
Manufacturer’s Batch Number: ________________________
Date of Manufacture: ________________________
Original Use-By Date: ________________________
Revised Use-By Date: ________________________

Overall Results: __ Pass __ Fail

Inspection Performed by: ________________________ Witnessed by: ________________________

<table>
<thead>
<tr>
<th>Inspections</th>
<th>User’s Actual Requirement</th>
<th>Test Result</th>
<th>P/F (*)</th>
<th>Tested by &amp; Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Metal Content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solder Ball</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slump</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alloy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flux</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powder Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% In Top Screen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% In Next Screen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% In Bottom Screen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% In Receiver Bottom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Powder Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powder Shape</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tack</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* P/F = PASS/FAIL; enter P if test results are within tolerance of actual requirement; otherwise, enter F
1 Scope  This method describes the measuring technique used to measure the physical dimensions of flexible flat cable.

2 Applicable Document  None

3 Test Specimen

3.1 The number of production samples shall be determined by the manufacturer and/or user, and as a minimum shall be three samples.

3.2 The test specimen shall be a minimum of 3 m.

4 Apparatus

4.1 Toolmakers microscope calibrated to 0.0001, or equivalent

4.2 Flange micrometer calibrated to 0.0001, or equivalent

4.3 Gauge blocks

5 Procedure

5.1 Prepare test specimens from Section 3 by cutting perpendicular to the edge across the full width of the cable using a paper cutter or other suitable cutter. A minimum of five random cuts are to be made per 3 m sample, resulting in six cable segments.

5.2 Measure cable thickness using apparatus from 4.2. Measurements shall be made across the full width of the cut edge of each cable segment.

5.3 Fixture each cable segment between two parallel gauge blocks, which are longer than the segment is wide. Cut edge of cable must be flush with surface "A" of the gauge blocks. All remaining dimensions are to be measured with the apparatus from 4.1. One edge of each of the segments is to be measured (see Figure 1).

Figure 1  Gauge Blocks and Test Specimen Example
1 Scope   This test method is used to evaluate 1:1 artwork masters for adequacy in meeting end product annular ring requirements for the existence of extra, missing, or mislocated pads, and for the correctness of conductor placement relative to the holes.

2 Applicable Documents   None

3 Test Specimens

3.1 1:1 artwork masters for each printed circuit layer

3.2 Drilled dummy panel

4 Apparatus

4.1 Light table

4.2 Magnifier

5 Procedure

5.1 Preparation/Drill Dummy

5.1.1 Prepare a drill tape to be used for the production PCB corresponding to the artwork masters being evaluated.

5.1.2 Drill a piece of copper clad circuit board material with the drill tape, but modify the hole sizes called out on the master drawing as explained in 5.1.2.1 through 5.1.2.3.

5.1.2.1 For all of the PTHs, drill 18 to 24 mils larger than the maximum after plating hole size called out on the master drawing for that hole.

Note: The exact number to be selected from this range (18 to 24 mils) will vary from shop to shop, depending on such variables as equipment, tooling, and panel size. As a general rule, lower numbers mean that smaller panels, better registration tooling, and more sophisticated production equipment must be used.

5.1.2.2 For all non-plated-through holes, drill the holes to the maximum size indicated on the master drawing.

5.1.2.3 Clean and deburr the drilled dummy panel.

5.1.3 Artwork Masters   A 1:1 artwork master must be prepared for evaluation for each printed circuit layer. The following options apply:

a. Negatives for each layer
b. Bleached positives for each layer
c. Diazo film for each layer
d. Combinations of the above

5.2 Test

5.2.1 Tape the drilled dummy panel to the light table.

5.2.2 Align the first piece of film to the dummy panel, averaging the relative positions of the drilled holes to the pads on the artwork master to maximize annular rings without breakout.

5.2.3 Evaluate the result under magnification, then remove the film.

5.2.4 Align the next piece of film and evaluate in the same manner. Continue this process until all layers have been evaluated.

5.3 Evaluation

5.3.1 Examine each layer when aligned to the drilled panel under magnification for the following deficiencies:

a. Breakout of hole to pad
b. Missing pads
c. Mislocated pads
d. Extra pads
e. Insufficient clearance between conductors and holes
f. Holes running through conductors
1 Scope  This test method is used to evaluate 1:1 artwork masters for layer to layer registration, conductor to edge spacing, screened nomenclature positioning, and solder mask to conductor relationships.

2 Applicable Documents  None

3 Test Specimens
3.1 1:1 artwork masters for each printed circuit layer

4 Apparatus
4.1 Light table
4.2 Magnifier

5 Procedure
5.1 Preparation of Artwork Masters
5.1.1 One layer must be selected and used for the evaluation of all other layers. The layer selected should have one or more of the following attributes:
   a. Layer used for drill programming
   b. Layer possessing the smallest pads
   c. Layer possessing all the pads
5.1.2 Prepare a positive film of the selected layer

5.2 Test
5.2.1 Tape the drilled positive artwork to the light table.
5.2.2 Align the first piece of negative film to the positive artwork master and adjust for maximum blockage of transmitted light. In the case of varying pad sizes, adjust for maximum concentricity.
5.2.3 Evaluate the result under magnification. Remove the negative.
5.2.4 Align the next negative and evaluate in the same manner. Continue this process until all layers have been evaluated.

5.3 Evaluation
5.3.1 Examine each layer when aligned to the positive under magnification for the following deficiencies:
   a. Misregistration of pads
   b. Misregistration of solder mask image
   c. Screened nomenclature falling on land areas
   d. Screened nomenclature falling in holes
   e. Conductors or ground planes too close to board edges

5.1.3 Prepare negatives of all the other layers.
1 Scope  This method defines the procedure for determining the roughness or profile of metallic foils.

1.1 The surface finish or roughness of foils shall be evaluated using $R_a$. $R_a$ is defined as the arithmetic average value of all absolute distances of the roughness profile from the center line within the measuring length.

1.2 The foil profile of foils shall be evaluated using the parameter $R_z$ (DIN) or $R_{TM}$, which is defined as the average maximum peak to valley height of five consecutive sampling lengths within the measurement length. This value is approximately equivalent to the values of profile determined from microsectioning techniques.

1.3 $R_z$ (ISO) is a different parameter from $R_z$ (DIN) and is not applicable to this method.

2 Applicable Documents

DIN 4768
ISO 4287

3 Test Specimens  Cut a specimen 101 x 101 mm [4 x 4 in] minimum from the representative sample. The location and number of specimens shall be defined in the material specification.

4 Apparatus/Materials

4.1 Knife or other suitable device.

4.2 Profilometer or surface roughness meter with a motorized drive and the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut Off</td>
<td>0.8 mm</td>
</tr>
<tr>
<td>Measuring Length</td>
<td>4.0 mm</td>
</tr>
<tr>
<td>Tracing Length</td>
<td>&lt;5 mm</td>
</tr>
<tr>
<td>Diamond Stylus Radius</td>
<td>0.005 mm</td>
</tr>
</tbody>
</table>

5 Procedure

5.1 Check the profilometer calibration using the appropriate roughness standard for the value $R_a$ or $R_{ZDIN}$ ($R_{TM}$) and magnitude to be measured. Insure the stylus moves perpendicular to the grooves and the surface.

5.1.1 Compare the values obtained on six different measurements taken at different locations within the standard to the certified (not nominal value) of the standard. If the average result is not within 2% of the standard value, adjust the instrument and repeat 5.1 until this tolerance is achieved.

5.2 Place the foil test specimen on the plate glass surface with the side to be tested away from the glass. Secure the specimen with tape or a weight at both ends to prevent movement or buckling during the measurement.

Roughness Parameter

$R_a$, per 1.1
$R_{ZDIN}$ or $R_{TM}$, per 1.2

Note: See Footnote No. 1 for equipment found suitable for determination of both $R_a$ and $R_{ZDIN}$ ($R_{TM}$). 1

4.3 Roughness Standard

Smooth Side: $R_a$ with 5% or better certified tolerance
Treated Side: $R_{ZDIN}$ ($R_{TM}$) with 5% or better certified tolerance

4.4 Plate glass or other smooth flat surface

4.5 Compressed air

4.6 Gloves, lint free

4.7 Tape or weight

1. Profilometers which have been used to measure both $R_a$ and $R_z$ or $R_{TM}$ are: Surtronic 3 by Taylor Hobson ($R_a$ and $R_{TM}$) (see 8.2); M4P by Perthen (see 8.1) ($R_a$ and $R_{ZDIN}$).

2. Standards for $R_{ZDIN}$ are available from: see 8.1, PGN-3 3 micrometer nominal, PGN-10 10 micrometer nominal.
5.3 If necessary, and for referee tests, blow the surface to be tested with clean compressed (or canned) air to remove loose debris.

5.4 Place the profilometer drive mechanism such that the probe travels across the foil in the transverse direction.

5.5 Set the measurement parameters required in 4.2.

5.6 Initiate the drive mechanism to make a single determination of the desired parameter.

5.7 Move the drive mechanism and make two additional measurements in two other areas of the specimen.

6 Calculation

6.1 Calculate the average value for the three determinations on the specimen.

6.2 Use the average value of one or more specimens to conform to the value specified in the material specification.

7 Report

7.1 Report the value required by the specification to the nearest 0.1 microinch or 0.01 micrometer for \( R_a \) and to the nearest 0.01 mils or 0.1 micrometer for \( R_z \).

8 Apparatus Sources

8.1 Perthometer M4P; STDS PGN-3 and PGN-10
Atlanta Tech Sales Inc.
8825 Roswell Rd., Suite 591
Atlanta, GA 30350
(404) 992-3329

8.2 Surtronic 3
Rank Taylor Hobson LTD
PO Box 36
Guthlaxton St.
Leicester LE2 0SL England 0533-23801

8.3 Rodenstock RM600 Laser Profilometer - Noncontacting
Mahr Corp.
11435 Williamson Road
Cincinnati, OH 45241
1.0 Scope
This test method is designed to determine the thickness of unclad or metallic clad laminate, with or without the cladding, using mechanical measurements.

2.0 Applicable Documents

IPC-TM-650
Method 2.3.6, Etching, Ammonium Persulfate
Method 2.3.7, Etching, Ferric Chloride
Method 2.3.7.1, Cupric Chloride Etching
Method 2.3.7.2, Alkaline Etching

3.0 Test Specimens
Consult with the applicable specification for size or configuration, quantity, and location taken from the laminate.

3.1 Size
Test specimens may be strips cut from the laminate and shall be 12.7 mm [0.5 in] wide, minimum. Sheets or cut-to-size panels may be used as specimens.

3.2 Sampling
Unless otherwise specified, two specimens shall be taken from locations within the sampling that represent the centermost area and the edges, but no closer than 25.4 mm [1.0 in] from the edge, of the as-manufactured sheet.

4.0 Apparatus or Material

4.1 Micrometer with a minimum throat depth of 25.4 mm [1.0 in] and with accuracy of 0.0025 mm [0.0001 in], or equivalent.

4.2 Etching system capable of complete removal of metallic cladding. IPC Test Methods 2.3.6, 2.3.7, 2.3.7.1, or 2.3.7.2 shall be used for referee testing.

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Method A, Metallic Cladding Removed
This method is used to determine base laminate thickness by direct measurement of the laminate without cladding. It shall be used for qualification or referee testing.

5.1.1.1 Completely etch the test specimen in accordance with accepted industry practices.

5.1.2 Method B, As Manufactured
This method is used to determine overall thickness of unclad or metallic clad laminates. It is used to determine base thickness of metallic clad laminates when evaluated in accordance with 5.3.2.2.2. Unless otherwise specified, it shall be used for product acceptance inspection.

5.1.2.1 The specimens shall be tested in the as-manufactured condition.

5.2 Measurements
Using the micrometer, determine the thickness of the specimen. Unless otherwise specified, specimens that are sheets or panels shall be measured at least 25.4 mm [1.0 in] from the edge at all four (4) corners.

5.3 Evaluation

5.3.1 Data Recording
For purposes including qualification or referee testing, product evaluation, statistical analysis, etc., each thickness measurement shall be recorded, unless otherwise specified.

5.3.2 Compliance to Specification

5.3.2.1 Unclad laminates or metallic clad laminates with overall nominal thickness
Measurements taken after specimen preparation per 5.1.2 shall be compared with the applicable specification for compliance to the required tolerances.

5.3.2.2 Metallic Clad Laminates with Base Nominal Thickness

5.3.2.2.1 Compliance to Specification Using Method A Specimen Preparation
Measurements taken after specimen preparation per 5.1.1 shall be compared with the applicable specification for compliance to the required tolerances.

5.3.2.2.2 Compliance to Specification Using Method B Specimen Preparation
5.3.2.2.1 Calculate the overall nominal thickness by adding to the base nominal thickness the total thickness of the metallic cladding. Thickness of metallic cladding shall be based on .035 mm [0.0014 in] per 45.7 g [1.0 oz], or as supplied by the foil supplier.

5.3.2.2.2 Calculate the minimum and maximum limits by subtracting and adding the required tolerance from the overall nominal thickness.

5.3.2.2.3 Measurements taken after specimen preparation per 5.1.2 shall be compared with the minimum and maximum limits as determined in 5.3.2.2.2.

5.4 Report Unless otherwise specified, report the average, minimum and maximum readings, and compliance with requirements, if applicable.

6.0 Notes

6.1 Use of hand or manual micrometers should be carefully administered. Pressure, anvil shape, and other features of the micrometer and its use must follow accepted industry practices, if not defined in the applicable specification.
1.0 Scope  This test method is designed to determine the minimum and maximum thickness of the base material of metallic clad laminates by microsectioning and optical measurement.

2.0 Applicable Documents
IPC-TM-650  Method 2.1.1, Microsectioning
IPC-TM-650  Method 2.2.18, Determination of Thickness of Laminates, by Mechanical Measurement

3.0 Test Specimens

3.1 Size  Unless otherwise specified, a specimen measuring 25.4 X 12.7 mm [1.0 X 0.5 in] shall be taken from the laminate sample.

3.2 Quantity and Sampling  Unless otherwise specified, two samples shall be taken from the lot that represent the centermost area and the edges, but no closer than 25.4 mm [1.0 in] from the edge, of the as-manufactured sheet.

4.0 Apparatus or Material

4.1 Any optical inspection measuring device with a capability of 100X and 200X with an accuracy to 0.0025 mm [0.0001 in].

4.2 A microsectioning system capable of preparing specimen mounts that can be used for this procedure.

5.0 Procedure

5.1 Preparation of Specimens  Each specimen to be measured shall be microsectioned in accordance with IPC-TM-650, Method 2.1.1. The long dimension of the specimen shall be in the plane of examination. Specimens may be ganged in accordance with the sampling procedure.

5.2 Evaluation  Examine the entire length of the specimen. Determine and record the minimum and maximum thickness of each specimen to the nearest 0.0025 mm [0.0001 in] using 100X magnification and in accordance with Figures 1 or 2, in accordance with the applicable specification. Unless otherwise specified, Figure 2 shall be used. Any referee measurements shall be made at 200X magnifications.

5.3 Report  Report the minimum and maximum readings found from each specimen inspected, and whether the Parallel (Figure 1) or Radius (Figure 2) Method was used.

6.0 Notes  Cross-sectional thickness relates to the effective electrical insulation thickness and will usually be less than that found by mechanical means (see IPC-TM-650, method 2.2.18). For determination of the laminate’s contribution to overall board thickness, the mechanical approach is preferred (when measuring thin cores for multilayer applications).
1 Scope  This is a non-destructive test method for quickly and accurately measuring hole pattern locations.

2 Applicable Documents  None

3 Test Specimen  Qualification inspection is performed on the standard IPC test board (A-41, A-42, A-43, A-44). Conformance testing is performed on production product.

4 Equipment/Apparatus  A CECO INSTRUMENT, Linear Micrometer model TA510CP3 with an accuracy of 0.005 mm per 25.4 mm, or equivalent, shall be used. Any optical, optical/mechanical or mechanical means is acceptable within the accuracy limits specified.

5 Procedure

5.1 Place the specimen face down on the measuring table and align the board’s tooling holes with the table pin locating holes.

5.2 Measure all holes for location accuracy, with respect to the datum (Registration to the Master Drawing).

6 Report  Report all hole measurements.
1.0 Scope  This method is designed to determine dimensional conformance to specification of production-cut panels of laminate or prepreg for length, width, and perpendicularity.

2.0 Applicable Documents

IPC-PC-90

3.0 Test Specimens

3.1 Size  Production cut panels in the dimensions intended for shipment shall be used.

3.2 Sampling  Sampling rates shall be in accordance with the applicable specification. (Also see 6.1.)

4.0 Apparatus or Material

Unless otherwise specified, precision of measurement apparatus shall be in accordance with the applicable specification.

4.1 Vernier calipers capable of measuring up to 914 ± 6.4 mm [36.0 ± 0.25 in] or equivalent.

4.2 Tape measure capable of measuring up to 1829 mm [72.0 in]

4.3 Carpenters square, or equivalent

4.4 Pin gauges, dial indicators or equivalent

5.0 Procedure

5.1 Length  Measure the length of the edges of the panel that are parallel to the grain direction using a vernier caliper.

5.2 Width  Measure the length of the edges of the panel that are perpendicular to the grain direction using a vernier caliper.

5.3 Perpendicularity

5.3.1 Method A: by diagonals

5.3.1.1 Measure the diagonals of the panel using vernier caliper or tape measure.

5.3.1.2 Calculate perpendicularity as follows:

\[ D = D_1 - D_2 \] (Maximum allowable difference in diagonals)

Where:

\[ D_1 = \sqrt{(L + T)^2 + W^2} \]

\[ D_2 = \sqrt{(L - T)^2 + W^2} \]

\[ L = \text{Nominal length of panel [ins]} \]

\[ W = \text{Nominal width of panel [ins]} \]

\[ T_{ii} = \text{Tolerance in inches per inch for perpendicularity shown in the procurement document.} \]

\[ T = T_{ii} \times W \] (Tolerance in inches)

5.3.1.3 Calculate the actual difference in the diagonals from the measurements taken.

5.3.1.4 Compare the actual difference to the allowable maximum.

5.3.2 Method B: By carpenters square ("Right Angle" Square)

5.3.2.1 Place the panel in the carpenters square, contacting the square by at least two corners.

5.3.2.2 Using suitable means (see 4.4) measure the distance of the panel’s corner that does not contact the square.

5.3.2.3 Calculate the perpendicularity by dividing the distance by the length of the longest dimension of the panel.

5.4 Evaluation  Compare the measurements with dimensional requirements of the applicable specification. Record the number of panels that do not comply. Record the number of noncomplying panels for each dimension—length, width, and perpendicularity.

5.5 Report the number of panels, specifying which dimension, that do not comply with the applicable specification.

6.0 Notes

6.1 Sampling may also be determined by IPC-PC-90 on materials produced by continuous processing.
1.0 Scope
This procedure determines the percent metal content for solder paste.

2.0 Applicable Documents
None

3.0 Test Specimen
50 grams of solder paste

4.0 Equipment/Apparatus
Balance
Crucible or Beaker
Heat Source
Flux Solvent

5.0 Procedure

5.1 Preparation

5.1.1 Weigh 10 to 50 grams (to the nearest 0.01 gram) of solder paste into a tared vessel suitable for melting the solder paste.

5.2 Test

5.2.1 Melt the solder at approximately 25°C above liquidus of the alloy, remove from heat and allow solder to solidify.

5.2.2 Extract melt from residual flux with a suitable solvent, dry and weigh metal to within 0.01 grams to determine % metal content.

5.3 Evaluation

\[
\text{Weight of extracted metal} \times 100 = \% \text{ Metal}
\]

Enter the results in Table 1 “Test Report on Solder Paste.”
Table 1 Test Report on Solder Paste

Enter appropriate information in top portion of report and complete report by entering the test results or checkmarks in the appropriate spaces.

**Inspection Purpose:**

---

- **QPL I.D. Number:**
- **Qualification Manufacturer’s Identification:**
- **Quality Conformance A Manufacturer’s Batch Number:**
- **Quality Conformance B Date of Manufacture:**
- **Shelf-Life Extension Original Use-By Date:**
- **Performance Revised Use-By Date:**

---

**Date Inspection Completed:**

---

Overall Results: __ Pass __ Fail

**Inspection Performed by:**

---

Witnessed by:

---

**Table 1 Test Report on Solder Paste**

User’s Actual Requirement | Test Result | P/F (*) | Tested by & Date
---|---|---|---
Material | | | |
Visual | | | |
Metal Content | | | |
Viscosity | | | |
Solder Ball | | | |
Slump | | | |
Alloy | | | |
Flux | | | |
Powder Size | | | |
% In Top Screen | | | |
% In Next Screen | | | |
% In Bottom Screen | | | |
% In Receiver Bottom | | | |
Max. Powder Size | | | |
Powder Shape | | | |
Tack | | | |
Wetting | | | |

* P/F = PASS/FAIL; enter P if test results are within tolerance of actual requirement; otherwise, enter F.
1 Scope  The object of a planarity measurement is to determine the effectiveness of a polymer thin film in smoothing topological features created by underlying layers of circuitry or etch patterns. In this case, the polymer thin film is a dielectric material for use in High Density Interconnect (HDI) and microvia technologies.

1.1 Test Structure  Schematics given in Figure 1 (end view) and Figure 2 (top view) depict the essential features of a recommended test structure for measuring the planarity as a function of feature size.

In the finished test structure, “d” is the step height over the circuit trace after the polymer has been deposited and cured. The planarity is dependent on the trace height, “b,” the polymer coating thickness, “c,” and the trace width, “a.” Rather than fully characterizing this relationship for each polymer coating, it is best to use simplified standard procedures for measurement and for comparing different types of coatings.

Planarity is also affected by the proximity of the line feature being used for measurement to any neighboring topological feature in the test structure. Planarity is generally much lower for isolated features. Therefore, in order to consider the “worst case” conditions, isolated lines are preferred in the test structure. To satisfy this requirement, no neighboring features can be within fewer than 15 line widths of the line in question.

The test pattern in Figure 2 is recommended as one that provides planarity characterization over a broad range of feature sizes. All lines are isolated in accord with the above guideline. It is recommended planarity be determined over the complete range of these widths (but the specific nominal values within that range are not important). Normally, one finds the planarity is high over narrow lines, but it progressively rolls off in proceeding toward wider ones. The roll-off rate is important, and it varies from polymer to polymer. Thus any report of planarity must include the line width measured and, preferably, a plot of planarity versus line width should be reported.

2 Applicable Documents

IPC-DD-135  Qualification for Deposited Organic Interlayer Dielectric Materials for Multi-Chip Modules

3 Test Specimens

3.1 Prepare Test Coupons  Prepare the surface of the test structure for polymer deposition in accordance with the procedure recommended by the manufacturer of the dielectric coating (follow all procedures for cleaning the surface and for deposition of a coupling agent if one is recommended). Coat the polymer resin in accordance with the manufacturer’s recommended procedure to provide an average film thickness of 63.5 µm (± 10%) for 18 µm copper over the substrate surface when the cure is completed. Cure the polymer thin film using
all steps recommended for full curing. For resin coated copper (RCC) foil, after laminating the foil, cure as per manufacturer’s instructions, then etch the copper layer and proceed as for other deposited dielectric materials (see Figure 3).

4 Equipment/Apparatus  This method uses profilometer measurements providing topological height variations as a function of displacement across the surface of a standard test structure.

Use a TENCOR Profilometer (Model: Alpha Step 200). Substitutions are acceptable, provided they can measure feature heights in the range used to within ± 2% and can provide a linear scan of at least 10 mm.

Note: As an alternate method, where a profilometer is not available, the measurements can be collected by cross-sectioning the test structures. This method will require one cross-section for each trace width in order to collect data for trace width effects.

5 Procedure  Prior to the polymer deposition, scan the profilometer stylus across all copper lines in the test structure, scanning in the direction indicated by the arrow in Figure 2. Measure and record the dimensions depicted as “a” and “b” in Figure 1 for each of the lines.

After polymer deposition and cure, measure the polymer film thickness at a location distant (at least 15 line widths) from any of the test structure’s copper lines. In order to do this, a “window” must be imaged in the dielectric down to the substrate. A “window” to the substrate may be opened by photo-imaging, chemical dissolution, laser ablation, or other appropriate method (see Figure 4). The sweep must allow measurements of the thickness of the dielectric entering and exiting the “window.” These measurements should be within ± 0.2 µm of each other. Record this dielectric thickness as dimension “c.”

Finally, measure the dimension shown in Figure 1 as the feature step height “d” of the polymer; use the profilometer, not an optical method. In measuring “d,” take the difference in height between the highest point on top of the copper line and the lowest point at least 15 line widths from the line to be measured.

5.1 Conditions of Test

5.1.1 Calibrate the profilometer before making measurements using the calibration procedure specified by the manufacturer of the equipment.

5.1.2 Measure at ambient room temperature and humidity.
5.1.3 To standardize measurements, use test structures in which \( b = 18 \mu m \), \( c = 63.5 \mu m \), and the ratio of \( c/b \) is \( 3.5 \pm 0.2 \). If a dielectric film is used, which has been produced at a fixed thickness other than that outlined above, maintain a \( c/b \) ratio as described. If the standard construction with this defined ratio cannot be maintained, the actual metal and dielectric thickness must be reported.

5.1.4 Make triplicate measurements and average the results at each line width.

5.2 Calculation of Planarity

5.2.1 Planarity for an individual trace, \( P_a \), can be defined by the following equation:
\[
P_a = (1 - d/b)100
\]
where “a” is the trace width, “d” is the bump height over the trace, and “b” is the copper trace height. For an ideal planar structure, the value of \( P \) is equal to 100%.

5.2.2 Average planarity, \( P_{ave} \), for a given trace width is calculated using the triplicate measurements:
\[
P_{ave} = \frac{P_{a1} + P_{a2} + P_{a3}}{3}
\]

5.2.3 Total average planarity, \( P_{total} \), is the average planarity for all widths of traces (where \( n = \) number of traces widths measured):
\[
P_{total} = \frac{P_{ave1} + P_{ave2} + \ldots + P_{ave n}}{n}
\]

5.3 Report

5.3.1 Report the average planarity for each trace width measured (see 5.2.2).

5.3.2 Report the total average planarity as a single average percentage of all seven trace width averages (see 5.2.3).

5.3.3 Also report the technique, profilometer or cross-section, used to obtain the measurements.

This calculation can be performed for each trace width to develop a planarity plot.

6 Notes

6.1 Cross Section Method Due to the field of view required for the larger trace widths (\( > 0.8 \) mm), accurate measurements of the dielectric “bump” may not be possible due to the low magnification. One option is to use a higher magnification and measure the total dielectric and copper trace height from the substrate surface and subtract the minimum dielectric height over the substrate alone.

6.1 Planarity Test Method Sample An example of a planarity test method is given in Figure 5.
Figure 5  Planarity Chart for Method.xls
1 Scope  This test method covers acceptance of incoming copper clad epoxy-glass laminates ranging in thickness from 0.8 mm to 6.5 mm, clad on one or both sides. It provides for a standard method of inspection and establishes operations that simulate the manufacture of PWBs. Specific values for the acceptability are based on copper foil adhesion and visual surface condition of the base laminate.

2 Applicable Documents
MIL-STD-105  Sampling Procedures and Tables for Inspection by Attributes
MIL-P-13949  Plastic Sheet, Laminated, Copper-Clad (For Printed Wiring)

3 Test Specimen
3.1 Specimen  One specimen shall be tested for each sample, except in the case where material is clad on both sides, in which case two specimens shall be processed for each sample (one for each surface). Each specimen will have four readings.

3.2 Sampling  The sampling procedure will be to MIL-STD-105. The inspection level shall be S-2 at 6.5 A.Q.L.

4 Apparatus
4.1 Complete photo processing facilities
4.2 Etching facilities

5 Procedures
5.1 Print and Etch  For print and etch testing use 5.3.1, 5.3.2, 5.3.4, 5.3.5, 5.3.7, 5.3.8, 5.3.9, 5.3.10, and 5.3.11 only.

5.2 Print, Etch, and Plate  For print, etch, and plate testing, use 5.3.1 through 5.3.11 inclusively.

5.3 Steps
5.3.1 Preparation
5.3.1.1 Sand the edges of the test specimens to remove burrs, allowing close contact between the specimen, negative, and frame glass, resulting in a better defined etched pattern.

5.3.1.2 Scrub the copper surface(s) with FFF pumice and brush to remove any contamination on the surface of the specimen until it passes a water break test.

5.3.1.3 Dry using compressed filtered air.

5.3.2 Apply Resist
5.3.2.1 Dip the specimens in the following photo-resist solution:
- One part KPR III
- One part Toluene
- One part Acetone

All parts are by volume and should be used at room temperature. Specific gravity of the solution is 0.920.

5.3.2.2 Hold the specimen by one corner when dipping. Allow excess solution to drain until dripping stops.

5.3.2.3 Put the specimens on the rack (after draining) into 80°C oven for three to five minutes to dry and harden KPR.

5.3.2.4 Remove the rack from the oven and allow the specimens to cool to room temperature.

5.3.2.5 Place the specimens upon the negative in the printing frame with the copper side against the negative.

5.3.2.6 Expose the mounted specimen for seven minutes, 75 mm from the fluorescent black light.

5.3.2.7 Develop in trichlorethylene vapor for 15 seconds. It may require two to six cycles until the pattern is clear. Air dry the specimen after developing.

5.3.2.8 Use artwork from MIL-P-13949.

5.3.3 Etch per MIL-P-13949, Method A or B
5.3.4 Drill 1.5 mm holes in the pads of the 3 mm lines with good fabricating practice.

5.3.5 Remove the developed KPR by rubbing the pattern lightly with cold trichlorethylene liquid. Rinse in water. Scrub the specimens with FFF pumice and water with a strong bristle brush.

5.3.6 Plate (this is simulated plating) per MIL-P-13949.

5.3.7 Deoxidize by dipping in 10% hydrochloric acid for two minutes and wash in running water for five minutes. Dry 30 minutes, minimum, at 105°C to 110°C.

5.3.8 Coat the etched copper surface with white petrolatum. Specimens shall be immersed horizontally in solder 6.5 mm below the surface for 20 ± 1 seconds at 260°C ± 5/-0°C measured 25 mm below the surface.

5.3.9 Remove the petrolatum from the surface of the specimen with a two minute scrub in cold trichlorethylene, followed by a one minute rinse in hot trichlorethylene.

5.3.10 Inspect the surface for weave exposure, measling, crazing, resin loss, delamination, and blistering.

5.3.11 Test four 1 mm lines on the specimen for peel strength per MIL-P-13949, reporting the average value for the four lines.
1.0 Scope  This method evaluates the chemical cleanability of metal-clad laminate surfaces of oxidation and anti-oxidation protective coatings.

2.0 Applicable Document  None.

3.0 Test Specimen  The size of the test specimen shall be determined by the post etching tests to be performed.

4.0 Apparatus

4.1 Standard conveyorized spray cleaning modules or suitable laboratory equipment.

4.2 Personal safety equipment needed to perform this test are as follows: rubber or polyethylene gloves, plastic or coated apron and safety goggles.

4.3 Chemicals

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Concentration</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Persulfate</td>
<td>1.5 lbs/gal</td>
<td>100°F ± 5°F</td>
</tr>
<tr>
<td></td>
<td>(± 0.5 lb/gal)</td>
<td>(38°C ± 3°C)</td>
</tr>
</tbody>
</table>

4.3.2 Method B—Ammonium Persulfate

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Concentration</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Persulfate</td>
<td>2.0 lbs/gal</td>
<td>100°F Max</td>
</tr>
<tr>
<td></td>
<td>(± 0.5 lb/gal)</td>
<td></td>
</tr>
</tbody>
</table>

5.0 Procedure

5.1 Specimen Preparation  Shear the material to the required specimen size and remove the rough edges from the specimen by sanding or other suitable means.

5.2 Cleaning

5.2.1 Conveyorized Spray Cleaning  Process the specimen through the conveyorized modules at a speed which will permit 30 ± 5 seconds of exposure to the micro etching solution. Rinse specimens with deionized water for 1-2 minutes after micro etching.

5.2.2 Laboratory Cleaning  Place the specimen in a cleaner/degreaser solution and gently agitate for 30 ± 5 seconds. Remove the specimen and flush with tap water. Next place the specimen in a micro etch solution for 30 ± 5 seconds and vigorously agitate. Remove the specimen and flush with deionized water for 1-2 minutes.

5.3 Surface Evaluation  The metal cladding on the test specimen shall be cleaned to a uniform matte finish. Deionized or distilled water poured on the metal surface does not bead or form puddles.

6.0 Notes

6.1 Sodium persulfate solution shall be replaced if the copper concentration exceeds 3.0 oz/gal (22.5 gal).

6.2 Solution spray from nozzles should be checked for uniformity across the specimen.
1 Scope  To determine the effect of chemicals used in printed wiring fabrication on flexible metal clad and bare flexible dielectric material.

2 Applicable Documents
IPC-TM-650  Method 2.4.9, Peel Strength, Flexible Printed Wiring Materials
IPC-TM-650  Method 2.4.10, Plating Adhesion

3 Test Specimen
3.1 Method A – Metal Clad Dielectric  The test specimen shall consist of a size commensurate with the peel strength test fixture and have an etched conductor pattern in accordance with Figure 1.

3.2 Method B – Bare Dielectric  The test specimen shall consist of a 12.7 mm x 203.2 mm strip of bare dielectric.

4 Apparatus/Material
4.1 Necessary equipment to produce printed wiring by the etched foil process using good commercial practices.

4.2 The following chemicals in sequence:
**Etchant**  450 grams Cupric chloride ·2H₂O, 150 ml HCl 20°  Be diluted in one liter of water, 55°C ± 5°C

**Strripper**  Monoethanol amine 0.5%/KOH 5.0%/ Monobutylether 0.5% in water, 55°C ± 5°C

**Cleaner**  2N Sulfuric Acid, 23°C ± 5°C

4.2.1 Other Chemicals  Other specified chemicals may be added where the customer/supplier have specific process requirements.

A list of fluids or chemicals may be specified where the end product circuit will be subjected to specific environments: fuels, cleaning solvents, etc.

4.3 Timing Device

5 Procedures
5.1 Method A—Metal Clad Dielectric
5.1.1 Preparation  Prepare a minimum of six (6) test specimens in accordance with Figure 1 using standard commercial practices. Do not remove the etch resist.

5.1.2 Conditioning  Condition each specimen for 24 hours at 23°C ± 2°C and 50% ± 5% relative humidity prior to testing.

5.1.3 Test  5.1.3.1 Sequential Chemical Exposure Test  Immerse three (3) specimens for one minute in each chemical of the specified chemicals in the sequence. After immersion in each nonsolvent chemical, rinse the specimen in water at 55°C ± 5°C for one minute. Within 15 to 30 minutes after completion of the sequential chemical exposure, observe for tackiness, blistering, bubbles, delamination, or swelling within the dielectric, blistering or delamination of the copper and dielectric, or change in color of dielectric. After 16 to 24 hours repeat observations and peel the conductors using the procedure IPC-TM-650, Method 2.4.9 (Method A), for the exposed and nonexposed specimens.

5.1.4 Evaluation of Test  Record and report all discrepancies noted during the observation periods. Record and report the average immersed and the non-immersed specimen peel strengths, using the evaluation section of IPC-TM-650,
Method 2.4.9 (Method A). Measure the conductor width of the test specimen. Compare the average peel strength of the immersed end with that of non-immersed end in accordance with the following formula.

\[
\text{Immersed Peel Strength} \times 100 = \% \text{ of Original}^* \\
\text{Non-immersed Peel Strength}
\]

5.2 Method B – Bare Dielectric

5.2.1 Preparation Cut a minimum of six (6) test specimens per Paragraph 2.3.2

5.2.2 Conditioning Condition each specimen for 24 hours at 23°C ± 2°C and 50% ± 5% relative humidity.

5.2.3 Test

5.2.3.1 Sequential Chemical Exposure Test Immerse three (3) specimens for one minute in each of the specified chemicals sequentially. After immersion in each nonsolvent chemical, rinse the specimen in water of 55°C ± 5°C for one minute. Within 15 to 30 minutes after completion of the sequential chemical exposure, observe for tackiness, blistering, bubbles, delamination, or swelling within the dielectric or change in color of dielectric. After 16 to 24 hours repeat observations and determine the tensile strength and elongation using the procedure given in IPC-TM-650, Method 2.4.10.

5.2.4 Evaluation Test Record and report all discrepancies noted during the observation periods. Record but do not report the non-immersed specimen tensile strength and elongation results. Record and report the tensile strength and elongation results of the immersed specimen.

*Values may be higher than 100%
1 Scope This method is designed for use in determining the chemical resistance of all substrates and plastic materials in PWBs.

2 Applicable Documents None

3 Test Specimen

3.1 Test specimen, 75 mm x 25 mm x thickness of the material with the cut edges smoothed by machining or fine sandpaper.

4 Apparatus

4.1 Accurate chemical balance

4.2 Suitable micrometers

4.3 Glass containers for test specimens

5 Procedure

5.1 Preparation of Reagents Mix sulfuric acid (30%) by slowly adding 199 milliliters (366g) of H2SO4 (sp. gr. 1.84) to 853 milliliters of water. Use sulfuric acid (3%) and slowly add 16.6 milliliters (30.6g) of H2SO4 (sp. gr. 1.84) to 988 milliliters of water. Use sodium hydroxide solution (10%) and dissolve 111 grams of NaOH in 998 milliliters of water. Use ethyl alcohol (50%) and add 598 milliliters (482g) of 95% undenatured ethyl alcohol to 434 milliliters of water. Acetone. Ethyl acetate, C. P. ethylene dichloride. Carbon tetrachloride, C. P. toluene. Heptane 1 commercial grade, boiling range 90°C to 100°C. Use sodium chloride solution (10%) and add 107 grams of NaCl to 964 milliliters of water. Use phenol solution (5%) and dissolve 47 grams of carbolic acid crystal, USP, in 950 milliliters of water. Use nitric acid (10%) and add 108 milliliters (153g) of HNO3 (sp. gr. 1.42) to 901 milliliters of water. Use hydrochloric acid (10%) and add 239 milliliters (238g) of HCl (sp. gr. 1.19) to 764 milliliters of water. Use acetic acid (5%) and add 48 milliliters (50.5g) of glacial acetic acid, C.P. Use ammonium carbonate solution (2%) and add 55 grams of Na2CO3H2O to 964 milliliters of water. Use ammonium hydroxide (10%) and add 375 milliliters (336g) of NH4OH (sp. gr. 0.90) to 622 milliliters of water. Use hydroperoxide solution (3%, or USP 10 volume) and add 98 milliliters (108g) of commercial grade (100 volume or 28%) hydrogen peroxide to 901 milliliters of water. Use citric acid (10%) and dissolve 104 grams of citric acid crystal in 935 milliliters of water.

5.2 Condition The specimen shall be conditioned for at least 48 hours in atmospheric conditions of 23°C ± 1°C and 50% ± 4% RH, then weighed separately. The thickness of each specimen at the center and the length and width or two diameters at right angles to each other shall be measured to the nearest 0.025 mm.

5.3 Exposure Place the specimens on the edge in the container so that it is supported at an angle by the bottom and side wall of the container, then totally immerse each specimen in separate containers in approximately 60 milliliters of reagent for seven days at 23°C ± 1.1°C. The reagents shall be stirred every 24 hours by moderate manual rotation of the container. Following the immersion period, the specimens shall be removed, washed in running water, wiped with a dry cloth, and immediately weighed in a closed weighing bottle. Each shall have the thickness measurement made at the centers and the length and the width.

5.4 Evaluation of Test Report the percent loss or gain in weight calculated to the nearest 0.01% and the increase or decrease in length and width or thickness. Include the general character of the specimen after immersion and the type of reagent used.

6 Notes

6.1 In making tests for periods longer than seven days, it is recommended that the test be run four times, made up of increments of four weeks.

6.2 All immersion testing shall be performed in a ventilated fume hood.
1.0 Scope
This test method is used for determining that marking inks and/or color coding will not become illegible or discolored when subjected to solutions that are normally used as cleaning agents for printed boards or printed board assemblies.

2.0 Applicable Documents
None

3.0 Test Specimens
Test specimens may consist of test coupons or production printed boards with the appropriate markings. The amount or size of the marking on the test specimen shall be sufficient enough to satisfactorily perform the procedure of section 5.

4.0 Apparatus or Material
4.1 Vessel for each solution used.
4.2 Toothbrush or suitable applicator for each solution used.
4.3 Optical Aid capable of a 3X magnification.
4.4 Solution A: Mixture of one part isopropyl alcohol and three parts by volume of mineral spirits at 25\(\pm\)5\(^\circ\)C.
4.5 Solution B: Terpene defluxer consisting of a minimum of 90\% d-limonene and 10\% surfactant at 25\(\pm\)5\(^\circ\)C.
4.6 Solution C: Mixture of 42 parts by volume of water (1 megohm resistivity), one part by volume of propylene glycol monomethyl ether, and one part by volume of monoethanolamine at 63 to 70\(^\circ\)C.

5.0 Procedure
5.1 The following procedure shall be using solutions A, B, and C individually.

5.1.1 The test specimens shall be submerged for a minimum of 3 minutes (+ .5 minutes/ – 0.0 minutes) in a vessel containing the solution.

5.1.2 The test specimens shall be removed from the vessel and with a toothbrush (wetted with solution) the specimen shall be brushed for a minimum of 10 strokes on the area where the marking is present.

5.1.3 Steps 5.1.1 and 5.1.2 shall be repeated on the test specimen two additional times.

5.1.4 After the third submersion and brushing, the test specimens shall be air or blown dry.

5.1.5 The test specimens shall be evaluated in accordance with 5.2.

5.2 Evaluation
After the test has been performed, the test specimens shall be examined for any markings that are missing in whole or part, faded, smeared, blurred or shifted to the extent that they cannot be identified from a distance of 150 mm [6.0 in] or by examining with a optical aid using a magnification of no more than 3X shall constitute a failure.

6.0 Notes
6.1 If test solutions other than those described herein are to be used, then the solutions should be agreed upon between the vendor and customer prior to testing.

6.2 The three solutions being used to perform this test exhibit some potential for health and safety hazards. Safety precautions shall be observed.

6.3 It is the intent of this test method to subject a different set of test samples to each test solutions. It is at the option of the tester to subject the samples through the test solutions consecutively. If the samples fail after consecutive solutions the test should be performed with individual test solutions.
1.0 Scope
This method is designed to evaluate the resistance of dielectric materials to organic chemicals representative of those used in printed board fabrication and assembly. It is intended to provide a distinction between materials of varying chemical resistance and, when applicable, an indication of the degree of cure.

2.0 Applicable Documents
IPC-TM-650
Method 2.2.18, Determination of Thickness of Laminates by Mechanical Measurement

3.0 Test Specimens
3.1 Number
Unless otherwise specified, three specimens shall be used.

3.2 Size
Unless otherwise specified, specimen shall be 50.8 x 50.8 mm ± 0.5 mm [2.0 x 2.0 ± 0.02 in] by the thickness of the material (see 5.1, Preparation). Edges shall be smooth, whether by the cutting procedure, or by sanding, or other means.

3.3 Location
Specimen may be cut from anywhere in the sheet of material, except no specimens shall be taken closer than 25.4 mm [1.0 in] from any edge as laminated.

4.0 Apparatus or Material
4.1 Analytical balance with a draft shield and .001 gram or better resolution.

4.2 Air circulating oven, capable of 105 ± 2°C [221 ± 3.6°F].

4.3 Desiccator capable of maintaining an atmosphere of less than 30% relative humidity at 23°C [73°F]. See 6.2.5

4.4 Cutting apparatus such as diamond saw, shear paper cutter or router.

4.5 Edge smoothing apparatus such as 400 grit or finer sandpaper.

4.6 One liter battery jar, with cover.

4.7 Metal tongs or forceps.

4.8 Metal rack (to support specimens vertically).

4.9 Metal support (e.g., mounting clip used for microsectioning).

4.10 Laminating press capable of the specified temperature and pressure.

4.11 Timer: 1 hour with 1 second resolution.

4.12 Timer: 60 seconds, 1 second resolution.

4.13 Solvent: Methylene Chloride, Reagent Grade or HPLC Grade. MC recovered by distillation back to reagent grade may be used. HPLC Grade shall be used for referee purposes.

4.14 Prepreg (for single sided laminate and coated foil test only).

4.15 Copper foil, 1 oz./ft² treated (for prepreg tests only).

4.16 Ventilation hood

4.17 Micrometer, capable of measuring to within 0.025 mm [0.001 in]

4.18 Water bath at 23 ± 0.5°C [73 ± 0.9°F].

4.19 Thermometer capable of measuring to within 0.1°C resolution.

4.20 Etching system capable of metallic cladding removal.

5.0 Procedure

5.1 Sample Preparation
5.1.1 Single-sided Laminate
Single-sided laminate less than 0.5 mm [0.020 in] shall be laminated together with the clad surfaces facing out. Two plies minimum of prepreg shall be used. The prepreg shall be of the same basic resin type...
and of a thickness when cured not greater than 0.13 mm [0.005 in] total, using the prepreg manufacturer’s recommended press cycle. Laminate over 0.5 mm [0.020 in] shall be treated like double clad laminate without lamination.

5.1.2 Resin-coated Foil Resin-coated foil samples shall be laminated together using at least two plies of prepreg between the coated sides of the foil. The prepreg shall be of the same basic resin type and of a thickness when cured not greater than 0.127 mm [0.005 in] total, using a press cycle and any subsequent post cure which meets the manufacturer’s recommendations for both the coated foil and prepreg. (See 6.2.1.1)

For qualification and referee tests, a 0.50 ± 0.10 mm [0.02 in] composite core is to be built.

5.1.3 Laminate with Coated Foil Surfaces Single-sided laminate shall be tested after lamination as in 5.1.1. Double-sided laminate with coated foil on one side shall have the foil etched from the uncoated side and shall subsequently be laminated as 5.1.1. Double-sided laminate with coated foil on both sides shall be tested as is.

5.1.4 Prepreg Prepreg shall be laminated to a thickness of 0.50 ± 0.10 mm [0.020 in] using treated copper foil on both sides and following the prepreg manufacturer’s recommended press and post cure cycle. (See 6.2.1.1) For prepreg less than 0.13 mm [0.005 in] thick when cured, at least two plies shall be bonded to either side of an etched laminate of a thickness such that the pressed sample satisfies the required thickness.

5.1.5 Double-sided Laminate Double-sided laminate shall be submitted for testing as is.

5.2 Specimen Preparation

5.2.1 Etching Samples, as specified in 3.0, shall be etched in accordance with standard industry practices. For referee purposes, 2.3.6, 2.3.7, 2.3.7.1, or 2.3.7.2 shall be used.

5.2.2 Cut the specimens to size per 3.2. Cutting shall be performed using apparatus and in such a manner that prevents edge damage. Edge smoothing is recommended to prevent excessive absorption.

5.2.3 Markings Each specimen shall be identified by marking with a lead pencil or equivalent technique which is not removed by the solvent and which doesn’t affect the results.

5.3 Preconditioning

5.3.1 Measure and record nominal thickness of the test specimen using IPC-TM-650, Method 2.2.18.

5.3.2 Place the etched specimens vertically in the metal rack and dry the specimens in the oven for 60 ± 5 minutes at 105°C [221°F]. Air flow around each specimen must be assured.

5.3.3 Remove the specimens from the oven and immediately place in the desiccator to cool for 60 ± 30 minutes.

5.4 Test Condition The test shall be performed at standard laboratory conditions: 23 ± 2°C [73 ± 0.9°F] and 50 ± 5% R.H.

5.5 Measurement

5.5.1 Fill the battery jar with 750 ml of solvent and maintain the solvent temperature at 23 ± 0.5°C [73 ± 0.9°F] using the water bath.

5.5.2 Remove the specimens individually from the desiccator and weigh to the nearest milligram on the analytical balance. Samples must be weighed within 60 seconds of removal from the desiccator. Record these weights as W1.

5.5.3 Place the rack into the beaker of solvent, start the 60 minute timer and using tongs place the specimens in the rack at suitable intervals (recommend approximately 2 minutes). Insure that the specimens are completely immersed.

5.5.4 Place the metal clip on the balance and tare it out.

5.5.5 After 10 minutes +15, –0 seconds, using the tongs remove the first specimen from the solvent and start the 60 second timer.

5.5.6 Slowly wag the specimen in the air. As soon as the specimen is free of surface wetness, but no longer than 30 seconds, place the specimen on the balance supporting it on the metal clip such that both surfaces of the specimen are exposed (placing the specimen flat on the balance pan is not permitted since evaporation from the side next to the pan will be reduced.)
5.5.7 After 60+5 – 0 seconds from the time of removal from the solution, note the weight of the specimen and record it as \(W_2\).

5.5.8 Repeat 5.5.5 – 5.5.7 for the remaining specimens insuring the immersion time of each specimen is kept within the tolerance.

5.5.9 A fresh batch of solvent shall be used for no more than 18 specimens or for a period of time no longer than 8 hours.

5.6 Evaluation

5.6.1 Weight Gain

5.6.1.1 Subtract the dry weight of each specimen, \(W_1\), from the final weight, \(W_2\) of each specimen after immersion. Record the weight gain in mg.

5.6.1.2 Calculate the average weight gain in mg.

5.6.2 Appearance Examine the specimens using 20/20 vision for any changes to the appearance of the material, such as hazing, whitening or swelling.

5.7 Report

5.7.1 Report the average weight gain in milligrams for the material tested.

5.7.2 Report the measured specimen thickness.

5.7.3 Report actual test conditions for temperature and humidity and the solvent temperature.

5.7.4 Report any anomalies in the test or any variations from the specified procedures or tolerances.

5.7.5 Report any changes in the visual quality of the specimens as determined in 5.6.2.

6.0 Notes

6.1 Safety Considerations See the MSDS sheet for the solvent used before running this test.

6.1.1 During test, the beaker with the test solvent should be covered or under a ventilation hood.

6.1.2 Dispose of the spent solvent in accordance with local regulations.

6.2 Factors Affecting Tests

6.2.1 Sample

6.2.1.1 Same Sample The results obtained on the same sheet of material may be significantly affected by the degree of cure of the material and the thermal history of the sample.

6.2.1.2 Variation Due to Thickness of Sample There is a very small difference due to sample thickness. This is under 10% on typical epoxy materials for 0.2 mm [0.008 in] to 1.5 mm [0.060 in] and under 5% on more chemical resistant material from 0.13 mm [0.005 in] to 1.5 mm [0.060 in].

6.2.2 Accuracy Since there are no standards for this type of test, the accuracy of the method cannot be established.

6.2.3 Precision the reproducibility of this test depends on the degree of control over the controlled variables and some other variables such as atmospheric pressure, which are generally not controlled in industrial laboratories. Precision between laboratories with 20% to 50% RH was 10% at the 90 mg level and 16% at the 25 mg level.

6.2.4 Desiccants Desiccants capable of 0.002 mg moisture levels include \(P_{2035}\), Mg \((C10H_2)_2\), anhydrous BaO and fused KOH.

Some other desiccants such as \(CaCl_2\) result in considerably higher moisture levels and may not be used in this test. (See Weast R.C., CRC Handbook of Chemistry and Physics, 65th edition, E–37, 1984.)

6.2.5 Humidity Considerations

6.2.5.1 Effect of Humidity Higher humidity will produce higher solvent pickup due to retarded solvent evaporation.

6.2.5.2 Control of Humidity Control of the critical environment can be obtained in uncontrolled laboratories using an enclosed balance with a saturated salt solution of Mg\((NO_3)_2\)\(_2\)\(\cdot\)6H\(_2\)O (for 50% RH).

All significant openings in the enclosure are sealed with tape and an inner door is fabricated with a small opening for sample entry and exit. A shallow pan is fabricated to occupy most of the balance floor without contacting the weighing
pan. If the balance door is closed immediately after sample entry and exit, 50 ± 5% RH can be maintained.

Verification of conditions in the enclosure during a simulated test can be made using a rapid response humidity probe; however, this should be done with unconditioned specimens since solvents will affect the response of many humidity probes.

6.2.6 Temperature Considerations The effect of the solvent temperature on results is severe. A variation of 5°C [9°F] can result in an error as high as 50% relative to values determined at 23°C [73°F].

6.3 Consideration of Other Test Parameters

6.3.1 Using Same Solvent Shorter dwell times, e.g., 3 minutes, generally result in better discrimination between material of varying chemical resistance. However, test variability is generally increased. Shorter tests are excellent for side by side comparisons of materials.

Longer tests, e.g., 30 minutes, often do not differentiate adequately between materials, and while useful on homogeneous material, variability on material with surface coatings may be excessive.

6.3.2 Other Solvent Blends Other solvents and various methylene chloride based combinations have been commonly used in the industry. However, results and precision of the test may vary significantly and the added problem of variability in solution make-up is introduced.

6.4 Supercension This test method supersedes 2.3.4.2, dated 5/86, and 2.3.4.3, dated 5/86.

6.5 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.
1.0 Scope  This test method is designed for use in determining the resistance of core (dielectric) materials used in printed wiring boards to methylene chloride at laboratory ambient temperature.

2.0 Applicable documents
IPC-TM-650 Method 2.3.6, Etching, Ammonium Persulfate Method
IPC-TM-650 Method 2.3.7, Etching, Ferric Chloride Method
IPC-TM-650 Method 2.3.7.1, Etching, Cupric Chloride Method

3.0 Test specimens

3.1 Dimensions The test specimens shall be 2.00 in. x 2.00 in. x thickness of material. Tolerance on the 2.00 in. dimensions shall be ± .03 in.

3.2 Edge finish The edges of the specimens shall be milled or sanded smooth with 400 grit sandpaper.

3.3 Number of specimens Three specimens shall be used for this test.

3.4 Removal of metal cladding The metal cladding shall be removed by etching per IPC-TM-2.3.6, 2.3.7, 2.3.7.1 or other suitable method which does not affect the surface of the pressed sample.

4.0 Apparatus

4.1 Oven Circulating air oven capable of maintaining a uniform temperature of 105° to 110°C (221° to 230°F).

4.2 Desiccator

4.3 Analytical balance

5.0 Procedure

5.1 Conditioning The specimens shall be conditioned by drying in an oven for 1 hour at 105° to 110°C (221° to 230°F), then cooled to room temperature in a desiccator.

5.2 Fill a 3000 ml beaker with methylene chloride to a depth of 3 in. and maintain at 23°± 2°C in a well-ventilated fume hood. Place a rack in the bottom of the beaker to hold the samples upright and apart.

5.3 Exposure Remove each specimen from the desiccator and immediately weigh to the nearest 0.1 milligram, recording the initial weight as “A”. Immerse each specimen in the methylene chloride for 30 ± 0.5 minutes. Remove from the beaker, air dry for 10 minutes ± 30 seconds, weigh immediately and record the final weight as “B.” Drying time includes weighing time.

5.4 Evaluation

5.4.1 Calculation Calculate and record the percent change in weight for each specimen to the nearest 0.01 percent as follows:

\[ \text{Change in weight, percent} = \left( \frac{B - A}{A} \right) \times 100 \]
1.0 **Scope**  A test method for determining density (specific gravity) of solid plastics by displacement of water; and weight and volume measurement.

2.0 **Applicable Document**  None

3.0 **Test Specimen**  The test specimen shall be a solid piece of any size and shape except that volume shall not be less than 0.125 cubic inches and have a smooth uniform surface.

4.0 **Apparatus**

4.1 Analytical balance and a specific gravity bridge or a jolly balance.

4.2 Metal scale graduated in hundredths of an inch, micrometers, gages, and calipers.

5.0 **Procedure**

5.1 Conditioning the specimen shall be prior to and during test at 23°C ± 1.1°C and 50 ± 4 percent relative humidity for the 48 hours of 1/8 inch or less in thickness and 96 hours for thicker specimens.

5.2 **Specific Gravity by Placement of Water**  The specimen shall be weighed in air and in distilled water at 23°C ± 1.1°C and a small amount of a wetting agent may be needed.

5.3 **Specific Gravity by Weight and Volume Measurement**  The dimensions of the conditioned specimen shall be determined and the specimen shall be weighed in air at 23°C ± 1.1°C and 50 ± 4 percent relative humidity.

5.4 **Calculations**

\[
\text{Specific Gravity} = \frac{\text{Wt. in Air}}{\text{Wt. in Air} - \text{Wt. in Water}}
\]

\[
\text{Specific Gravity} = \frac{\text{Wt. of Specimen in Air}}{\text{Volume of Specimen} \times \text{Density of Water at 23°C}}
\]

5.5 **Evaluation of Test**  The value of the density of water at 23°C is 0.9976 grams per cubic centimeter and the specific gravity of the material at 23°C.
1.0 Scope  To determine the quality of the dielectric material after etching with ammonium persulfate.

2.0 Applicable Document  None.

3.0 Test Specimen  Specimen 2 in. x 2 in. X thickness of one ounce or two ounces copper clad.

4.0 Apparatus

4.1 Heated Electrical Equipment for etching the specimen.

4.2 Air Circulating Chamber capable of maintaining 80°C ± 3°C (176°F).

4.3 Equipment and Chemicals needed to perform this test are as follows: Rubber or polyethylene gloves, lint-free cloth, grade FFF pumice and plastic scrubbing brushes, distilled water, 10% solution oxalic acid, ammonium persulfate solution, methylethyl ketone, toluol, and trichlorethylene.

5.0 Procedure

5.1 Preparation of Specimen  Remove rough edges from the specimen by sanding or other suitable means.

5.2 Etching  Etch specimen with vigorous agitation for the minimum time in 66° BAUME ammonium persulfate solution monitored at 43°C ± 3° (109.4°F). After removal of the copper, immediately wash the specimen with running tap water for 2 to 5 minutes and keep the specimen from drying until the specimen is placed in the chamber. Immerse the specimens in a 10% solution of oxalic acid in distilled water 25°C ± 8° (77°F) for 15 to 20 minutes providing gentle circulation of the oxalic acid solution during this period. Flush the specimen with tap water for 2 to 5 minutes, then scrub the specimens with pumice to remove resist. Wipe the resist off with a lint free cloth moistened with a suitable solvent. Scrub the specimen with a plastic bristled brush under running tap water for 2 to 5 minutes. Rinse the specimen again in distilled water.

5.3 Condition  Dry the specimens for 1 hour in a chamber maintained at 80°C (176°F). If specimens are for electrical tests, handle only with rubber or polyethylene gloves.

5.4 Evaluation of Test  Examine specimens for white deposits or other surface contaminants, loss of surface resin, softness, delaminations, blistering or measling. Clad specimens also should be evaluated for blisters or delamination of the copper foil.

6.0 Notes

6.1 If the etching time exceeds 15 minutes for 1 ounce copper or 30 minutes for 2 ounces copper, renew the etching solution.

6.2 Oxalic acid is very toxic and extreme care should be exercised.

6.3 The time to produce a clean pattern with a minimum of undercutting is approximately 7 minutes for 1 ounce copper and 15 minutes for 2 ounces copper, using fresh solution.
1.0 Scope  To determine the quality of the dielectric material after etching with ferric chloride.

2.0 Applicable Documents  None.

3.0 Test Specimen  Specimen 2 in. x 2 in. X thickness of one ounce or two ounces copper clad.

4.0 Apparatus

4.1 Heated Electrical Equipment for etching the specimen.

4.2 Air Circulating Chamber capable of maintaining 80°C ± 3°C (176°F).

4.3 Equipment and Chemicals needed to perform this test are as follows: Rubber or polyethylene gloves, lint free cloth, grade FFF pumice and plastic scrubbing brushes, distilled water, 10% solution oxalic acid, ferric chloride solution, methylethyl ketone, toluol, and trichlorethylene.

5.0 Procedure

5.1 Preparation of Specimen  Remove rough edges from the specimen by sanding or other suitable means.

5.2 Etching  Etch specimens with vigorous agitation for the minimum time in 42° BAUME ferric chloride solution monitored at 30°C ± 6°C (86°F). After removal of the copper, immediately wash the specimen with running tap water for 2 to 5 minutes and keep the specimen from drying until the specimen is placed in the chamber. Immerse specimens in a 10% solution of oxalic acid in distilled water at 25°C ± 8°C (77°F) for 15 to 20 minutes providing gentle circulation of the oxalic acid solution during this period. Flush the specimens with tap water for 2 to 5 minutes, then scrub the specimens with pumice to remove resist. Wipe the resist off with a lint free cloth moistened with a suitable solvent. Scrub the specimen with a plastic bristled brush under running tap water for 2 to 5 minutes, then rinse for 30 minutes. Rinse the specimen again in distilled water.

5.3 Condition  Dry the specimens for 1 hour in a chamber maintained at 80°C (176°F). If specimens are for electrical tests, handle only with rubber or polyethylene gloves.

5.4 Evaluation of Test  Examine specimens for white deposits or other surface contaminants, loss of surface resin softness, delamination, blistering or measling. Clad specimens also should be evaluated for blisters or delamination of the copper foil.

6.0 Notes

6.1 If the etching time exceeds 15 minutes for 1 ounce copper or 30 minutes for 2 ounces copper, renew the etching solution.

6.2 Oxalic acid is very toxic and extreme caution should be exercised.

6.3 The time to produce a clean pattern with a minimum undercutting is approximately 7 minutes for 1 ounce copper, and 15 minutes for 2 ounce copper using a fresh solution.
1.0 Scope
This method is a means for preparation of test specimens for determination of bare dielectric material quality and properties, using cupric chloride as the etching solution for removal of copper cladding.

2.0 Applicable Documents
IPC-TM-650
Method 2.3.1.1, Chemical Cleaning of Metal Clad Laminate

3.0 Test Specimens
The size of lot samples or test specimens shall be determined by the inspections or tests to be performed after etching and the capabilities of the etching equipment.

4.0 Apparatus or Material
4.1 Standard chemical etching chamber or laboratory equipment suitable to the etchant chemistry.
4.2 Air circulating oven capable of maintaining the specified temperatures and tolerances.
4.3 Personal safety equipment shall include: rubber or polyethylene gloves, plastic or coated apron and safety goggles.

4.4 Chemicals
<table>
<thead>
<tr>
<th>Chemical</th>
<th>Concentration</th>
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</thead>
<tbody>
<tr>
<td>Cupric Chloride, CuCl₂-2H₂O</td>
<td>0.54 kg/l 4.5 lb/gal</td>
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<tr>
<td>Hydrochloric Acid, HCl</td>
<td>9.3% by weight (3N)</td>
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<tr>
<td>Distilled/Deionized Water</td>
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<tr>
<td>Sodium Hydroxide, NaOH</td>
<td>10% by weight</td>
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<tr>
<td>IPA</td>
<td>16% by weight</td>
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</table>

4.5 Pattern Developing Materials
Etch resist system or materials capable of producing the applicable conductor patterns.

5.0 Procedure
5.1 Preparation of Specimen
5.1.1 Shear the material to the appropriate sample or specimen size and if necessary remove the rough edges from the specimen by sanding or other suitable means. Specimens may be chemically cleaned in accordance with IPC-TM-650, Method 2.3.1.1. Specimens may also be mechanically cleaned.

5.1.2 If a conductor pattern is required, prepare the material by applying etch resist according to standard industry practices.

5.2 Etching
5.2.1 Remove the metal cladding by etching in a spray chamber or other suitable container containing 30-32° BAUME cupric chloride solution maintained at 51.7 ± 5.6°C [125 ± 10°F]. Etching time shall be minimized to prevent over-exposure of the bare laminate material to the etching solution and yet allow for complete removal of the exposed metal cladding. If the specimens are etched in a laboratory environment, vigorous agitation may be required.

5.2.2 Rinse the specimens thoroughly.

5.2.3 For referee purposes, neutralize any residual etchant by quickly dipping in a 10% solution of NaOH solution and then rinse thoroughly with distilled or deionized water. Note: If this step is not followed, undercutting of the circuitry is possible, which in time could lead to inaccurate test data, such as low peel strength.

5.3 Cleaning
5.3.1 If etch resist has been used, samples shall have the resist or tape removed by standard industry practices.

5.3.2 When electrical testing is required on the material, do not allow the etched specimens to dry before they go through the cleaning process. For general testing, scrubbing with a soft natural bristle brush under running tap water and rinsing with distilled water or deionized water may be adequate. For critical testing and for referee testing, laminates shall be soaked for 10 minutes in reagent grade IPA followed immediately by a 10 minute rinse in flowing 16 megaohm deionized water.
5.4 Drying  Samples may be air dried for subsequent material evaluations. For referee testing, an oven bake for 1 hour at 80 ± 5.6°C [176 ± 10°F] is required.

5.5 Evaluation  Determine and record whether the etching procedure resulted in any unusual events, such as:

a. Dwell time in etcher necessary for complete copper removal, if longer than normal.

b. Warpage or distortion of the material.

c. Discoloration or other visual changes to the material.

6.0 Notes  None
1.0 Scope
This method is a means for preparation of test specimens for determination of bare dielectric material quality and properties, using an alkaline etching solution for removal of copper cladding.

2.0 Applicable Documents

IPC-TM-650
Method 2.3.1.1, Chemical Cleaning of Metal Clad Laminate

3.0 Test Specimens
The size of lot samples or test specimens shall be determined by the inspections or tests to be performed after etching and the capabilities of the etching equipment.

4.0 Apparatus or Material

4.1 Standard chemical etching chamber or laboratory equipment suitable to the etchant chemistry.

4.2 Air circulating oven capable of maintaining the specified temperatures and tolerances.

4.3 Personal safety equipment shall include: rubber or polyethylene gloves, plastic or coated apron, and safety goggles.

4.4 Chemicals

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride</td>
<td>170 grams per liter</td>
</tr>
<tr>
<td>Copper</td>
<td>150 grams per liter</td>
</tr>
<tr>
<td>Ammonium Hydroxide</td>
<td>5.5 M</td>
</tr>
<tr>
<td>(NH₄OH)</td>
<td>Specific gravity = 1.20</td>
</tr>
<tr>
<td>Reagent grade isopropyl alcohol (IPA)</td>
<td>As required</td>
</tr>
<tr>
<td>Distilled/Deionized Water</td>
<td>As required</td>
</tr>
</tbody>
</table>

4.5 Pattern Developing Materials
Etch resist system or materials capable of producing the applicable conductor patterns.

5.0 Procedure

5.1 Preparation of Specimen

5.1.1 Shear the material to the appropriate sample or specimen size and if necessary remove the rough edges from the specimen by sanding or other suitable means. Specimens may be chemically cleaned in accordance with IPC-TM-650, Method 2.3.1.1. Specimens may also be mechanically cleaned.

5.1.2 If a conductor pattern is required, prepare the material by applying etch resist according to standard industry practices.

5.2 Etching

5.2.1 Remove the metal cladding by etching in a conveyerized spray chamber or other suitable vessel containing 22 to 23 BAUME alkaline etching solution maintained at 51.7 ±5.6°C [125 ±10°F]. Etching time shall be minimized to prevent overexposure of the bare laminate material to the etching solution and yet allow for complete removal of the exposed metal cladding, if the specimens are etched in a laboratory environment, vigorous agitation may be required.

5.2.2 Rinse the specimens thoroughly.

5.3 Cleaning

5.3.1 If etch resist has been used, samples shall have the resist or tape removed by standard industry practices.

5.3.2 When electrical testing is required on the material, do not allow the etched specimens to dry before they go through the cleaning process. For general testing, scrubbing with a soft natural bristle brush under running tap water and rinsing with distilled water or deionized water may be adequate. For critical testing and for referee testing, laminates shall be soaked for 10 ±1 minutes in reagent grade IPA followed immediately by a 10 minute rinse in flowing 16 megaohm deionized water.

5.4 Drying
Samples may be air dried for subsequent material evaluations. For referee testing, an oven bake for 1 hour at 80 ±5.6 °C [176 ±10°F] is required.

5.5 Evaluation
Determine and record whether the etching procedure resulted in any unusual events, such as:
a. Dwell time in etcher necessary for complete copper removal, if longer than normal.

b. Warpage or distortion of the material.

c. Discoloration or other visual changes to the material.

6.0 Notes

6.1 If the etching time exceeds 15 minutes for 1 oz/sq. ft. copper or 30 minutes for 2 oz/sq. ft. copper, renew the etching solution.

6.2 Alkaline etchant is toxic and extreme caution should be exercised.

6.3 The time to etch a clean pattern with a minimum of undercutting should be approximately 7 minutes for 1 oz./sq. ft. copper, and 15 minutes for 2 oz./sq. ft. copper using a fresh solution.
1 Scope This method describes a procedure for determining the relative flammability of organic films and reinforced composites by measuring the minimum concentration of oxygen in a gaseous mixture of oxygen and nitrogen that will just support combustion. It is based on ASTM Standard D2863-77 but modified to cover thin flexible printed wiring materials.

2 Applicable Documents None

3 Test Specimen

3.1 When evaluating copper clad laminate, the copper foil shall be removed by standard commercial practices before conducting this test. After etching, the samples shall be dried 30 minutes at 107°C in a forced air oven.

3.2 Condition samples for 24 hours at 23°C ± 2°C and 50% ± 5% RH.

3.3 Cut at least 10 specimens 6.25 mm wide by an appropriate length. With a suitable marker, make a transverse line across the specimen 50 mm from one end.

3.4 Using protective gloves, crease non-reinforced materials in half and parallel to the long axis of the specimen. Open specimen before testing.

4 Test Equipment

4.1 Test Column This is a heat-resistant glass tube of 7.5 cm minimum inside diameter and 45 cm minimum height. The bottom of the column or the base to which the tube is attached shall contain noncombustible material to mix and evenly distribute the gas mixture entering at this base. Glass beads 3 mm to 5 mm in diameter in a bed 80 mm to 100 mm deep have been found suitable (an example is shown in Figure 1).

4.2 Specimen Holder Details of the recommended specimen holder are shown in Figure 2.

4.3 Gas Supply Commercial grade (or better) oxygen and nitrogen shall be used.

4.4 Flow Measurement and Control Devices Suitable flow measurement and control devices shall be available in each line, which will allow monitoring the volumetric flow of each gas into the column within 1%. After the flow is measured in each line, the lines should be joined to allow the gases to mix before being fed into the column.
4.5 Ignition Source  The igniter should be a tube with a hydrogen, propane, or natural gas flame at the end of the column to ignite the test specimen. A suitable flame may be from 6 mm to 12 mm long.

4.6 Timer  A suitable timer capable of indicating at least 10 minutes and accurate to five seconds shall be used.

4.7 Soot, Fumes, and Heat Removal  To ensure the removal of toxic fumes, soot, heat, and other possible noxious products, the column shall be installed in a hood or other facility to provide adequate exhaust.

5 Procedure

5.1 Calibrate the flow measuring system at least every six months.

5.2 Clamp the specimen in the holder vertically in the approximate center of the column with the top of the specimen at least 100 mm below the top of the open column.

5.3 Select the desired initial concentration of oxygen based on past experience with similar materials. If there is no experience with the material, light a specimen in the air and note the burning. If the specimen burns rapidly, start at a concentration of about 18% but, if the specimen goes out, select a concentration of about 25% or higher, depending on the difficulty of ignition and time of burning.

5.4 Set the flow valves so that the desired initial concentration of oxygen is flowing through the column. The gas flow rate in the column shall be 4 cm ± 1 cm/sec., as calculated at standard temperature (0° C) and pressure (760 mm Hg) from the total flow of the gas in cm³/sec. divided by the area of the column in cm².

5.5 Allow the gas to flow for 60 seconds to purge the system.

5.6 Ignite the top of the specimen until ignition is apparent or for a maximum of 15 seconds. Remove the ignition flame and start the time.

5.7 A valid test shall be when a sample burns uniformly for three minutes or a distance of 50 mm.

5.8 The concentration of oxygen must be raised if the specimen is extinguished before burning three minutes or 50 mm.

5.9 Adjust the oxygen concentration, insert a new specimen or, if the previous specimen is long enough, turn it end for end or cut off the burned end, then purge and reignite.

5.10 Continue repeating the test until the limiting concentration of oxygen is determined. This is the lowest oxygen concentration that will meet the conditions of 5.3. At the next lower oxygen concentration possible with the equipment, the specimen should extinguish.

5.11 For a material having consistent burning characteristics, the difference in oxygen concentration between burning and extinguishing will be reproducible within 0.1% to 0.3%, depending on the sensitivity of the flow measuring equipment and upon the particular oxygen concentration involved. Some materials, however, exhibit erratic burning characteristics because of inhomogeneity, char formation, dripping, bending, etc., which cause less reproducible results. In such cases, the limiting concentration should be determined by a statistical testing method.

5.12 Perform the test at least three times by starting at a slightly different flow rate still within the 3 cm/sec. to 5 cm/sec. limit.

5.13 Calculate the oxygen index, n, of the material as follows:

\[ n, \% = \left(\frac{100 \times O_2}{O_2 + N_2}\right) \]

where \( O_2 \) is the volumetric flow of oxygen, \( cm³/sec. \), at the limiting concentration determined, and \( N_2 \) is the corresponding volumetric flow rate of nitrogen, \( cm³/sec. \).

5.14 Report  The report shall include everything stated in 5.14.1 through 5.14.5.
5.14.1 Description of the material tested including as much as is known about the type, source, manufacturer, manufacturer’s code number, form and principle dimensions, and previous history

5.14.2 Test specimen dimensions

5.14.3 Average oxygen index value

5.14.4 Individual oxygen index values found for each of the tests

5.14.5 Description of any unusual behavior such as charring, dripping, bending, etc.

6 Notes

6.1 Oxygen Index The minimum concentration of oxygen, expressed as volume percent, in a mixture of oxygen and nitrogen that will only support combustion of a material under the conditions of this method.

6.2 Principle of Method The minimum concentration of oxygen is in a slowly rising mixture of oxygen and nitrogen that will just support combustion and is measured under equilibrium conditions of candle-like burning. The balance between the heat from the combustion of the specimen and the heat lost to the surroundings establishes the equilibrium. This point is approached from both sides of the critical oxygen concentration in order to establish the oxygen index.
1 Scope  This test method exists to determine the degree of flame resistance of flexible printed wiring.

2 Applicable Documents  None

3 Test Specimen

3.1 Flexible printed wiring being evaluated

4 Equipment/Apparatus

4.1 A laboratory hood, totally enclosed, with a heat resistant glass window for observing the test, shall be used. The exhaust fan shall be turned off during the test, but may be turned on periodically between tests to clear out fumes and residuals. A clamping device shall be provided within the test chamber so that the specimen will hang freely and offer appropriate exposure per 5.2.

4.2 There shall be provision for remote position within the chamber of a lighted Bunsen burner.

4.3 Bunsen burner and fuel a supply having a heat of combustion of 1000 BTU/0.03 cubic meters. The referee fuel shall be methane.

4.4 Dry, absorbent surgical cotton

4.5 Stop watch, reading in seconds

5 Procedure

5.1 Test

5.1.1 Specimens to be tested shall be conditioned in standard ambient laboratory conditions for a minimum of four hours prior to testing.

5.1.2 The specimen shall be clamped to the clamping device in a manner that will expose the most susceptible portion of the sample to the Bunsen burner flame (e.g., a portion of the sample without coverlayer). The dry, absorbent surgical cotton shall be placed below the burner and the portion of the sample to be exposed to flame. The edge of the sample to be exposed to flame shall be at a height 25 mm greater than the height of the burner, as shown in Figure 1.

5.1.3 The Bunsen burner shall be lit and the flame adjusted to a non-luminous cone of 25 mm. The lit burner shall be positioned under the exposed portion of the sample, using the remote positioning device described in 4.2, allowing the flame to impinge upon the sample. After impingement of five seconds, the flame shall be removed using the remote positioning device. If ignition of the sample occurs, start the stop-watch and record the time of burning after removal of the Bunsen burner.

5.2 Evaluation

5.2.1 Non-Burning (NB)  If the sample does not ignite after two attempts, it is judged non-burning by this test.

5.2.2 Burning (B)  If the sample ignites and burns to the clamp, burns longer than 10 seconds, or drips particles that cause ignition of the dry, absorbent surgical cotton under the sample, it is judged burning by this test.

5.2.3 Self-Extinguishing (SE)  If the sample ignites but extinguishes within 10 seconds, does not burn to the clamp, and does not drip particles that ignite the dry absorbent, surgical cotton under the sample, it is judged self-extinguishing by this test.
1.0 Scope  This test method is designed to determine the degree of flame resistance of laminates less than 0.5 mm [0.020 in] in thickness, and prepreg.

2.0 Applicable Documents
IPC-TM-650
Method 2.3.6, Etching, Ammonium Persulfate
Method 2.3.7, Etching Ferric Chloride
Method 2.3.7.1, Cupric Chloride Etching
Method 2.3.7.2, Alkaline Etching

3.0 Test Specimens
3.1 Size  The test specimen shall be 25.4 mm [1.0 in] wide by 457 mm [18 in] long by the thickness of the material cut from the sheet such that the 457 mm [18 in] dimension is parallel to the warp yarn. The specimen shall be marked 152.4 mm [6 in] from one end. This mark may be made by cutting a small nick into the edge of the strip.

3.2 Quantity and Sampling  A minimum of three specimens shall be used for each material tested and each test condition, unless otherwise specified. The specimens shall be cut from various locations across the width of the sheet no closer than 25.4 mm [1.0 in] from the edge of the sheet.

4.0 Apparatus or Material
4.1 Test Chamber  A laboratory hood, totally enclosed, with a heat-resistant glass window for observing the test, shall be used. The exhaust fan shall be turned off during the test, but may be turned on to clear out the fumes between tests.

4.2 Specimen Holder  Clamping device shall be provided within the test chamber so that the specimen will hang with its length in a vertical position approximately coincident with the central vertical axis of the test chamber.

4.3 Laboratory Burner  A Bunsen or Tirrill Burner shall be used having a tube length of 101.6 mm [4.0 in] and an inside diameter of 9.4 mm [0.370 in]. The burner shall not be equipped with end attachments.

4.4 Gas Supply  The gas supply shall be regulated and metered for uniform flow. The standard gas shall be Technical Grade methane. Natural gas having a nominal heat content of 1000 BTU per cubic foot [37 MJ/m³] or [37 megajoule per cubic meter] may be substituted. Other fuel gases such as butane, propane and acetylene may be used provided they are equivalent in flame temperature. Technical grade methane shall be used for referee testing.

4.5 Timer  Stopwatch or other suitable timing device with a precision of 0.5 seconds, minimum.

4.6 Desiccator  Desiccation chamber capable of maintaining an atmosphere of less than 30% RH at 23°C [73°F].

4.7 Conditioning oven of circulating draft type capable of maintaining 125 ± 2°C [257 ± 3.6°F].

4.8 Thin steel scale or template for gauging flame height.

4.9 Etching system capable of complete removal of the metal cladding.

4.10 Cutting apparatus such as shears or equivalent equipment.

5.0 Procedure
5.1 Specimen Preparation  Metal-clad laminates shall be completely etched using standard industry practices (see IPC-TM-650, Methods 2.3.7, 2.3.7.1, or 2.3.7.2). Unclad laminate and prepreg shall be tested in the as-is condition. Specimens shall be cut to size in accordance with 3.1.

5.2 Conditioning  Unless otherwise specified, the specimens shall be conditioned in standard ambient laboratory conditions of 23 ± 2°C [73 ± 3.6°F] and 50 ± 5% RH for a minimum of 24 hours prior to testing.

5.3 Specimen Mounting  A specimen shall be clamped to the clamping device in the chamber so that the specimen hangs with its length in a vertical position approximately coincident with the central vertical axis of the test chamber. The marked end of the specimen shall be nearest the laboratory burner. The lower end of the specimen shall be at a height 25.4 mm [1.0 in] more than the height of the laboratory burner used to provide the ignition, as shown in Figure 1.
5.4 Adjustment of Test Flame  The burner is ignited and adjusted to produce a blue flame 25.4 mm [1.0 in] high. The correct flame is obtained by adjusting the gas supply and the air ports of the burner until a blue flame with a yellow-tipped outer cone 25.4 mm [1.0 in] high is produced. The air supply is increased slightly by opening the air ports only until the yellow tip just disappears and completely blue inner and outer flame cones are formed. The flame is remeasured for correct height. The procedure is repeated as necessary until all conditions are met. The burner tube is vertical during adjustment and testing.

5.5 Measurement  Position the burner beneath the specimen and allow the flame to impinge upon the specimen for 5 ± 0.5 seconds (see 6.3). Remove the burner from beneath the specimen, and determine the time from removal of burner to when burning has stopped. Record the time of burning and record whether the burning has progressed beyond the 152.4 mm [6.0 in] length. If the burning has progressed beyond the 152.4 mm [6.0 in] mark, measure the total length of the burned material.

5.6 Evaluation

5.7.1 Nonburning by This Test  If the specimen does not ignite on two attempts, it shall be reported as “Nonburning by this test.”

5.7.2 Burning by This Test  If a specimen burns up to 152.4 mm [6.0 in], it shall be reported as “Burning by this test.”

5.7.3 Self-extinguishing by This Test  If a specimen begins to burn after the first or second ignition but extinguishes before the flame burns up to 152.4 mm [6.0 in], it shall be reported as “Self-extinguishing” by this test.

5.8 Report the total time of burn and the total length of burn.

6.0 Notes

6.1 Since laminates and prepregs do not drip molten or flaming material, provisions for this evaluation have been deleted from the method.

6.2 The inside of the burner barrel should be cleaned frequently. Specimen combustion by-products can collect around and inside the barrel tip. These deposits can be flushed out during burner ignition and flame adjustment resulting in a false yellow flame tip. Proper flame adjustment becomes very difficult.

6.3 Desiccator Conditions  The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.
1.0 Scope  This test method is designed to determine the degree of flame resistance of metal-clad or unclad laminate. It is intended for use on laminate of thicknesses 0.51 mm [0.020 in] and greater.

2.0 Applicable Documents

IPC-TM-650
Method 2.3.6, Etching, Ammonium Persulfate Method
Method 2.3.7, Etching, Ferric Chloride Method
Method 2.3.7.1, Cupric Chloride Etching Method
Method 2.3.7.2, Alkaline Etching
UL-STD-94, Flammability

3.0 Test Specimens

3.1 Size  Test specimens shall be 127 ± 0.64 mm [5.0 ± 0.025 in] in length and 12.7 ± 0.51 mm [0.5 ± 0.020 in] in width by the thickness being tested. Edges shall be smoothed after cutting; any radius imparted to the corners shall not exceed 1.27 mm [0.05 in].

3.2 Quantity and Sampling  Specimens may be taken parallel to either grain direction, unless otherwise specified. Five specimens shall be prepared for each condition required. Reserve sets of five specimens should also be prepared in the event a retest is necessary.

4.0 Apparatus or Material

4.1 Test Chamber  A laboratory hood, totally enclosed, with a heat-resistance glass window for observing the test, shall be used. The exhaust fan shall be turned off during the test, but may be turned on periodically to clear out the fumes between tests.

4.2 Specimen Holder  Clamping device adjustable for vertical positioning of the test specimen shall be provided within the test chamber so that the specimen will hang with its length in a vertical position approximately coincident with the central vertical axis of the test chamber.

4.3 Laboratory burner  A Bunsen or Tirrill Burner shall be used having a tube length of 101.6 mm [4.0 in] and an inside diameter of 9.4 mm [0.370 in]. The burner shall not be equipped with end attachments.

4.4 Gas supply  The gas supply shall be regulated and metered for uniform flow. The standard gas shall be Technical Grade methane. Natural gas or other fuel gases such as butane, propane and acetylene may be used, provided they have a nominal heat content of 1000 BTU per cubic foot. Technical grade methane shall be used for referee testing.

4.5 Timer  Stopwatch or other suitable timing device with a precision of 0.5 seconds minimum.

4.6 Desiccator  Desiccation chamber capable of maintaining an atmosphere of less than 30% RH at 23°C [73°F].

4.7 Conditioning oven of circulating draft type capable of maintaining 125 ± 2°C [257 ± 3.6°F].

4.8 Thin steel scale or template for gauging flame height.

4.9 Etching system capable of removing metal-cladding from the laminate.

4.10 Cutting and edge smoothing apparatus such as shears, diamond blade saw, or other equipment, and sanding or routing equipment for smoothing.

5.0 Procedure

5.1 Specimen Preparation  Metal-clad laminates shall be completely etched using standard industry practices (see IPC-TM-650, Methods 2.3.7, 2.3.7.1, or 2.3.7.2). Unclad laminates shall be tested in the as-is condition. Specimens shall be cut to size and the edges smoothed, in accordance with 3.1.

5.2 Specimen Conditioning

5.2.1 Specimen sets shall be conditioned prior to testing by exposure to standard laboratory conditions of 23 ± 2°C [73 ± 3.6°F] and relative humidity of 50 ± 5% for 24 hours minimum.

5.2.2 If specified, a second set of specimens shall be conditioned for 24 ± 2 hours at a temperature of 125 ± 2°C
[257 ± 3.6°F], then cooled in a desiccator for 4 hours minimum prior to testing.

5.2.3 Reserve sets of specimens may also be conditioned concurrently for failure verification purposes.

5.3 Preparation for Testing

5.3.1 Adjustment of Test Flame  The burner is ignited and adjusted to produce a blue flame 19 mm [0.75 in] high. The correct flame is obtained by adjusting the gas supply and the air ports of the burner until a blue flame with a yellow-tipped outer cone 19 mm [0.75 in] high is produced. The air supply is increased slightly by opening the air ports only until the yellow tip just disappears and completely blue inner and outer flame cones are formed. The flame is remeasured for correct height. The procedure is repeated as necessary until all conditions are met. The burner tube is vertical during adjustment and testing. (See 6.2, 6.3, and 6.4.)

5.3.2 Specimen Mounting  Each specimen is mounted in the test fixture with its longitudinal axis vertical. The clamp used shall cover no more than the upper 6.4 mm [0.25 in] of the specimen. The vertical position of the test fixture/specimen assembly is adjusted so that the lower end of the specimen is 9.5 mm [0.375 in] above the top of the burner tube.

5.4 Measurement

5.4.1 The test flame is placed centrally under the lower end of the specimen for 10 ± 0.5 seconds. The burner is withdrawn from the specimen. If active combustion ceases prior to the specimen being completely consumed, the test flame is to be immediately placed under the specimen for an additional 10 ± 0.5 seconds, then withdrawn as before.

5.4.2 Evaluation and Report  Steps 5.5.1, 5.5.2, and 5.5.3 shall be performed for each test condition.

5.5 Recording Data  The following data is to be observed and recorded.

5.5.1 Duration of specimen burning to the nearest second after the first test flame application for each specimen.

5.5.2 Duration of specimen burning to the nearest second after the second test flame application for each specimen.

5.5.3 Duration of specimen burning plus glowing to the nearest second after the second test flame application for each specimen, only if required by the specification.

5.5.4 If any specimen burns up to the holding clamp on any ignition.

5.6 Calculation

5.6.1 Calculate the total specimen burning time and the average burning time based on ten ignitions per set of five specimens.

5.6.2 Calculation of the glowing time for each specimen, if required by the specification.

5.7 Report  The material shall be reported as out of compliance for one or more of the following test results, unless otherwise specified.

5.7.1 More than one specimen per set burns up to the holding clamp on any ignition.

5.7.2 More than one specimen per set burns for a period of time longer than allowed by the specification for a single specimen.

5.7.3 The total specimen burning time or the average specimen burning time as applicable exceeds the maximum allowed by the specification and is beyond the tolerance specified in 5.5.4.

5.7.4 More than one specimen glows for a period of time greater than allowed by the specification (when applicable).

5.8 Retest  If only one specimen per set fails to comply with the requirements, the reserve set of specimens shall be tested. In the case of total or average specimen burning time, the reserve set shall be tested only if these calculated values exceed the specification maximum by five seconds or less. All specimens from the reserve set shall comply with the requirements.

6.0 Notes

6.1 Most laminates covered by this test method do not drip molten or flaming material, and therefore provisions for this evaluation have not been described. If necessary, refer to UL-STD-94.

6.2 The inside of the burner barrel should be cleaned frequently. Specimen combustion by-products can collect around and inside the barrel tip. These deposits can be
flushed out during burner ignition and flame adjustment resulting in a false yellow flame tip. Proper flame adjustment becomes very difficult.

6.3 When the flame is correct and the specimens end is at the proper height above the burner 9.5 mm [0.375 in], the inner blue cone of the flame will just meet the end of the specimen. The specimen will then be ignited by the hottest area of the flame.

6.4 Accurate centering of the flame under the specimen is essential for consistent testing.

6.5 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.
1 Scope  This test method is intended to evaluate the relative flame resistance characteristics of a permanent solder mask coating on specified printed wiring laminates. It is intended for use on laminate 0.5 mm thick and greater. It should indicate to what degree, if any, that the coating may diminish the flammability of the laminate. The performance level of a material by these methods should not be assumed to correlate with its performance in end-use applications.

2 Applicable Documents


2.3.6 Etching, Ammonium Persulfate Method
2.3.7 Etching, Ferric Chloride Method
2.3.7.1 Cupric Chloride Etching Method

3 Test Specimen

3.1 Test specimens shall be prepared using vendor recommendations or manufacturers’ production process and fabricated parallel to either the warp or the fill direction as convenient.

3.2 Test specimens shall be 130 mm ± 5 mm in length and 13 mm ± 0.5 mm in width by the thickness being tested. Metal cladding shall be removed by etching, using IPC-TM-650, Test Method 2.3.6, 2.3.7, or 2.3.7.1.

3.3 The solder mask coating shall be applied evenly at both the minimum and maximum anticipated coating thickness over both the minimum and maximum laminate thickness desired.

3.4 All of these specimen sets, as well as one specimen set of uncoated laminate, for each laminate thickness, should come from the same laminate lots. In addition, if other solder masks are to be compared, all should be applied to the same lots, or results can vary widely. Pretesting of laminate lots is recommended.

3.5 Edges may be smoothed after fabrication, providing that any radius imparted to the corners does not exceed 12.5 mm.

3.6 Five specimens shall be prepared for each condition required (two conditions—see specimen conditioning). Reserve duplicates of five specimens are also required in the event a retest is necessary. Total specimens per set are therefore equal to 20. Total sets required, including uncoated substrate, would be six.

Note: Additional coatings tests would not have to include the uncoated sets if the laminate lots are the same and submitted simultaneously.

4 Apparatus

4.1 Test Chamber  A laboratory hood, totally enclosed, with a heat resistant glass window for observing the test, shall be used. The exhaust fan shall be turned off during the test, but may be turned on periodically to clear out the fumes and carbonized airborne particles between tests.

4.2 Clamping Devices  A clamping device, adjustable for vertical positioning of the test specimen, shall be provided within the test chamber so the specimen will hang with its length in a vertical position approximately coincident with the central vertical axis of the test chamber.

4.3 Laboratory Burner  A Bunsen or Tirrell Burner shall be used having a tube length of 100 mm and an inside diameter of 9.4 mm ± 1.5 mm. The burner shall not be equipped with end attachments.

4.4 Gas Supply  The gas supply shall be regulated and metered for uniform flow. The standard gas shall be technical grade methane. Natural gas having a nominal heat content of 1000 BTU per cubic foot may be substituted. Other fuel gases, such as butane, propane, and acetylene may be used; however, technical grade methane will be used for referee testing.

4.5 Timing Device  A stop watch or other suitable timing device with a precision of 0.5 seconds minimum

4.6 Desiccator  A desiccator containing dried silica gel or calcium chloride

4.7 Circulating Oven  A conditioning oven of circulating draft type capable of maintaining 70°C ± 1°C
4.8 Flame Gauging Device A thin steel scale template for gauging flame height

4.9 Burner Base A block support for use as a burner base with a 20° incline for proper positioning of the burner flame under the sample

5 Procedure

5.1 Specimen Conditioning

5.1.1 Specimen sets should first be brought to room temperature (23°C ± 2°C) for 24 hours prior to being thermal shocked within the specifications of both the laminate and solder mask being tested.

5.1.2 Specimen sets shall then be divided into two groups of 10 each. The first group shall be conditioned prior to testing by exposure to standard laboratory conditions of 23°C ± 2°C and RH of 50% ± 5% for a minimum of 48 hours.

The first set shall be referred to as “as received” specimen.

5.1.3 The second group shall be conditioned for a duration of 168 hours (seven days) at 70°C ± 1°C and then cooled in a desiccator over anhydrous calcium chloride for at least four hours at room temperature (23°C ± 2°C) prior to testing.

This second set shall be referred to as “conditioned” specimen.

5.1.4 From each of these groups, one half (five specimens) will be burned for the evaluation, with the remaining five specimens being held in reserve for retest if needed.

Note: See 5.6 to determine if and when the reserve sets will be needed.

5.2 Adjustment of Test Flame The burner is ignited and adjusted to produce a blue flame 19 mm high. The correct flame is obtained by adjusting the gas supply and the air ports of the burner until a blue flame with a yellow tipped outer cone 19 mm high is produced. The air supply is increased slightly by opening the air ports until only the yellow tip just disappears and it forms completely blue inner and outer flame cones. The flame is remeasured to assure correct height. The procedure is repeated as necessary until all conditions are met. The burner tube is vertical during the adjustment and measuring (see Figure 1).

5.3 Specimen Mounting Each specimen is mounted in the test fixture with its longitudinal axis vertical. The clamp used shall cover no more than the upper 6.5 mm of the specimen. The vertical position of the test fixture/specimen assembly is adjusted so that the lower end of the specimen is 9.5 mm above the top of the burner tube (see Figure 2).

5.4 Flame Test The test flame is placed centrally under the lower end of the specimen. Timing begins immediately for 10 ± 0.5 seconds. The burner is withdrawn at least 152 mm away from the specimen. If active combustion ceases prior to the specimen being completely consumed, the test flame is to be immediately placed under the specimen again for an additional 10 ± 0.5 seconds, then withdrawn as before.

5.5 Data to be Observed and Recorded The following test data is to be recorded:

a. Duration of specimen burning to the nearest second after the first test flame application for each specimen
b. Duration of specimen burning to the nearest second after the second test flame application for each specimen
c. Duration of specimen burning plus glowing to the nearest second after the second test flame application for each specimen, only if required by the specification
d. If any specimen burns up to the holding clamp on any ignition
e. If any specimen drips flaming particles, and if they ignite the dry absorbent surgical cotton located 305 mm below the test specimen
f. Calculation of the total specimen burning time or the average specimen burning time as applicable based on 10 ignitions per set of five specimens (see Figure 3)

g. Calculation of the glowing time for each specimen if required by the specification

5.6 Evaluation and Reporting  The material shall be considered to be out of compliance with the specification if:

a. More than one specimen per set burns up to the holding clamp on any ignition

b. More than one specimen per set burns for a period of time longer than allowed by the specification for a single specimen

c. The total specimen burning time as applicable exceeds the maximum allowed by the specification and is beyond the tolerance specified in 5.6.2

d. More than one specimen glows for a period of time greater than allowed by the specification (when applicable)

e. More than one specimen drips flaming particles, which ignite the dry absorbent surgical cotton

5.6.2 Reporting  Each test condition is reported separately. The parameters outlined in 5.6 are to be reported only as applicable.

5.6.3 Retests  If only one specimen per set (five) fails to comply with the requirements, the reserve set of specimen shall be tested. In the case of total and/or average specimen burning time, the reserve set shall be tested only if these calculated values exceed the specification maximum by five seconds or less. All specimens, their total, and their average from the reserve set shall comply with the requirements.

6 Notes

6.1 The inside of the burner barrel should be cleaned frequently. Specimen combustion by-products can collect around and inside the barrel tip. These deposits can be flushed out during burner ignition and flame adjustment, resulting in a false yellow flame tip. Proper flame adjustments then become very difficult if allowed to remain.

6.2 When the flame is correct and the specimen’s end is at the proper height above the burner (9.5 mm), the inner blue cone of the flame will just meet the end of the specimen. The hottest area of the flame will then ignite the specimen.

6.3 Accurate centering of the flame under the specimen is essential for consistent test results.
<table>
<thead>
<tr>
<th>Solder Mask</th>
<th>Color</th>
<th>Vendor</th>
<th>Lot</th>
<th>Laminate (ANSI type)</th>
<th>Color</th>
<th>Vendor</th>
<th>Lot</th>
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<th>Max:</th>
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<table>
<thead>
<tr>
<th>Substrate Thickness−(mm)</th>
<th>Min:</th>
<th>Max:</th>
</tr>
</thead>
</table>

### Solder Shock Parameters
- Time (seconds) ___________
- Temperature ___________ °C

#### Check One
- Actual Solder ☐
- Fluidized Alumina ☐

### Conditioning: ≥48 Hours @ 23°C ± 2°C & 50% ± 5% RH

<table>
<thead>
<tr>
<th>Specimen Number</th>
<th>Total Thickness</th>
<th>Time of Combustion or Combustion &amp; Glowing</th>
<th>Total Flaming Time/ea.</th>
<th>Total Flaming &amp; Glowing</th>
<th>Within (W) or Exceeds (E) Spec. Limits</th>
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<tbody>
<tr>
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<td>2nd Flame Application</td>
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<td>Glowing (sec.)</td>
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<td></td>
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</tr>
<tr>
<td>5</td>
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### Conditioning: 168 ± 2 Hours @ 70°C ± 1°C Desiccator Cooled

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<th>Time of Combustion or Combustion &amp; Glowing</th>
<th>Total Flaming Time/ea.</th>
<th>Total Flaming &amp; Glowing</th>
<th>Within (W) or Exceeds (E) Spec. Limits</th>
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<td>2nd Flame Application</td>
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<tr>
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<td></td>
<td>Flame (sec.)</td>
<td>Flame (sec.)</td>
<td>Glowing (sec.)</td>
<td></td>
</tr>
<tr>
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<td>5</td>
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Figure 3  Vertical Burn Flammability Data
1 **Scope**  The purpose of this test method is to provide a procedure for examining glass fabric to determine its construction, including its weight, thickness, strength, and type of weave. Since this method may be used to examine glass fabric used in PCB laminate and pre-impregnated “B” stage glass fabric, the method provides a procedure for removing any obscuring resin by a combustion process.

2 **Applicable Documents**

   IPC-EG-140  Specification for Finished Fabric Woven from “E” Glass for Printed Boards

3 **Test Specimen**

3.1 Three pieces of material, 5 cm x 5 cm

4 **Equipment/Apparatus**

4.1 Muffle furnace capable of maintaining 538°C ± 14°C

4.2 Analytical balance capable of weighing to the nearest milligram (0.001 g)

4.3 Micrometer capable of measuring to the nearest 0.0025 mm

4.4 Binocular microscope, magnification to 30X

5 **Procedure**

5.1 A minimum of three specimens of each test material shall be tested by the following procedure: Place a specimen in a crucible of suitable size and place in muffle furnace maintained at 538°C ± 14°C for 30 minutes. Remove from muffle furnace and allow to cool.

5.2 **Examine Residual Material**

5.2.1 If the residue shows any evidence of glass fusion, repeat 5.1, but with the muffle furnace temperature maintained at 488°C ± 14°C. If there is evidence of glass fusion at this lower temperature, again repeat the procedure of 5.1, lowering the temperature by 50°C increments until there is no evidence of glass fusion.

5.2.2 If the residue shows evidence of incomplete removal of resin, increase the temperature of the furnace by 50°C and repeat 5.1.

5.2.3 After the initial period and cooling to room temperature, the residual glass fabric must be white, free of resin residue, and exhibit no evidence of glass fusion.

5.3 **Thickness Measurement**  Place the glass fabric specimen between two flat plates and measure the thickness with a micrometer. Remove the glass fabric specimen and measure the thickness of the two flat plates. The thickness of the glass fabric shall be determined by subtracting the thickness of the two flat plates without the glass fabric from the measurement obtained with the glass fabric between the plates. The thickness of at least three specimens shall be measured and recorded. The thickness of each specimen shall be determined as the average of five separate measurements.

5.4 **Glass Fabric Weight**

5.4.1 The length and width dimensions of the glass fabric specimens shall be measured to the nearest 0.25 mm.

5.4.2 The weight of the specimen shall be determined using the analytical balance and weighing to the nearest milligram.

5.4.3 The weight of the glass fabric shall be determined using IPC-EG-140.

5.5 **Fabric Construction**  The number of yarns in the warp and fill used in constructing the fabric shall be determined by counting a 2.5 sq. cm area of the fabric using a microscope.

5.6 All other properties in Table 1 shall be as specified in the procurement document.

5.7 **Report**  The results of testing glass fabric by this test method shall be reported in a written report, which (as a minimum) contains the following:

1. Certification that the test was performed in accordance with this test method
2. Identification of the specimens tested
3. Dimensions of each specimen (length and width)
4. Thickness of the specimens
5. Fabric construction
6. Weight of each specimen in ounces per square yard
7. Results of any additional tests required by the test request or purchase document
8. Conclusions as to whether the test specimens meet the requirements of the glass fabric specified
Table 1

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<th>Cloth No.</th>
<th>Nominal Width Inches</th>
<th>Thickness Inch</th>
<th>Weight Per Square Yard Ounces</th>
<th>Yarn, Warp, and Fill</th>
<th>Construction</th>
<th>Minimum Breaking Strength Per Inch of Width</th>
<th>Yards per Standard Roll</th>
<th>Type of Weave</th>
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1.0 Scope  This test method specifies two methods for the
determination of the acid value of a flux of types L, M, or H.
Method A is a potentiometric titration method and is to be
considered as the reference method.
Method B is an alternative, visual end-point, titration method.

2.0 Applicable Documents

ISO 9455  Soft Soldering Fluxes, Test Methods
2.3.34  Solids Content, Flux

3.0 Test Specimen  A minimum of 2.0 grams of liquid flux,
10 grams of solder paste, 150 grams of cored wire or 10
grams of solder preforms.

4.0 Apparatus and Reagents

4.1 General
1. Use only reagents of recognized analytical quality and only
distilled or deionized water.
2. Ordinary laboratory apparatus.

4.2 For Potentiometric Titration Method (Method A).

4.2.1 Tetrabutyl ammonium hydroxide. 0.1 M (0.1 mol/1).
Use a commercially available standard solution or one pre-
pared from a commercially available concentrated standard
solution by dilution with 2-propanol (4.2.2). Alternatively, pre-
pare an 0.1 mol/1 tetrabutyl ammonium hydroxide solution by
diluting commercial concentrated solution with 2-propanol
and standardize this solution against an accurately weighed
amount of benzoic acid (about 0.5 g) dissolved in dimethylfor-
mamide, previously neutralized to thymol blue.

4.2.2 2-Propanol. Neutralized with tetrabutyl ammonium
hydroxide solution (4.2.1) to a faint pink color using phenol-
phthalein as an indicator.

4.2.3 Ethanol. Anhydrous, neutralized with tetrabutyl amm-
ionium hydroxide solution (4.2.1) to a faint pink color using phe-
olphthalein as an indicator.

4.2.4 Toluene. Neutralized with tetrabutyl ammonium
hydroxide solution (4.2.1) to a faint pink color using phenol-
phthalein as an indicator.

4.2.5 Ethanol/toluene mixture. Mix equal volumes of the
anhydrous ethanol (4.2.3) and toluene (4.2.4).

4.2.6 Millivoltmeter or pH meter.

4.2.7 Glass electrode.

4.2.8 Saturated calomel, or silver chloride/silver, electrode.

4.2.9 Magnetic or mechanical stirrer with variable speed
drive.

4.3 For titration with visual End-Point (Method B).

4.3.1 Ethanol, anhydrous. Neutralized with potassium
hydroxide, 0.1 M in alcohol (4.3.5), to a faint pink color using
phenolphthalein as an indicator.

4.3.2 Toluene. Neutralized with potassium hydroxide, 0.1 M
in alcohol (4.3.5), to a faint pink color using phenolphthalein as
an indicator.

4.3.3 Ethanol/toluene mixture. Mix equal volumes of the
anhydrous ethanol (4.3.1 and toluene 4.3.2).

4.3.4 2-Propanol. Neutralized with potassium hydroxide, 0.1
M in alcohol (4.3.1), to a faint pink color using phenolphthalein
as an indicator.

4.3.5 Potassium hydroxide solution. 0.1 M in alcohol. Use a
commercially available standard solution or one prepared from
a commercially available concentrated standard solution by
dilution with ethanol (4.3.1). Alternatively, prepare an 0.1
Mol/1 potassium hydroxide solution by dissolving 3 +/-0.1 g
potassium hydroxide (KOH) in 500 ml of ethanol (4.3.1), and
standardize this solution against an accurately weighed
amount of benzoic acid (about 0.5 g) dissolved in ethanol
(4.3.1).
4.3.6 Phenolphthalein indicator solution. Add 1g of phenolphthalein to approximately 50 ml methanol and mix. When dissolved, dilute to 100 ml with methanol and mix.

5.0 Procedures

5.1 Potentiometric Titration (Method A)

5.1.1 By preliminary experiments, determine whether the sample is soluble in 2-propanol, anhydrous ethanol, toluene or the ethanol/toluene mixture. If it is not completely soluble in any of these solvents, select the one in which it appears to be the most soluble. If it is equally soluble in all four solvents then use 2-propanol.

5.1.2 Carry out the following procedure, in triplicate, on the flux sample.

5.1.2.1 Weigh, to the nearest 0.001 g, 2.0 to 5.0 g of the liquid flux sample taking steps to prevent loss of volatile matter during the weighing. The larger size sample is required for very low solids fluxes. Transfer the weighed sample to a 250 ml low form beaker.

5.1.2.2 Dilute sample to 100 ml with 2-propanol, or the selected solvent (4.2.3 to 4.2.5), according to the solubility characteristics of the flux. Cover with a watch glass and dissolve the flux by gentle agitation.

5.1.2.3 Place the beaker on the stand of the titration assembly with the electrodes, stirrer and burette in position. Adjust the speed of the stirrer to give vigorous stirring without splashing. Titrate with the tetrabutyl ammonium hydroxide solution (4.2.1), adding 1 ml portions and recording the pH, or mV meter readings after each addition. As the end point is approached, reduce the additions of titrant to 0.1 ml and continue titrating past the end point.

5.1.2.4 Plot the pH, or potential values against the volume of titrant added to obtain the titration curve. The point of inflection of the curve corresponds to the end-point of the titration.

Note: The point of inflection of the curve may conveniently be determined by using the derivative curve.

5.1.2.5 Carry out a blank determination, using all reagents, for comparison purposes.

5.2 Visual Titration (Method B)

5.2.1 By preliminary experiments, determine whether the sample is soluble in 2-propanol anhydrous ethanol, toluene or the ethanol/toluene mixture. If it is not completely soluble in any of these solvents, select the one in which it appears to be the most soluble. If it is equally soluble in all four solvents then use ethanol as the selected solvent.

5.2.2 Carry out the following procedure, in triplicate, on the flux sample.

5.2.2.1 Weigh, to the nearest 0.001 g sufficient of the flux sample to correspond to approximately 1 g of non-volatile matter (see IPC-TM-650, test method 2.3.34), taking steps in the case of liquid flux samples to prevent loss of volatile matter during the weighing.

5.2.2.2 Transfer the weighed sample to a suitable flask or beaker and add 100 ml of the selected solvent. Stir until the sample has dissolved as completely as possible. Do not heat.

5.2.2.3 Add 3 drops of phenolphthalein indicator (4.3.6) and titrate with the potassium hydroxide (4.3.5) until a faint pink color persists throughout the titrated solution for 15 seconds.

5.2.2.4 Carry out blank determination, using all reagents, for comparison purposes.

5.3 Calculation of Results

The acid value is expressed in milligrams of potassium hydroxide per gram of non-volatile matter, regardless of the alkali used to perform the titration.

5.3.1 The acid value (expressed in milligrams of potassium hydroxide per gram of non-volatile matter) is given by:

$$\frac{56.11 VM}{m S}$$

Where:

V is the volume, in ml, of alkali used (tetrabutyl ammonium hydroxide for method A, potassium hydroxide for method B).

M is the molarity of the alkali used.

m is the mass, in grams of the sample taken.

S is the percentage non-volatile matter determined as described in IPC-TM-650, test method 2.3.34.

The acid value (expressed in milligrams of potassium hydroxide per gram of flux) is given by:

$$\frac{56.11 VM}{m}$$
5.3.2 The acid value of the flux under test is calculated as the mean of the results obtained on each of the three test samples.

6.0 Notes

6.1 Safety Operator should be trained and familiar with the hazards inherent to the chemicals being used and analyzed. Proper personal safety equipment, such as safety glasses, gloves and splash apron, and adequate ventilation should be used.
1 Scope  This test method provides a standard method for evaluating the effect of established processing operations used in the manufacture of PWBs on materials that are considered for use in the manufacture of PWBs. Specific criteria for the acceptability are based on copper foil adhesion and visual surface condition of the base laminate.

2 Applicable Documents

2.4.8 Peel Strength of Metallic Clad Laminates
MIL-P-13949

3 Test Specimens

3.1 Copper-clad epoxy glass laminate materials ranging from 0.8 mm to 6.5 mm thick, clad on one or both sides.

3.2 Three specimens shall be tested from each material, except in the case where the material is clad on both sides, and then six specimens shall be processed for each material. Each specimen will have four readings for peel strength (see IPC-TM-650, Method 2.4.8).

4 Equipment/Apparatus

4.1 Etching  Typical production printing, etching, and plating equipment and materials

4.2 Tester  For peel strength equipment (see IPC-TM-650, Method 2.4.8)

5 Procedure

5.1 Print and Etch

5.1.1 Sand the edges of the test specimens to remove burrs, allowing close contact between the specimen, negative, and frame glass, resulting in a better defined etched pattern.

5.1.2 Scrub the copper surface(s) with FFF pumice and a brush to remove any contamination on the surface of the specimen until it passes a water break test.

5.1.3 Dry the specimens using compressed filtered air.

5.1.4 Dip the specimens in the following photoresist solution at room temperature:
One part by volume KPR III
One part by volume toluene
One part by volume acetone
The specific gravity of the solution is 0.920.

5.1.5 Hold the specimen by one corner when dipping. Allow excess solution to drain until dripping stops.

5.1.6 Put the specimens on rack (after draining) into 80°C oven from three to five minutes to dry and harden KPR.

5.1.7 Remove the rack from the oven and allow the specimens to cool to room temperature.

5.1.8 Place the specimens upon the negative in the printing frame with the copper side against the negative.

5.1.9 Expose the mounted specimen 76 mm from the fluorescent black light for seven minutes.

5.1.10 Develop in trichlorethylene vapor for 15 seconds. It may require two to six cycles until the pattern is clear. Air-dry the specimen after developing.

Note: Use the test pattern in Method 2.4.8.

5.2 Etching Process and Etchant Removal

5.2.1 Method A

5.2.1.1 Etch the specimens with vigorous aeration for the minimum time (the time to produce a clean pattern with a minimum of undercutting is approximately seven minutes for 34 mm and 15 minutes for 69 mm copper, using fresh ferric chloride solution) in 42° Baume (be) ferric chloride solution maintained at 24°C to 38°C. The etching solution shall be renewed when the etching time exceeds 15 minutes for 34 mm copper or 30 minutes for 69 mm copper.

5.2.1.2 After removal of the copper, immediately wash the specimens with running tap water at 16°C to 32°C for two to five minutes. Thereafter, keep the specimens from drying until reaching step 5.2.1.7.
5.2.1.3 Immerse the specimens in a 10% solution of oxalic acid in water at 16°C to 32°C for 15 to 20 minutes. Provide gentle circulation of the oxalic acid solution during this period. Flush the specimens with running tap water at 16°C to 32°C.

Caution: Oxalic acid is toxic.

5.2.1.4 Scrub the specimens with Grade FFF pumice to remove resist, or wipe off the resist with a lint-free cloth moistened with a suitable solvent (i.e., methylethyl ketone, trichloroethylene, or toluol). In cleaning the specimens, care must be exercised to avoid abrading the adhesive layer with the pumice or attacking the adhesive or laminate with the solvent. Specimens not involving the use of resist need not be scrubbed.

5.2.1.5 Scrub the specimens with a plastic-bristled brush under running tap water at 16°C to 32°C and rinse for 30 minutes.

5.2.1.6 Rinse the specimen in distilled water.

5.2.1.7 Dry the specimens for one hour in an oven at 80°C ± 3°C. If specimens are for electrical tests, handle only with rubber or polyethylene gloves.

5.2.2 Method B

5.2.2.1 Remove foil from the specimen using a solution containing 298 g ± 10 per liter of ammonium persulfate and 15.5 mL ± 1.0 per liter of sulfuric acid, specific gravity 1.836 (66°Be). The temperature shall be 43°C ± 3°C.

5.2.2.2 Rinse the specimens thoroughly in running water and dry with a clean air blast.

5.2.2.3 Dry the specimens in an oven at 80°C ± 3°C for one hour and allow the specimens to cool.

5.3 Petrolatum Evaluation

5.3.1 Drill 1.5 mm holes in the pads of the 3 mm lines with good fabricating practice.

5.3.2 Remove the developed KPR by rubbing the pattern lightly with cold trichlorethylene liquid. Rinse in water. Scrub the specimens with FFF pumice and water with a strong bristle brush.

5.3.3 Plate per MIL-P-13949. Deoxidize by dipping in 10% hydrochloric acid for two minutes and wash in running water for five minutes. Dry 30 minutes, minimum, at 105°C to 110°C.

5.3.4 Coat the etched copper surface with white petrolatum. Specimens shall be immersed horizontally in solder 6.5mm below the surface for 20 ± 1 seconds at 260°C +5°C/-0°C) measured 25 mm below the surface.

5.3.5 Remove the petrolatum from the surface of the specimen with a two minute scrub in cold trichlorethylene, followed by a one minute rinse in hot trichlorethylene.

5.3.6 Inspect the surface for weave exposure, measling, crazing, resin loss, delamination and blistering.

5.3.7 Test four 0.8 mm lines on the specimen for peel strength and report the average value for the four lines. This test shall be performed in accordance with Method 2.4.8.

5.4 Report

5.4.1 The results of the testing by this test method shall be reported in a written report, which contains the following as a minimum:
1. Certification that the test was performed in accordance with this test method
2. Identification of specimens tested
3. Test results for each of the specimens tested, including the results of the visual inspections and peel tests
1.0 Scope  This is an electrogravimetric method for determining the purity of copper foil or plating.

2.0 Applicable Documents  None

3.0 Test Specimens  Each copper specimen must weigh approximately 5 grams and be raw copper foil or plating without treatment.

4.0 Apparatus or Material

4.1 Electrodes for Electrogravimetric Analysis  A platinum gauze cathode. A platinum gauze rotating anode or a spiral platinum wire anode.

4.2 Reagents

4.2.1 Acid mixture for dissolving sample: Add 300 ml of concentrated H₂SO₄ slowly with stirring to 750 ml of water. Cool and add 210 ml of HNO₃.

4.2.2 For cleaning the sample use 5% H₂SO₄. For cleaning of the interior of the glassware use diluted HNO₃ (1 part acid plus 3 parts distilled or deionized water by volume).

4.2.3 For final rinsing use absolute methanol or equivalent.

4.2.4 Distilled or deionized water.

4.3 Other apparatus

4.3.1 Fume hood for removing fumes from dissolution.

4.3.2 Hot plate for heating the test solution to 80-90°C (176-194°F).

4.3.3 Analytical balance capable of weighing copper sample and platinum cathode to the nearest 0.1 milligram.

4.3.4 Oven for drying the specimen and cathode at approximately 110°C (230°F).

4.3.5 Current source capable of supplying a current density based on the cathode area of at least 0.6 A/dm².

4.3.6 Tall-form 180 ml to 300 ml lipless beaker provided with a close-fitting split cover.

5.0 Procedure

5.1 Test

5.1.1 Clean the copper foil by dipping in 5% H₂SO₄ at room temperature, wash thoroughly in tap water, then distilled water, rinse in absolute methanol or equivalent, dry for a few minutes in hot air oven at 110°C (230°F) and cool in a desiccator. Weigh the copper test specimen to the nearest 0.1 mg and transfer to a tall-form 180 ml to 300 ml lipless beaker provided with a close-fitting cover. Place the beaker into a fume hood.

5.1.2 Add 45 ml of H₂SO₄-HNO₃ mixture and allow to stand covered for a few minutes until reaction has nearly ceased.

5.1.3 Heat at a temperature of 80-90°C (176-194°F) until dissolution is complete and brown fumes have been expelled. Never boil.

5.1.4 Cool slightly and carefully wash down the cover and insides of the beaker with distilled water and dilute the solution sufficiently to cover the cathode cylinder. The purpose of the wash is to make sure that any of the ionized copper that may be on the cover or inside surface of the beaker is in the solution from which the copper is to be reduced by electroplating onto the platinum cathode.

5.1.5 Allow solution to cool to ambient conditions.

5.1.6 Weigh the cathode to the nearest 0.1 mg.

5.1.7 Insert the electrodes in the solution, cover to prevent splashing or evaporation, and electrolyze at a current density of 0.6 A/dm². (When a current density of 0.6 A/dm² is used, the electrolysis takes about 16 hours and is conveniently carried on overnight.)

5.1.8 When the solution becomes colorless, reduce the current density to about 0.3 A/dm² and wash down the cover glasses, electrode stems and the inside of the beaker.
5.1.9 Continue the electrolysis until the deposition of the copper is complete, as indicated by failure to plate on a new surface of the electrode stem when the level of the solution is raised by adding distilled water. (Metal added to solution by washing glass and cover will typically plate in approximately 1 hour.)

5.1.10 Without interrupting the current, remove the electrodes from the solution.

5.1.11 Remove the cathode. Wash with distilled water. Dip in absolute methanol or equivalent and dry rapidly in a hot air oven at 110°C (approximately 5 minutes). Cool to ambient in a desiccator and weigh to the nearest 0.1 mg.

5.1.12 Shut off current supply to just set up.

5.2 Calculations

5.2.1 Calculate the percentage of copper by weight by the following method:

\[ \text{Weight of copper recovered } C_R = A - B \]

where:

\[ A = \text{weight of cathode plus deposited copper in grams.} \]
\[ B = \text{initial weight of the cathode in grams} \]

Copper, by weight (%) = \( \frac{C_R}{C_i} \times 100 \)

where:

\[ C_R = \text{weight of copper recovered in grams} \]
\[ C_i = \text{initial weight of copper test sample in grams} \]

6.0 Notes

6.1 Interferences In this method any silver present in the test sample is deposited with the copper, and is reported as copper.
1.0 Scope  This method is designed to determine the resin content percent of prepreg which is reinforced with inorganic fabric, by removal of the resin from the reinforcement using a burn-off step.

2.0 Applicable Documents  None.

3.0 Test Specimens

3.1 Size  Specimens shall be approximately 102 mm x 102 mm [4.0 in. x 4.0 in]. If the reinforcement is a continuous fiber woven fabric, the sides shall be cut on a bias to the orientation of the fabric.

3.2 Quantity and Sampling  Unless otherwise specified, three specimens shall be taken equally spaced across the width (web) of a roll or from different locations in a predetermined quantity of paneled prepreg, such as an inspection lot.

4.0 Apparatus or Material

4.1 Analytical Balance  Analytical balance capable of weighing to the nearest milligram [0.001 gram].

4.2 Muffle Furnace  Muffle furnace capable of maintaining 550 ± 50°C [1022 ± 90°F].

4.3 Crucible  Crucible of sufficient size and type to hold the specimen when placed in a muffle furnace.

4.4 Cutting Apparatus  Shears or other equipment capable of cutting specimens to the specified size.

4.5 Desiccator  Desiccation chamber capable of maintaining an atmosphere less than 30% R.H., at 23°C [73°F].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Cut the specimens to the specified size.

5.1.2 Unless the prepreg is tested within 10 minutes of its manufacture, the specimens shall be desiccated for a minimum of 4 hours. For referee testing, the specimens shall be desiccated.

5.2 Measurement

5.2.1 Each specimen shall be weighed in a previously weighed crucible to the nearest milligram.

5.2.2 Place the crucible containing the specimen in the muffle furnace maintained at 550 ± 50°C [1022 ± 90°F] for 5 minutes, minimum.

5.2.3 Remove the crucible with contents from the furnace and place in the desiccator until cooled to room temperature.  

Note: If the contents of the crucible shows evidence of glass fusion, discard the specimen and repeat the test with a new specimen, except lower the temperature of the muffle furnace by 50°C [122°F]. If the contents show evidence of incomplete combustion of the resin, increase the temperature of the furnace or extend the time of combustion. In any case, the residual glass cloth, after combustion, must be completely free of resin residue, and show no evidence of glass fusion.

5.2.4 Weigh the crucible with contents to the nearest milligram.

5.2 Calculation  The resin content of the prepreg is calculated as follows:

\[
\text{Resin content (\%)} = \frac{\text{Loss of Weight of Specimen}}{\text{Original Weight of Specimen}} \times 100
\]

5.3 Report  The results shall be recorded in a report indicating resin content percent for each specimen and the average of all specimens of the same materials.

6.0 Notes

6.1 Reinforcements used for prepreg covered by this test method may be woven or nonwoven, and continuous or non-continuous fibers, any of which are referred to as fabrics.

6.2 Desiccator Conditions  The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.
1.0 Scope
This method is designed to determine the resin content of a prepreg without removing the resin from the reinforcement. The basis weight of the fabric must be known. This method is applicable to both organic and inorganic reinforcements.

Note: For referee testing of prepregs with inorganic reinforcement, Method 2.3.16 shall be used.

2.0 Applicable Documents
IPC-EG-140 Specification for Finished Fabric Woven from “E” Glass for Printed Boards
IPC-SG-141 Specification for Finished Fabric Woven from “S” Glass
IPC-A-142 Specification for Finished Fabric Woven from Aramid for Printed Boards
IPC-QF-143 Specification for Finished Fabric Woven from Quartz (Pure Fused Silica) for Printed Boards
IPC-TM-650 Method 2.1.6.1, Weight of Fabric Reinforcements
Method 2.3.17, Resin Flow Percent of Prepreg
Method 2.3.19, Volatile Content of Prepreg Materials

3.0 Test Specimens
3.1 Size
Specimens shall be 101.6 mm x 101.6 mm [4.0 in x 4.0 in]. If the reinforcement is a continuous fiber woven fabric, the sides shall be cut on a bias to the orientation of the fabric.

3.2 Quality and Sampling
Unless otherwise specified, three specimens shall be taken equally spaced across the width (web) of a roll or from different locations in a predetermined quantity of paneled prepreg, such as an inspection lot. If specimens are to be used for Resin Flow Percent (TM 2.3.17), then four specimens shall be used, cut from adjacent points in a roll or cut panels (see 6.4).

4.0 Apparatus or Material
4.1 Analytical balance, capable of weighing to the nearest milligram (0.001 gram).

4.2 Static shield (a thin piece of metal, e.g., 7 oz./sq. ft. copper foil 5 in x 5 in [127 mm x 127 mm] or larger). This is not needed if the balance pan is larger than the specimen.

4.3 Sample cutting apparatus—die cut press, or equivalent, capable of cutting specimens to the specified size.

4.4 Desiccator capable of maintaining an atmosphere less than 30% R.H. at 23°C [73°F].

Note: Do not use vacuum or other means which would be capable of removing solvent or resin fractions.

5.0 Procedure
5.1 Preconditioning
Unless the prepreg is tested within 10 minutes of production the specimen shall be desiccated for a minimum of 4 hours. For referee testing, the specimens shall be desiccated.

5.2 Test Conditions
The test shall be performed at standard laboratory conditions. For materials which absorb moisture rapidly, care should be taken to insure that moisture content is not significant by measurement immediately after removal from desiccation.

5.3 Measurement
5.3.1 Place the static shield on the balance pan.
5.3.2 Zero the balance.
5.3.3 If applicable, remove the specimens from the desiccator. Place the specimens together on the balance, insuring that they sit entirely on the balance pan, or the static shield if needed (see 6.4).
5.3.4 Determine and record the weight of the specimens to the nearest 0.1g. For prepregs of nominal 0.15 mm [0.006 in] thickness and less, weigh to the nearest 0.001g.

5.4 Calculations
5.4.1 Determine the basis weight of the fabric using one of the methods of Appendix A.
5.4.2 Calculate the Resin Content (RC) of the material from the treated weight (TW) and the basis weight (BW) of the fabric for 41,290 mm² [64 in²]. The basis weight may be determined by any suitable method in Appendix A.

\[
RC = \left(1 - \frac{BW}{TW}\right) \times 100
\]

where:
- \(RC\) = Resin Content in %
- \(BW\) = weight of the fabric as determined in accordance with Appendix A
- \(TW\) = treated weight from 5.3.4.

5.5 Report

5.5.1 Report the Resin Content to the nearest .1%.

5.5.2 Report the method used to determine the basis weight of the reinforcement.

5.5.3 Report any anomalies in the test or any variations from the specified procedures or tolerances

6.0 Notes

6.1 The solvent or volatile content of the prepreg (excluding moisture) is considered part of the treated weight using this method. If it is desired to exclude solvent content, the specimens should be vacuumed for an appropriate time and temperature.

6.2 The accuracy of this method for determination of resin content is dependent primarily upon the accuracy of the basis weight and the consistency of the reinforcement.

6.3 The effect of static charges may present a serious problem in weighing material which has been stored if the sample is larger than the sample pan.

6.4 If it is desired to check variation across the web the individual specimens may be weighed separately or 4 specimens may be cut down the web at each location to be tested.

6.5 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

Appendix A

Determination of Basis Weight of Reinforcement All the following methods consider any finishes applied to the fabric as part of the fabric. In most cases, the level of organic material is negligible; however, special considerations have to be made for material such as greige goods, which have substantial amount of organic (5% or more), and for organic fabrics which may have significant moisture content.

Methods shown are based on four specimens, with a total area of 41,290 mm² [64.0 in²].

Method 1 Determine the Basis Weight from the actual length, width and weight of the roll.

\[
BW = \frac{806.4 \times WR}{L \times W}
\]

\(BW\) = Basis Wt in g
\(WR\) = Roll weight in lb.
\(L\) = Roll length in yds.
\(W\) = Roll width in in.

Method 2 Determine the Basis Weight from median statistical or typical fabric weight in oz/yd²

\[
BW = 1.40W
\]

\(BW\) = Basis wt in g
\(W\) Weight of 1 yd² in oz.

Method 3 Determine the Basis Weight from the actual fabric weight at the beginning of the roll, using Method 2.1.6.1.

Method 4 Determine the Basis Weight from the reported weight supplied by the manufacturer.

\[
BW = 1.40W
\]

\(BW\) = Basis Wt in g
\(W\) = Weight of 1 yd² in oz.

Method 5 Determine the Basis Weight by consulting the unit weight tables in the applicable documents; see 2.0.
1.0 Scope
This method is designed for determining the treated weight of a specific area of prepreg. Treated weight is an alternative to Resin Content Percent as a means of determining the usability and functionality of prepreg. This method is applicable to both organic and inorganic reinforcements but effective use of this technique requires knowledge of resin and reinforcement specific gravity, as well as basis weight of the reinforcement.

2.0 Applicable Documents

<table>
<thead>
<tr>
<th>Document</th>
<th>Description</th>
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<tbody>
<tr>
<td>IPC-EG-140</td>
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<tr>
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<td>Specification for Finished Fabric Woven From “S” Glass</td>
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</tr>
<tr>
<td>IPC-TM-650</td>
<td>Method 2.4.38, Prepreg Scaled Flow Testing</td>
</tr>
</tbody>
</table>

3.0 Test Specimens

3.1 Size
The prepreg specimen shall be two or more die cut plies. Each ply shall be 140 ± 0.25 mm [5.5 ± 0.01 in] by 178 ± 0.25 mm [7.0 ± 0.01 in]. Use of the specimen for scaled flow test (IPC-TM-650, Method 2.4.38) is recommended. See 2.4.38 for additional criteria.

Alternate specimen sizes such as 102 mm x 102 mm [4 in x 4 in] or 457 mm x 610 mm [18 in x 24 in] are acceptable by agreement between supplier and user.

3.2 Quantity and Sampling
Unless otherwise specified, three specimens shall be taken from the lot at randomly selected locations, whether taken from a roll or from precut panels. Specimens shall be taken from the fabric roll (as supplied by the manufacturer) no closer to the selvage (or cut edge) than a distance equal to one-tenth of the width of the roll.

4.0 Apparatus or Material

4.1 Analytical balance capable of weighing to the nearest 0.001g.

4.2 Static shield (a thin piece of metal, e.g., 7 oz copper foil at least 25.4 mm [1.0 in] larger in length and width than the prepreg specimen). This is not required if the balance pan is larger than the specimen.

4.3 Sample cutting press with die 140 ± 0.25 mm x 178 ± 0.25 mm [5.50 ± 0.01 in x 7.00 ± 0.01 in].

4.4 Kraft paper or equivalent back up material for cutting press.

4.5 Desiccator capable of maintaining an atmosphere less than 30% R.H. at 23°C [73°F].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Cut the specimens to the specified size and configuration, see 3.1.

5.1.2 Preconditioning
Unless the prepreg is tested within 10 minutes of production, the specimen shall be desiccated for a minimum of 4 hours. For referee testing, the specimens shall be desiccated.

5.2 Test Conditions
The test shall be performed at standard laboratory conditions. For materials which absorb moisture rapidly, care should be taken to insure that moisture content is not significant by measurement immediately after removal from desiccation.

5.3 Equipment Setup
Place the static shield on the balance pan and zero the balance.

5.4 Measurement

5.4.1 Place each specimen on the balance, ensuring that it sits entirely on the static shield.

5.4.2 Determine and record the treated weight of each specimen to the nearest 0.001g.
5.5 Report

5.5.1 Average the individual specimen weight and report the average per ply treated weight to the nearest 0.001g per 25.4 sq mm [1.0 sq in].

6.0 Notes

6.1 The volatile content of the prepreg (excluding moisture) is considered part of the treated weight using this method. If it is desired to exclude volatile content, the specimen should be baked for an appropriate time and temperature.

6.2 The effect of static charges may present a serious problem in weighing material if the specimen size is greater than the sample pan.

6.3 If it is desired to check variation across or along the web, individual specimens should be taken from the location in question.

6.4 If it is desirable to check the weight uniformity of the reinforcement, this can be done by burn-off similar to IPC-TM-650, Method 2.3.16, if inorganic.

6.5 Calculations  Treated weight can be used to specify and/or predict prepreg thickness and resin content. Equations to calculate thickness and resin content for woven fabric “E”-glass reinforced epoxy FR-4 prepreg are given below. The calculations assume a resin specific gravity of 1.37 gr/cc and an “E”-Glass specific gravity of 2.59 gr/cc.

Woven “E”-glass fabric nominal dry weights and tolerances are assumed the values given in IPC-EG-140. The nominal dry weights and tolerances for other reinforcements, such as “S” glass, woven aramid, and quartz fabric, can be found in IPC-SG-141, IPC-A-142, IPC-QF-143. Appropriate values for the specific gravities of other resins and reinforcements and the basis weights of other reinforcements are the responsibility of the vendor or can be negotiated between vendor and user. Inorganic reinforcement basis weight can be measured as given in 6.4.

6.5.1 Resin Content  The resin content can be calculated from the average per ply treated weight and the measured or nominal unit glass fabric weight. Conversely, the treated weight can be calculated from the resin content. Equations to calculate both are shown below:

\[ \text{RC} = \left( 1 - \frac{\text{BW}}{\text{TW}} \right) \times 100 \]
\[ \text{TW} = \frac{\text{BW}}{1 - \left( \frac{\text{RC}}{100} \right)} \]

Where:
- RC = resin content by weight
- TW = treated weight (weight per area per ply)
- BW = unit basis weight (weight per area per ply)

6.5.2 Prepreg Thickness  The average prepreg thickness can be calculated using the average per ply treated weight and the measured or nominal unit glass fabric weight. Equations to calculate prepreg thickness for Scaled Flow test sized specimens (38.5 square inches per ply) are given below:

In general:

\[ H_0 = 1.585 \frac{\text{TW}}{W_f} - 1.585 \frac{W_f (d_r - d_f)}{d_r d_f} \]

For “E”-glass reinforced FR-4 epoxy prepreg:

\[ H_0 = 1.157 \text{ TW} - 0.545 W_f \]

Where:
- \( H_0 \) = prepreg thickness (mils per ply)
- TW = treated weight (weight per 38.5 sq in per ply)
- \( W_f \) = unit glass fabric weight (weight per 38.5 sq in per ply)
- \( d_r \) = resin density (grams per cubic centimeter)
- \( d_f \) = fabric fiber density (grams per cubic centimeter)

6.6 Desiccator Conditions  The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.
1.0 Scope
This test method is designed to measure the Resin Flow Percent by weight in prepreg.

2.0 Applicable Documents
None

3.0 Test Specimens

3.1 Size and Configuration
A specimen shall consist of multiple plies of prepreg cut 102 ± 0.25 mm [4.0 ± 0.010 in] by 102 ± 0.25 mm [4.0 ± 0.010 in]. If the reinforcement is a continuous fiber woven fabric, the sides shall be cut on a bias to the fabric weave. Unless otherwise specified, the test specimen shall have four plies. (Note: an alternative specimen configuration commonly used is a stack that weighs approximately 20 g.)

3.2 Quantity and Sampling
Unless otherwise specified, the number of specimens tested shall be as follows: for qualification testing, 3 specimens shall be tested with the pieces for each specimen taken from areas of the prepreg that represents the center and both sides of the material as impregnated. For lot testing, one specimen shall be tested, with the pieces randomly taken. Pieces shall be taken no closer to the selvage (or cut edge) than a distance equal to one-tenth of the width of the roll.

4.0 Apparatus or Material

4.1 Laminating Press
Unless otherwise specified, laminating press capable of maintaining a temperature of 171 ± 3°C [340 ± 5°F] and capable of providing a pressure of 1380 ± 70 kPa [200 ± 10 psi] on the test specimen (see 6.1).

4.2 Analytical Balance
Analytical balance capable of weighing to the nearest 0.001 gram.

4.3 Plates
Caul plates approximately 3.2 mm [0.125 in] thick and at least 152 mm x 152 mm [6.0 in x 6.0 in], but no larger than the press platen size, and made from type 304 steel, or equivalent.

4.4 Circle Punch
A punch or die set capable of cutting a circle 81.1 mm [3.192 in] in diameter.

4.5 Desiccator
Desiccation chamber capable of maintaining an atmosphere of less than 30% R.H. at 23°C [73°F].

4.6 Release Material
The release material shall be Tedlar, Type MR, (polyvinyl fluoride, PVF) or equivalent, cut at least as large as the caul plates.

5.0 Procedure

5.1 Specimen Preparation

5.1.1 The prepreg shall be cut to conform with the specimen size and configuration, see 3.1.

5.1.2 For referee purposes only, specimens shall be desiccated for a minimum of 4 hours.

5.2 Measurement

5.2.1 Determine the weight of each specimen to the nearest 0.005 gram. Record this as the original weight, or $W_o$.

5.2.2 Stack the plies of prepreg for one specimen with the grain of the cloth aligned in the same direction and place between two pieces of release film. Place this package between two caul plates that are at room temperature.

5.2.3 Place specimen and caul plates in a preheated laminating press maintained at the specified temperature and immediately apply pressure such that the specified pressure is achieved within 5 seconds after press closure. Unless otherwise specified, the temperature shall be 171 ± 3°C [340 ± 5°F] and the pressure shall be 200 ± 10 psi [1380 ± 70 kPa].

5.2.4 Maintain the specified pressure for $10 + 6, - 0$ minutes.

5.2.5 Open press, remove specimen, and allow to cool to room temperature.

5.2.6 If applicable, post cure the test specimen in accordance with the manufacturer’s post cure method (in order to prevent specimen damage by cutting).

5.2.7 Using the punch and die set, remove a circular disc measuring 81.1 mm [3.192 in] in diameter from the center of the specimen.
5.2.8 Weigh the circular specimen on the analytical balance to the nearest 0.005 gram. Record this as the disc weight, or $W_D$.

5.3 Calculation The resin flow is calculated as follows:

\[
\text{Resin Flow, Percent} = \left( \frac{W_O - 2W_D}{W_O} \right) \times 100
\]

$W_O$ = Original weight of the specimen
$W_D$ = Disc weight of the specimen (cut from the specimen after pressing)

5.4 Report The resin flow, percent, for each specimen tested and the average of all specimens tested shall be reported.

6.0 Notes None

6.1 Other resins may require different temperature settings to achieve flow. Pressure may also be dependent on the resin chemistry. Agreement of temperature and pressure by supplier and user other than as specified should be included in the report, see 5.4.

6.2 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.
1 Scope  This test is to measure the flow properties of cast adhesive freefilms or coverfilms used in the manufacture of flexible circuitry. The test also provides a measure of the squeeze out, which might be expected to occur around terminal pads or other boundary spaces.

1.1 Limitations  It is not possible to define a universal set of laminating conditions that suit all of the various adhesive types. This test is dependent on sample preparation, which is consistent with good industry practice and in accordance with the suppliers’ suggested laminating procedures.

2 Applicable Documents  None

3 Test Equipment

3.1 Copper foil  Foil may be treated one side or untreated.

3.2 A laminating press in good working order with platen surfaces of 30.5 cm x 30.5 cm minimum. Platens must be sufficiently flat and parallel to allow uniform lamination.

3.3 Paper punches with circular punch sizes of 1.6 mm, 3.2 mm, 4.8 mm, and 6.4 mm.

3.4 A suitable instrument for measuring thickness of the adhesive.

4 Test Procedure

4.1 Layup for Adhesives Cast on Coverfilms  With the release film intact, punch seven graduating holes across the coverfilm (see Figure 1), then remove release. Alternative punched hole diameters may be agreed upon between user and vendor.

4.2 Layup of Freefilm Adhesive  The freefilm must be transferred to a suitably thick polyimide or polyester film. This effectively creates a coverfilm, which may be laid up per 4.1. A 0.005 mm polyimide film shall be used as a referee in the event of conflict.

4.3 Lamination  To be accomplished by time, temperature, press pad, and pressure parameters as agreed upon between supplier and user. A prebake may be used to simulate extended storage conditions. Prebake conditions must be agreed upon by supplier and user.

4.4 Evaluation

4.4.1 Squeezeout Characteristics  Measuring squeezeout on specimen punched holes at 90° intervals around the circumference of the holes; averaging the four readings for each hole to arrive at an average squeezeout.

Calculation:

\[
\frac{\text{average}}{\text{adhesive thickness}} = \text{microns/micron}
\]

5 Notes

5.1 Fill and squeezeout properties of cast adhesive films are a complex variable. Different adhesives will exhibit different abilities to flow. The amount of retained solvent, adhesive thickness, shelf aging, and substrate thickness will cause the flow properties to vary within any one adhesive. The uniformity of lamination, press pad, and thermal excursion is critical in obtaining test repeatability.
1.0 Scope  This test method is designed to measure the Resin Flow of “no flow” prepreg used for bonding and adhesion without formation of resin bead as caused by flow of the resin.

2.0 Applicable Documents  None

3.0 Test Specimens

3.1 Size and Configuration  A specimen shall consist of multiple plies of prepreg cut approximately 102 mm [4.0 in] x 102 mm [4.0 in]. If the reinforcement is a continuous fiber woven fabric, the sides shall be cut on a bias to the fabric weave. Unless otherwise specified, the test specimen shall have three plies.

3.2 Quantity and Sampling  Unless otherwise specified, the number of specimens tested shall be as follows: For qualification testing, 3 specimens shall be tested, with the pieces for each taken from areas of the prepreg that represents the center and both edges of the material as impregnated. For lot testing, one specimen shall be tested, with the pieces randomly taken from the prepreg. Pieces shall be taken no less than 25.4 mm [1.0 in] from the impregnated edge.

4.0 Apparatus or Material

4.1 Laminating Press  Unless otherwise specified, a laminating press capable of maintaining at a temperature of 171 ± 2.8°C [340 ± 5°F] and capable of providing a pressure of 1380 ± 70 kPa [200 ± 10 psi] on the test sample, see 6.1

4.2 Hole Punch  Hole cutting tool, such as a hole punch or die set capable of cutting a 25.4 ± 1.3 mm [1.0 ± 0.05 in] hole.

4.3 Materials

4.3.1 Release material shall be Tedlar type (polyvinyl fluoride, PVF), or equivalent, of 0.05 mm [0.002 in] thickness, maximum, at least as large as the size of the caul plates.

4.3.2 Any copper-clad laminate of thickness between 0.25 mm [0.010 in] and 0.38 mm [0.0151 in] shall be cut to approximately 152 mm x 152 mm [6.0 in x 6.0 in].

4.3.3 Conformal press pad material equivalent to 0.5 mm [0.020 in] cotton linter paper, and cut to approximately 152 mm x 152 mm [6.0 in x 6.0 in].

4.4 Measuring Microscope  Bausch and Lomb, model SUB–73 stereozoom microscope with 31–16–08 micrometer disc, Carl Zeiss Stage Micrometer, or equivalent.

4.5 Caul Plates  Caul plates shall be 3.2 mm [0.125 in] thick and 152 mm [6.0 in] square and made from type 304 steel, or equivalent.

4.6 Desiccator  Desiccation chamber capable of maintaining an atmosphere of less than 30% RH, at 23°C [73°F].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 The prepreg shall be cut to conform with the specimen size and configuration as per 3.1.

5.1.2 If testing is to be performed more than 10 minutes after the prepreg has been manufactured, specimens shall be desiccated for 4 ± 1/4 hrs. prior to testing.

5.1.3 Cleaning of Copper Cladding  When applicable for referee purposes, clean the metallic cladding on the copper clad laminate by wiping the copper cladding with isopropyl alcohol. The copper clad laminate shall be immersed in suitable container containing 22-23° BAUME 20 percent by volume solution of hydrochloric acid, technical grade, maintained at 21°C ± 5.6°C [170°F ± 10°F] for a period of 15 seconds. After removal of the copper clad laminate from the hydrochloric acid, the copper cladding then shall be rinsed with a cold water spray rinse for 5 seconds and blown dry with filtered, oil free, compressed air.

5.2 Measurement

5.2.1 A specimen shall be formed by stacking three plies of prepreg with the grain of the reinforcement aligned in the same direction. Only if necessary to prevent ply slippage, tack the three plies together using a standard soldering iron within one quarter inch from one or more corners so that the plies
lay flat to one another. Using a 25.4 mm [1.0 in] diameter hole punch, cut 2 holes at least 25.4 mm [1.0 in] apart (See Figure 1) in approximately the middle of the specimen. Caution should be taken during cutting in order to prevent any loose fibers from protruding into the clearance hole. Measure the diameter of each hole in 3 places, each approximately 60° radial angle from the others and determine the average diameter of the holes.

5.2.2 Place the stack onto and in the middle of a 152 mm x 152 mm [6.0 in x 6.0 in] copper clad laminate of thickness between 0.25 mm [0.010 in] and 0.38 mm [0.015 in] thick and cover the stack with a sheet of release film. Over the release film place 2 pieces press pad material. For referee purposes, the surface of the copper cladding shall be cleaned immediately prior to lay-up using the procedure in paragraph 5.1.3. (The cleaning is to standardize the surface against which the resin will flow.)

5.2.3 Place the stack (specimen plus laminate, release, and padding) between the two caul plates. Load the stack into the laminating press maintained at 171° ± 2.8°C [340° ± 5°F] and close immediately to 1380 ± 70 kPa [200 ± 10 psi]. After holding at full pressure for 20 minutes, minimum, release the pressure and remove the package.

5.3 Evaluation After the package has cooled to room temp, measure the diameter of the punched holes at the point of maximum and minimum diameter as formed by the resin flow. Subtract the average diameter of holes obtained in 5.2.1 from the maximum and minimum diameters.

5.4 Report The results shall be reported including the following:

1. Identification of specimens tested.
2. Resin flow, for each specimen tested in terms of the maximum flow and minimum flow in millimeters (thousands of an inch) for both die-cut holes.

6.0 Notes

6.1 Agreement between supplier and user other than that specified in 4.1 may be necessary for specific resin chemistries.

6.2 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.
1.0 Scope

1.1 The purpose of this test method is to provide a procedure for determining the gel time of resin preimpregnated “B” Stage glass fabric.

2.0 Applicable Documents

None.

3.0 Test Specimen

3.1 Sufficient quantity of prepreg to yield approximately 1000 milligrams of dry resin powder.

4.0 Equipment/Apparatus

4.1 Platen, hot plate or melting point apparatus capable of maintaining a temperature of 171 ± 0.5°C (340 ± 0.9°F).

4.2 Timer, capable of determining time within ± 1 second.

4.3 Toothpicks.

4.4 Plastic/polyethylene bags or suitable container.

4.5 Analytical balance capable of weighing within ± 20 milligrams.

4.6 Wire Mesh—60 mesh.

4.7 Montan Wax.

5.0 Procedure

5.1 Place the prepreg (B-Stage) in a plastic bag or other suitable container, and extract the dry resin from the B-Stage by folding or crushing.

5.2 Allow the B-Stage resin to collect in the bottom of the plastic bag.

5.3 Pour the collected resin into a container through 60 wire mesh, to remove any fiber glass particles.

5.4 Set the melting point apparatus at 171 ± 0.5°C (340 ± 0.9°F) and allow to stabilize at that temperature.

5.5 Using the analytical balance weigh out 200 ± 20 milligrams of resin on to 3 in. x 3 in. sheet of wax paper or a suitable container.

5.6 Make sure that the melting point apparatus is clean; mold released with montan wax or equivalent; and wiped free of any visible mold release.

5.7 Pour 200 milligram sample of resin on the center of the melting point apparatus and start the timing device immediately.

5.8 Place the tapered end of a round toothpick against the surface of the cure plate (end of the toothpick not in contact with surface of the cure plate will have to be elevated slightly).

5.9 Roll toothpick back and forth, maintaining contact with the surface of the cure plate until 20 seconds have elapsed.

5.10 At this time start stroking the resin immediately, using a circular motion 3/8 in. to 1/2 in. in diameter. Stroke in such a manner that every circle moves part of the resin from the center of the pool to the outside, and part of the resin from the outside of the pool toward the center. Care should be taken to limit the pool size to an area 3/4 in. to 7/8 in. in diameter.

5.11 Keep the toothpick in contact with resin and surface of the cure plate at all times. As the resin becomes stiff, it will not be possible to continue exchanging outside resin with inside resin, but continue stroking with as much exchange as possible without breaking the toothpick.

5.12 If the resin breaks up, continue stroking the largest piece. If this piece breaks up, continue stroking the largest remaining piece of this portion even though now a larger piece of the original pool may be present at some other place on the hot plate.

5.13 When the stroked piece separates from the hot plate, stop the watch. This is the end point, and the total elapsed time in the gel time.
1.0 Scope  This test method is designed to measure the volatile content of prepreg used as bonding plies in the manufacture of laminate and printed boards.

2.0 Applicable Documents  None

3.0 Test Specimens

3.1 Specimen Size  The test specimen shall be a ply of prepreg cut with its diagonal parallel to the X or Y axis of the prepreg. The specimen shall be approximately 101.6 x 101.6 mm [4 in x 4 in]. A hole approximately 3.18 mm [0.125 in] in diameter shall be punched in one corner of the specimen.

3.2 Quantity and Sampling  Unless otherwise specified, for each material tested, three specimens shall be prepared; one specimen shall be cut from the center of the width and one each from each edge of the sheet of prepreg. Specimens shall be cut no closer than 25.4 mm [1 in] from the edge of the prepreg sheet.

4.0 Apparatus or Material

4.1 Analytical Balance  Analytical balance capable of weighing to the nearest milligram [0.001 gram].

4.2 Oven  Air circulating oven capable of maintaining ±2.8°C [±5°F] at the specified test temperature (see Table 1).

4.3 Desiccator  Desiccation chamber capable of maintaining an atmosphere less than 30% R.H. at 23°C [73.4°F]. Vacuum drying systems, or equivalent, that could absorb or remove organic components shall not be used.

5.0 Procedure

5.1 Specimen Preparation  
5.1.1 The prepreg shall be cut to conform with the specimen size and configuration as per 3.1.

5.1.2 Preconditioning  Unless the prepreg is tested within 10 minutes of manufacture, specimens shall be desiccated for 24 ± 2 hours before testing. Specimens tested as part of manufacturing control procedures are exempt from desiccation. For referee testing, desiccation shall be performed. (See 6.1.)

5.2 Method A

5.2.1 Apply mold release to the hanging device and allow to air dry.

5.2.2 Weigh the hanging device to the nearest milligram [0.001 gram]. Record as W1.

5.2.3 Weigh each specimen with a hanging device to the nearest milligram [0.001 gram]. Record as W2.

5.2.4 Place each specimen and hanging device in the air circulating oven at the temperature and for the time specified in Table 1 or by the governing document.

5.2.5 Remove each specimen with the hanging device and weigh within two minutes to the nearest milligram [0.001 gram]. Record as W3.

5.2.6 Calculate and record the volatile content as follows:

\[
\text{Volatile content (\%)} = \left( \frac{W_2 - W_3}{W_2 - W_1} \right) \times 100
\]

\[W_1 = \text{(see 5.2.2)}\]
\[W_2 = \text{(see 5.2.3)}\]
\[W_3 = \text{(see 5.2.5)}\]

Table 1

<table>
<thead>
<tr>
<th>Prepreg Type</th>
<th>Oven Temperature</th>
<th>Test Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difunctional Epoxy, Tetrafunctional Epoxy, Multifunctional Epoxy, Polyimide Blend</td>
<td>163°C (325°F)</td>
<td>15 ± 1 minute</td>
</tr>
<tr>
<td>Polyimide</td>
<td>225°C (437°F)</td>
<td>30 ± 1 minute</td>
</tr>
<tr>
<td>Cyanate Ester</td>
<td>145°C (293°F)</td>
<td>15 ± 1 minute</td>
</tr>
</tbody>
</table>

(1) For material types that do not conform to the types listed, follow the manufacturer’s instructions for temperature and time.
5.3 Method B

5.3.1 Apply mold release to the alligator clips on the apparatus shown in Figure 1 and allow to air dry.

5.3.2 Weigh each specimen to the nearest milligram [0.001 gram]. Record as W1.

5.3.3 Secure each specimen at diagonally opposite corners from the metal hanging apparatus as shown in Figure 1.

5.3.4 Place the apparatus with specimens in the air circulating oven at the temperature and for the time specified in Table 1 or by the governing document.

5.3.5 Remove the specimens from the oven and from the holding apparatus and weigh each specimen within two minutes to the nearest milligram [0.001 gram]. Record as W2.

5.4 Calculation

Calculate and record the volatile content as follows:

\[
\text{Volatile Content (\%)} = \left( \frac{W_1 - W_2}{W_1} \right) \times 100
\]

5.5 Report

The results should be reported and shall contain the following:

(1) Identification of prepreg material type tested.
(2) Percent volatile content for each specimen tested and the average.
(3) Test temperature and time in oven.
6.0 Notes

6.1 Moisture Content

6.1.1 Exclusion of Moisture Content  Desiccation of the specimens is performed for the following reasons.

6.1.1.1 This test method is based on the understanding that “Volatile Content” refers to organic solvents and other ingredients of the prepreg that may remain in the material after curing. Water or moisture content is not considered as a “Volatile” for purposes of this test, and therefore desiccation is a fundamental step to exclude H₂O from the data. It is not possible to remove all H₂O from material that is hygroscopic, but the most significant content is removed.

6.1.1.2 This method has a high intrinsic variability potential, and since moisture content is extremely variable and dependent on the storage environment, meaningful data is best achieved by removing the moisture.

6.1.2 Moisture Content Determination  This method can be performed in an alternative manner, in which the specimen is weighed before it is desiccated. The difference between the “As Is Weight” and the “Weight After Desiccation” (but before oven drying) is the moisture content.

6.2 Alternate Specimen Holder  Method B has been designed to minimize the problem of specimens flopping around in the air circulating oven.

6.3 Desiccator Conditions  The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.
1.0 Scope

1.1 The Hull Cell is a miniature plating unit designed to produce cathode deposits on a panel that correlates the characteristics of the plating unit being evaluated. Interpretation of the “as plated” cathode panel give rapid information about brightness levels, irregular plate deposits, uniformity of deposits, coverage, throwing power, impurities, and plating bath chemistry.

1.2 Theory: Within the parameters of recommended operating characteristics of a particular plating solution, the HULL CELL will duplicate what is actually occurring in the plating unit proper. Correlation of the “as plated” panel and the HULL CELL SCALE allows rapid, nondestructive testing of plating solutions for research, preventative maintenance, troubleshooting, and quality control.

2.0 Applicable Documents
R. O. Technical Bulletin No. 404
The Hull Cell, by Sedusky and Mohler

3.0 Test Specimen

3.1 Description of Specimen A representative sample from the plating unit to be evaluated is withdrawn and should be a composite sampling from various areas in the plating tank and from various depths within these areas.

3.2 Specimen Preparation The representative sample should be analyzed chemically for those critical components recommended by the supplier of the plating bath. Correlation of Hull Cell panels without the information on the bath chemistry can be very misleading.

3.3 Operating Conditions Particular attention shall be given to the physical conditions of the plating unit at the time of sampling and these operating conditions should be duplicated during Hull Cell testing. If this is not done, interpretation will be meaningless. Example: temperature, cathode agitation, air agitation.

4.0 Apparatus

4.1 Description of Equipment A bench or portable miniature plating cell is employed using the following components.

a. A rectifier (D.C. power source) with variable controls for amperage from 0-10 amps, 0-12 volts. This power source should have less than 5% ripple.

b. Hull Cell Anode “+” chemistry of the anode the same as is in the plating unit or as recommended by the chemical supplier. Example: zinc anode for zinc plating bath.

c. Color coded coated cables capable of carrying the current required with an alligator clip soldered to cell end. Color code recognized universally is as follows: anode “+” black; cathode “−” red.

d. Hull Cell Cathode Panels—two most widely used are zinc plated steel and thin plastic protected brass panels.

e. Hull Cell—with scribed solution level line, 267 ml, 524 ml, or 1000 ml size. The most commonly used size is the 267 ml. Hull Cells are available in Lucite, Polypropylene, and Porcelain.

f. Hull Cell Scale—a calibrated ruler for interpretation of 1, 2, 3, and 5 amp panels to determine current densities.

g. Hull Cell Agitator—optional motor driven arm and panel assembly for duplicating solution and/or cathode agitation.

h. Air Agitation Hull Cell—specially designed for introducing air into the miniature plating unit to duplicate air agitation operations.

i. Timer—separate or built into the DC power unit depending upon the sophistication desired.

5.0 Procedure

5.1 Preparation (It is recommended that panels be handled with tweezers and gloves to prevent misleading results.)

5.1.1 Pre-clean cathode test panel.

5.1.2 For zinc plated steel panels: immerse in 50% by volume C.P. Hydrochloric acid to strip off protective zinc film.
5.1.3 Cold water rinse.

5.1.4 Wipe surface with Hull Cell sponge that has been soaked in D.I. water.

5.1.5 Observe panel for water break free condition. Repeat 5.1.4 and 5.1.5 as necessary.

5.1.6 For plastic coated brass panels-remove plastic film by peeling it off.

5.1.7 Soak in mild soak cleaner.

5.1.8 Reserve current clean at 2 amps for one minute.

5.1.9 Cold water rinse.

5.1.10 Acid dip 10% C.P. Hydrochloric Acid for 5 seconds.

5.1.11 Cold water rinse.

5.1.12 Observe for water break free surface; repeat steps 5.1.7 through 5.2.11 if necessary.

5.2 Test

5.2.1 Hook red cable to anode (+).

5.2.2 Hook black cable to cathode (−).

5.2.3 Set timer to prescribed time (see tech bulletin).

5.2.4 Turn on power source.

5.2.5 Adjust power to described amperage.

5.2.6 Start time.

5.2.7 At prescribed time, shut off power.

5.2.8 Disconnect cathode cable.

5.2.9 Remove cathode panel.

5.2.10 Cold water rinse.

5.2.11 Complete desired post plate treatment if any-example: dipping panel in 1/4 to 1/2 of 1% by volume. Nitric Acid (C.P. Grade) for 3-5 seconds enhances the ability to interpret the panel on zinc and cadmium plating solutions.

5.2.12 Warm Water Rinse.

5.2.13 Dry, forced air or even wiping with a water absorbent paper towel.

5.2.14 An alternate method of drying the panels is to water rinse followed by an alcohol rinse to drive off the water. Also, a method of preserving samples is to spray them immediately with a clear lacquer to prevent oxidation.

5.3 Evaluation

5.3.1 See Bulletin “The Hull Cell” or proprietors data sheets utilizing the Hull Cell Scale appropriate for the amperage used as the guide to current densities.

5.3.2 Hull Scale use: place the bottom edge of the “as plated” on the line that matches the amperage plating was performed. The areas on the panel above these numbers are the area of that number’s current density.
### 6.0 Notes

### 6.1 Preventative Maintenance, Troubleshooting

**6.1.1** Depending upon the bath chemistry as analyzed, condition of the panel relative to uniformity, burning, cloud patterns skip plate, etc., modification by controlled additions can be made to the Hull Cell plating solution and procedures can be repeated. Changes caused by addition to the Hull Cell will duplicate results to be expected by the same proportionate additions to the main plating bath.

**6.1.2** Correlations of thickness checks in the controlled time, temperature, amperage cathode panel will also tell the optimum plating range to obtain plating thickness desired.

**6.1.3** Source of applicable documents:

R.O. Hull and Co., Inc.
3203 W. 71st
Cleveland, OH 44102
1 Scope  This test method is used to determine the presence and effectiveness of the protective coating deposited over the PWB to prevent oxidation and facilitate good wetting during soldering operations. The coating is removed during soldering.

2 Applicable Documents  None

3 Test Specimens

3.1 Any pre-production or production copper clad board at least 5 cm x 5 cm. The specimen must either contain circuitry or be completely copper clad. An uncoated bare copper clad specimen must also be available for control purposes.

4 Equipment/Apparatus

4.1 Reagent or commercial grade ferric chloride (42BE') etchant

4.2 Petrie dishes or glass trays

4.3 Stop watch

4.4 Lint-free cloth

5 Procedure

5.1 Test

5.1.1 Place one drop of ferric chloride on several locations on the test specimens and the bare copper control specimens.

5.1.2 Allow to stand 10 seconds, then rinse with tap water and wipe dry.

5.2 Evaluation

5.2.1 Examine specimens and compare with bare control specimen. Test specimens must show no copper etching, proving the presence and effectiveness of protective coating.

6 Note  Slight “mottling” or a slight attack on the coated surface indicates uneven deposition or insufficient solids of the coating.
1.0 Scope  This test method covers the cure, or permanence, testing of thermally cured solder mask (solder resist) organic coatings. Solder masking is the application of either a liquid film or dry film coating on all types of laminates and circuits. The coating is applied where no solder is to appear and, conversely, is omitted where soldering is intended.

2.0 Applicable Documents  None

3.0 Test Specimens  IPC Test Board IPC-B-25 preproduction board, or a sample production board with the solder mask coating applied and cured as recommended by the manufacturer.

4.0 Apparatus

4.1 Reagent grade methylene chloride

4.2 Methyl Chloroform

4.3 Petrie dishes

4.4 Lint free cloths

4.5 Stop watch

4.6 Cotton Swab (Q-tips, or equivalent brands having a wooden blunt end).

4.7 Rubber Gloves

5.0 Procedure

5.1 Preparation  Prepare specimens as described by the manufacturer or as described below. Apply the solder mask to the clean test specimen surface and cure per the vendor’s recommendation. When a batch type chamber is used, it is essential to have a good exhaust to remove the evaporating solvent vapors. After curing, clean the surface, rinse, dry, and seal with manufacturer’s recommended sealant.

6.0 Test

6.1 Place several drops of room temperature methylene chloride or methyl chloroform on separate locations on the surface of the solder mask (see 6.1.3).

6.2 Immediately attempt to wipe off the solder mask using a lint free cloth. Repeat if evaporation is too rapid to achieve meaningful results.

6.3 Scratch the surface with the blunt wooden end of a cotton swab to determine permanence.

6.4 If no attack is observed, the solder mask has sufficient permanency.

7.0 Notes

7.1 These test methods do not adequately predict the ability of the solder mask to withstand hot solvent vapors, such as degreasers. Any chemicals used in the production of circuit boards may be applied as described in paragraph 4.1 and the samples evaluated.

7.1.1 The insulation resistance of the solder mask is critical, since it becomes a permanent part of the wiring board. Performance of an occasional electrical resistance test is also recommended because this result is dependent on the degree of cure. The more complete the cure, the higher the resistance.

7.1.2 Caution:  Methylene chloride (dichloromethane) is a halogenated solvent. It is irritating to the eyes and skin. Because of its low boiling point, high concentrations can be reached in a short time as the liquid evaporates quickly. High concentrations of vapor can cause dizziness or drowsiness.

7.1.3 Methylene chloride is a more aggressive solvent, however, due to health concerns currently being considered, other chemical options have been permitted.
1.0 Scope  This test method covers the cure, or permanence testing of ultraviolet-initiated dry film solder mask (solder resist) organic coatings. Dry film solder masking is the application of a film coating on laminates and circuits. Following processing and curing, the dry film mask covers only those areas where no solder is to appear and, conversely, does not cover those areas where soldering is intended.

2.0 Applicable Documents  None

3.0 Test Specimens  IPC Test Board IPC-B-25 preproduction board, or a sample production board with the dry film solder mask coating applied and cured as recommended by the manufacturer. See Procedure 5.1.

4.0 Apparatus

4.1 MESERAN Surface Analyzer Model 1200 or equivalent. (Cf. 6.1, 6.2).

4.2 MESERAN Test Solution TSAL2X, TSBH2X, or TSAJ or equivalent. (Cf. 6.1, 6.2).

4.3 Ultraviolet intensity monitor.

5.0 Procedure

5.1 Preparation and testing of REFERENCE specimens.

5.1.1 Prepare specimens as described by the solder mask manufacturer and with attention to the following instructions.

5.1.1.1 Use U.V. intensity monitor to assure the output of the U.V. lamps giving careful attention to the variability of each lamp in the curing system if multiple lamps are used.

5.1.1.2 Test according to paragraph 6.1 - 6.3 a minimum of two REFERENCE specimens prepared as follows:
   a. One specimen at manufacturer’s recommended U.V. level but omitting final baking process.
   b. Another specimen at manufacturer’s recommended U.V. level and bake cycle.

   These REFERENCE specimens become the standards from which the test method will measure cure differences. If end-use performance standards for the solder masks are desired in addition to those of the solder mask manufacturer, prepare the REFERENCE standards accordingly.

6.0 Test

6.1 Load pre-selected test solution into Surface Analyzer. The manufacturer recommends specific test solutions, which are commercially available, for particular dry film solder masks.

6.2 Following proper exposure to U.V. curing, but prior to baking cycle, cool the board to room temperature (can be accelerated with a fan).

6.3 Place board to be tested into Surface Analyzer and initiate 4-minute automatic analysis as recommended by manufacturer.

6.4 If the cure value, as determined by the Surface Analyzer, is equal to the cure value of the REFERENCE standard 5.1.1.2.a, continue the baking cycle of the tested board. If, however, additional U.V. exposure is required, adjust the line speed of the U.V. curing system using lamp intensity monitor and test a new specimen. Repeat U.V. adjustments until REFERENCE cure values are achieved.

6.5 Following the completed baking process and cooling to room temperature, test board as described in 6.3 above. The cure value should equal that of the REFERENCE standard prepared in 5.1.1.2.b above. If not, the baking cycle must be adjusted and testing on a new specimen is required.

7.0 Notes

7.1 MESERAN is a registered U.S. Trademark

7.2 MESERAN Surface Analyzers and MESERAN Test Solutions are manufactured and marketed by:

The MESERAN Company
P.O. Box 15035
Chattanooga, TN 37415
(615) 875-3931

The Surface Analyzers are automatic instruments with microcomputer-based controls.
7.3  The test method described herein is a solvent swell/diffusion test based on the principle of Evaporative Rate Analysis (ERA).

The ERA technique involves deposition onto a test surface of ca. 20 ul of a low boiling solvent containing ca. 0.4 microgram of a high boiling, but volatile, C-14 labeled material. Then, with metered dry nitrogen gas flowing between the test surface and a detector positioned just above the surface, the rate at which the radiochemical evaporates is a function of the degree of cure when the solvent has been properly preselected. The less the count from molecules retained at the surface, the more the cure.
1 Scope
This test method provides procedures to determine the porosity of gold plating on both copper and nickel surfaces by chemical means. This method may also be used to test rhodium or palladium.

2 Applicable Documents
None

3 Test Specimens
3.1 Any test, pre-production, or production sample of gold-plated circuitry

4 Apparatus
4.1 Whatman No. 542 filter paper
4.2 Glass lab trays
4.3 Powdered Alumina (or Magnesia)
4.4 Distilled water, 4 liters
4.5 Aluminum panels, 15 cm x 15 cm (high purity)
4.6 12 volt DC power supply
4.7 Photographic blotting paper
4.8 One pint of 10% solution cadmium chloride
4.9 One pint of hydrochloric acid (1.16 to 1.8 specific gravity)
4.10 One pint of 5% solution sodium sulfide
4.11 Lab press (or clamps)
4.12 0.8% solution Nioxime (cyclohexane 1:2 dione dioxime)

5 Procedure
5.1 Preparation

5.1.1 The high-purity aluminum panels must at all times be free from grease and foreign matter likely to cause inoperative areas on the cadmium sulfide paper.

5.1.2 In order to preserve the active life of the cadmium sulfide papers, they should be stored in a dark, sealed container. The shelf life of the papers is approximately four to six weeks.

5.1.3 After this test, the contacts must be cleaned again as before, rinsed in hot distilled water, and carefully dried. The used cadmium sulfide paper must not be stored in contact with the plated surface of the board.

5.2 Gold on Copper Test Method

5.2.1 Soak the Whatman 542 filter paper for 10 minutes in a fresh 10% solution of cadmium chloride in distilled water containing 0.1% by volume of hydrochloric acid.

5.2.2 Remove the excess solution by blotting.

5.2.3 Allow the paper to dry partially, then immerse in a fresh 5% solution of sodium sulfide in distilled water for 30 seconds, after which time the paper must be of a uniform yellow color (indicating a complete precipitate of cadmium sulfide).

5.2.4 Soak the photographic blotting paper in distilled water and dry to a degree of dryness that produces consistent, sharply defined electrograms.

5.2.5 Lightly clean the gold plating with powdered alumina (or magnesia) and water to remove any extraneous surface contamination, then flush with distilled water and dry. The cleaned surfaces must be kept clean until the test is completed.

5.2.6 Place a piece of the cadmium sulfide paper on the plated sample (which acts as the anode) followed by a piece of the photographic blotting paper, the latter being in contact with a freshly cleaned high-purity aluminum panel (which acts as the cathode).
5.2.7 Compress the assembly so that the pressure between the cadmium sulfide paper and the sample is uniform and between 14 kg/cm² and 18 kg/cm².

5.2.8 While the assembly is under compression, pass a smooth, ripple free DC source not exceeding 12 volts between the cathode and anode.

5.2.9 Set the current initially at 8 mA/cm² of anode area and energize for 30 seconds.

5.2.10 Allow the electrograms produced on the cadmium sulfide paper to dry.

5.2.11 A corresponding brown stain on the paper reveals the presence of any defect in the plated coating.

5.2.12 Visually examine the specimen at 10X magnification.

5.3 Gold on Nickel Method

5.3.1 Soak the Whatman 542 filter paper for 10 minutes in a 0.8% solution of nioxime (cyclohexane 1:2 dione dioxime) and distilled water.

5.3.2 Remove the excess solution with blotting paper. The paper must be hung up to dry.

5.3.3 Repeat the steps in 5.2, except moisten the piece of nioxime paper with distilled water and expose the ammonia vapor.

5.3.4 Remove the excess by blotting. The “backing pad” of photographic blotting paper is to be used dry.

5.3.5 Expose the electrograms produced on the nioxime paper to ammonia vapor, then allow to dry.

5.3.6 A corresponding purple-red stain on the paper reveals the presence of any defects in the gold plating.

5.3.7 Visually examine the specimens at 10X magnification.
1 Scope  This test method provides a procedure for testing the porosity of gold electroplated from an alkaline (cyanide), acid, or neutral gold plating solution on a nickel substrate in contact with the gold deposit.

2 Applicable Documents  None

3 Materials and Equipment

3.1 Materials  Acetone, Sodium Nitrate, Reagent GD. (NaNO₃), Sodium Carbonate, Anhydrous, Reagent GD. (Na₂CO₃), Dimethylglyoxime, Denatured Ethyl Alcohol No. 3A, Reagent GD. (C₂H₅OH), Photographic Paper with Silver Halide removed. (Kodabromide, glossy finish, single wt. photographic paper (fixed before use), Ammonium Hydroxide, Reagent GD. (NH₄OH)

3.2 Equipment

3.2.1 DC power supply to 0 amp to 1 amp. DC minimum, 0 volts to 10 volts

3.2.2 DC Milliammeter, 0 mA to 100 mA

3.2.3 Electrographic Clamp-Press

4 Equipment/Apparatus  None

5 Procedure

5.1 Solution Make Up

5.1.1 Electrolyte  Concentration: NaNO₃ 1% (wt.) Na₂CO₃, Anhydr. 4% (wt.) Distilled water – balance by wt. Preparation of 500 g (Vol. of 485 ± 10 ml.) of solution

5.1.1.1 Obtain the tare weight of 600-ml glass beaker.

5.1.1.2 Add 400 ml of distilled water to beaker.

5.1.1.3 Using agitation and, if necessary, heating to 48.9°C, dissolve the following in the water:

Sodium nitrate – 5 g
Sodium carbonate – 20 g

5.1.4 After salts are dissolved, add distilled water until the net weight of the solution is 500 g.

5.1.5 Cool the solution to room temperature before use.

5.2 Indicator Solution  The solution is a concentration of dimethylglyoxime – 1% (wt.) denatured ethyl alcohol No. 3A – Balance.

Perform the preparation of 300 g (vol. of 380 ± 10 ml.) of solution as explained in 5.2.1 through 5.2.4.

5.2.1 Obtain the tare weight of 400-ml glass beaker.

5.2.2 Add 275 ml denatured ethyl alcohol to the beaker.

5.2.3 Using agitation only (do not heat), dissolve 3 g of dimethylglyoxime in the alcohol.

5.2.4 After all additions are dissolved, add denatured ethyl alcohol until the net weight of the solution is 300 g.

5.3 Electrographic Test

5.3.1 Cleaning Procedure

5.3.1.1 Using a cloth, wash the contact area with alconox solution.

5.3.1.2 Rinse the contact area in tap water.

5.3.1.3 Rinse the contact area in deionized water.

5.3.1.4 Rinse the contact area with acetone and air dry.

5.4 Cut a piece of silver halide-free photographic paper to a size slightly larger than the area of the sample or part of the sample being tested. The dimensions of the photographic paper should not exceed the dimension of that part of the sample being porosity tested by more than 0.79375 mm in any one direction.

5.5 Wet the photographic paper, cut in 5.2 with the electrolyte solution prepared in 5.1.1. The photographic paper is immersed for 30 minutes or more in the electrolyte.
After saturating the photographic paper with electrolyte, press the paper between two paper towels to ensure any excess electrolyte is removed from the photographic paper.

5.6 Assemble the sample being tested for porosity and the photographic paper of 5.5 in the electrographic clamp-press as explained in 5.6.1 through 5.6.6.

5.6.1 Place a piece of Teflon or equivalent insulating material on the platform of the compression spring and piston device on the clamp-press.

5.6.2 Place the back of the sample or area of sample being tested on top of and in contact with the Teflon.

5.6.3 Place the silver halide-free photographic paper saturated with electrolyte in 5.5 on top of and in contact with the face of the sample or area of the sample being tested. The emulsion side of the paper should be in contact with the test sample.

5.6.4 Place a piece of pure gold or gold-clad copper on top of the photographic paper so the gold surface is in contact with the photographic paper.

The gold or gold-clad material placed on the photographic paper is to have the same maximum dimensions as that part of the sample being porosity tested. The minimum dimensions of the gold or gold-clad material is to be not more than 0.79375 mm shorter than the dimensions of the area being tested in any one direction. Attach a lead wire to the gold or gold-clad material in order to make electrical contact.

5.6.5 Place a piece of Teflon or equivalent insulating material on the back of the gold or gold-clad material.

5.6.6 Lower the screw of the clamping and screw the device until the pressure end of the screw is just in contact with the back of the Teflon and holds the assembly in place. Do not apply force at this time. See 5.11 for a schematic diagram of assembly.

5.7 Compress the spring of the clamp-press by tightening the screw device until a pressure is exerted on the assembly as in 5.6.6.

5.8 Connect a DC power source so the positive (+) voltage contacts the sample being tested and the negative (-) voltage is connected to the lead of the gold or gold-clad material of 5.6.6. Apply a current, such that the current density is 250 mA ± 50 mA per square inch of surface in contact with the photographic paper. Applied voltage should not exceed 10 volts. If the current density of 250 ± 50 mA/sq. in. cannot be obtained at ≤10 volts, then the time of current flow should be increased while holding the potential at 10 volts. The increased time of current flow can be calculated by the following formula.

\[
\text{Time of current flow (sec)} = \frac{250 \text{ mA/sq. in. of surface in contact with paper}}{\text{Current density in mA/sq. in. at 10 volts}} \times 60 \text{ sec}
\]

The time of the current flow should be 60 ± 1 sec.

5.9 Unclamp the assembly and remove the silver halide-free photographic paper.

5.10 Apply one to two drops of the indicator solution from 5.2. to the photographic paper.

5.11 Develop the photographic paper containing indicator solution by holding the paper over an ammonium hydroxide solution.

5.12 Dry the photographic paper to which indicator solution was added and read the test results.

5.13 Observe the porosity test schematic, as shown in Figure 1.

5.14 Test Results

5.15 Nickel exposure through the gold will show up on the indicating photographic paper as a red stain. Copper exposure will show up as green stains. This exposure is caused by pores, cracking, or unplated areas. These stains should be examined under 10X min, 15X max.

5.15.1 Pores Pores will show up as fine dots.

5.15.2 Cracking Cracks will show up as continuous fine lines.

5.15.3 Unplated Areas Unplated areas will show up as large blots or red lines.
Figure 1 Porosity Test Schematic
1.0 Outline for Methods
The part is exposed to an atmosphere that is corrosive to the basis metal. Where there is porosity, the reagent attacks the basis metal and generates corrosion products. The part is examined for corrosion products.

1.1 Method 1 (Nitric Acid Vapor-Gold on Copper) This method applies only to gold coatings on copper and copper-base alloys.

1.2 Method 2 (Extended Nitric Acid Vapor) This method applies only to gold coatings on copper and copper-base alloys.

1.3 Method 3 (Nitric Acid Vapor - Gold on Nickel) This method applies to gold coatings on copper, copper-base alloys, and nickel.

2.0 Nitric Acid Vapor - Gold on Copper

2.1 Apparatus Methods 1, 2, and 3.

2.1.1 Collimated Incandescent Lamp No. 31-33-53, Bausch and Lomb Co., or No. 359, American Optical Co., or equivalent.

2.1.2 Desiccator (Glass) Fisher Scientific Co. Series 8-595 or 8-624 or equivalent. The size of the desiccator shall be chosen so that no more than 164 cm³ of air space exists for 6.45 cm² of nitric acid surface area when approximately 301 ml of acid are placed in the bottom.

Caution: No sealant (e.g., stopcock grease, etc.) shall be applied to the mating surfaces of the desiccator cover or bottom. Sealants may cause these to stick together, and any method employed to release a stuck cover is likely to be extremely hazardous.

2.1.3 Part Support A supporting structure made of glass or other material not attached by nitric acid vapors to hold the parts under test in the upper part of the desiccator.

2.1.4 Oven An oven capable of drying parts at 125°C.

2.2 Reagents Methods 1 and 2. Nitric Acid, 69.0 to 71.0 Percent HNO₃.

3.0 Procedure

3.1 Method 1 (Nitric Acid Vapor-Gold on Copper) Caution: Perform all work in hood, since the vapors given off are toxic. Chemical goggles, completely closing the eyes, should be worn and eyewash facilities should be readily available.

To minimize and tendency for the cover to stick, press a minimum of three strips of the pressure polytetrafluoroethylene tape (adhesive side down) at equal intervals around the mating surface of the bottom of the desiccator. Place approximately 300 ml of nitric acid in the bottom of the desiccator. Cover the desiccator and allow about 30 minutes for equilibrium to be established before starting the test. This equilibrium is necessary only when the nitric acid is first placed in the desiccator.

Clean the part with 1,1,1-trichloroethane or toluene or other suitable solvent and dry with filtered dry air (gage pressure less than 207 kPa (30 psi)).

Inspect the cleaned part at 10 power magnification for evidence or particulate matter of the surface. If any remains, reclean the solvent or use a clean soft brush to remove it prior to the start of the porosity test.

Place the clean part on the support so that adequate space exists to allow circulation of acid vapor and air around it.

Carefully remove the desiccator cover, place the support in the desiccator and immediately replace the cover to prevent an excessive loss of vapors that would disrupt the equilibrium previously established. The test shall be performed at a temperature of 24 ± 3°C and a maximum relative humidity of 60 percent. Unless otherwise specified, the time of exposure to the reagent vapor shall be one hour.
Remove the part from the desiccator and immediately transfer it to an oven at 125°C for 30 minutes. Remove and inspect the part with 10 power magnification using the collimated incandescent light source arranged so that the light beam strikes the surface being examined at an angle of less than 15 degrees. The presence of blue, green, or bluish-white protrusions indicates that the coating is discontinuous (i.e., porous, scratched, etc.) at these spots. The acceptable number, sizes, and location of these protrusions shall be as specified on the appropriate drawing or specification.

3.2 Method 2 (Extended Nitric Acid Vapor-Gold on Copper)

Procedure This method is an extension of method 1 and may be used only after the test specimen has passed the requirements of the visual examination with the collimated light source. The method permits the determination of the actual sizes of the larger pores. The inspection should be performed as indicated below.

After examining the oven-dried test specimen in accordance with Method 1, brush the corrosion products from the specimen. Inspect the area where the corrosion products appeared at a magnification that permits measurements of the largest dimensions of the discontinuities with reasonable accuracy. The acceptable distribution of pore sizes shall be as specified on the appropriate drawing or specification.

3.3 Method 3 (Nitric Acid Vapor-Gold on Nickel)

3.3.1 Apparatus The apparatus described in methods 1 and 2.

3.3.2 Reagents Nitric acid, 69.0 to 71.0 percent HNO₃, Sodium Hydroxide 10 percent by weight solution. Polysulfide reagent.

3.3.3 Procedure Caution: Perform all work in a hood, since vapors given off are toxic. Chemical goggles, completely enclosing the eyes, should be worn and eye wash facilities should be readily available.

Use the procedure for Method 1 up to removal from nitric acid vapors.

At the end of the one hour exposure to the nitric acid vapors, remove the part from the desiccator and immediately dip it in the 10 percent by weight sodium hydroxide solution for 25 to 30 seconds at room temperature. Rinse the part with water and then dip it for 25 to 30 seconds in the polysulfide reagent at room temperature. Then rinse it in water and dry using filtered compressed air (gage pressure less than 207 kPa).

Inspect the part at 10 power magnification. The presence of black corrosion products is evidence of porosity. The acceptable number, sizes, and locations of pores shall be as specified on the appropriate drawing or specification.

3.4 Polysulfide Reagent Makeup Dissolve sodium sulfide crystals in water until solution is saturated. Add excess flow- ers of sulfur (more than 250 grams per 1000 ml). Stir and allow solution to stand 24 hours. Filter and dilute with water to a specific gravity of 1.142 at room temperature as defined in ASTM Designation E 41. The solution should be a red-orange color.

To check reagent effectiveness, dip a clean copper or high (more than 95 percent) copper alloy specimen into the reagent at room temperature as defined in ASTM Designation E 41. It shall blacken within 10 seconds.
1 Scope
This test is used to determine the total ionic content extractable from on, and absorbed within, the surface of printed wiring boards (PWBs), for the purposes of process control. The conductivity of the extract solution is measured and the results are expressed as sodium chloride equivalence per unit area.

2 Applicable Documents
IPC-TM-650 Test Method 2.3.25, Detection and Measurement of Ionizable Surface Contaminants by Resistivity of Solvent Extract (ROSE)

3 Test Specimens
The test specimen may be any unpopulated PWB. The number of specimens depends on the process control plan or product drawings/prints.

4 Apparatus or Material
- An automated Resistivity of Solvent Extract (ROSE) tester
- Conductivity dip probe with appropriate meter with temperature compensation
- Hydrometer (0.800 - 0.900) for ROSE tester calibration
- Thermometer for ROSE tester calibration
- Clean room (non-ionic) gloves or forceps
- KAPAK™ plastic bags or equivalents (see 6.9)
- Bag sealing equipment
- Water bath, capable of sustaining an 80°C ± 2°C [176°F ± 3.6°F] temperature
- Second water bath capable of sustaining a 25°C ± 1°C [77°F ± 1.8°F] temperature
- Precision solvent measurement equipment, such as class A pipettes
- Volumetric glassware
- Plastic ware - high density polyethylene, polymethylpentene (polypentene) or equivalent.
- Extract solution: 25% v/v deionized water (18 MΩ-cm nominal resistivity), 75% v/v 2-propanol (electronic or HPLC grade). No alternative solution or composition is allowed.
- Sodium chloride - reagent grade
- Analytical balance accurate to 0.0001 grams

WARNING: 2-propanol is a flammable material. The 2-propanol / water mixture is also flammable. Exercise caution when using this solution.

5 Procedure
5.1 Extraction
NOTE: Throughout this procedure, do not touch the sample boards with bare hands. Use the clean room gloves specified or use clean forceps.

5.1.1 Calculate the surface area of the PWB using:

\[
\text{Area (in cm}^2\text{)} = \text{Length} \times \text{Width} \times 2
\]

5.1.2 Prepare a volume of extract solution specified in 4.

5.1.3 Using clean room gloves or clean forceps, place the PWB into virgin KAPAK™ bags. Choose the bag size to give at least an additional 2.5 cm [1.0 in] on each side of the board to minimize the amount of extract solution used. Allow at least an additional 5 cm [2.0 in] above the board top.

5.1.4 Using a pipette or graduated cylinder, add a volume of the extract solution into the bag. The amount will depend on the area of the board surface. This usually varies from 0.8 mL/cm² [5.2 mL/in²] up to about 3 mL/cm² [19 mL/in²]. For example, a 10 cm x 11.5 cm [3.94 in x 4.53 in] board would require about 100 mL of solution. The amount of solution should just cover the board completely when most of the air is forced out of the bag.

5.1.5 Force most of the air from the bag and heat seal the bag. This involves contact with a hot metal bar. Take reasonable precautions to keep extract solution from contacting the hot bar. Alternatively, the top of the bag may be folded over and clipped shut.

5.1.6 Place the bag(s) vertically in a water bath which has stabilized at 80°C [176°F]. Make sure that the boards do not float above the water line. Do not allow the water from the bath to enter the bag or for extract solution to leak out of the bag.
5.1.7 Allow the boards to extract in this manner for a period of time of 60 ± 5 minutes.

5.1.8 Following the extraction of 5.1.7, remove the bags from the water bath and allow the extract solution to cool for at least 30 minutes, with the specimen still in the bag.

5.1.9 Using clean tongs or forceps, remove the PWB from the bag.

5.2 Measurement – DIP Probe Method

5.2.1 Calibration of Bridge This is essential in this method because there can be no correlation between resistivity/conductivity readings and NaCl equivalents without calibration.

5.2.1.1 Prepare a standard NaCl solution from a weight of dry reagent grade NaCl salt dissolved in deionized water to produce a final diluted concentration of 0.06 g/liter NaCl (5 mL equals 300 µg NaCl).

5.2.1.2 Place 1 liter of the 2-propanol water solution (at the calibration temperature of the bridge in use) in a plastic beaker.

NOTE: The 75 % v/v 2-propanol solution must be used in this calibration. Water cannot be used since it is not the test solution used in the procedure. The test solution used in this calibration can be recleaned by passing through the DI column until the required resistivity/conductivity is obtained.

5.2.1.3 From a 50 mL burette, add to the liter of test solution, 5 mL of the standard 0.06 g/liter NaCl solution. Stir and measure resistivity/conductivity.

5.2.1.4 From a 50 mL burette, add to the liter of test solution, 20 additional mL of the standard 0.06 g/liter NaCl solution, for a total of 25 mL. Stir and measure resistivity/conductivity.

5.2.1.5 From a 50 mL burette, add to the liter of test solution, 25 additional mL of the standard 0.06 g/liter NaCl solution, for a total of 50 mL. Stir and measure resistivity/conductivity.

5.2.1.6 Plot a three point nomogram of Conductivity vs. Solution Concentration (in µg/liter NaCl). See Figure 1 for example. You should get a linear relationship. Use a best fit line obtained with a piecewise linear method.

5.2.2 Test Procedure - DIP Probe

NOTE: If desired, this test can be run at other temperatures; however, the calibration process must be repeated for the alternative temperature. This calibration process need only be done once, providing the conductivity cell has not been exposed to harsh chemicals which would alter the cell constants. If the conductivity cell is routinely used on harsh chemical solutions (e.g., plating baths), then the calibration should be repeated before every test run.

5.2.2.1 Place the Kapak™ bags containing the extract solutions into the 25°C [77°F] water bath and allow the extract solutions to reach 25°C [77°F].

5.2.2.2 Insert the conductivity probe into the Kapak™ bag containing the room-temperature extract solution. It is important that the extract solution be measured at the same temperature used for the calibration solutions. Immerse the probe to a suitable depth.

NOTE: A “suitable depth” is one which covers the cell electrodes, but not an immersion which covers the wiring. Many cells are marked with a scribed line which indicates the proper immersion depth.

5.2.2.3 Gently agitate the solution. Read the conductivity of the solution. The time between immersion of the cell and taking the reading should be the same as used for the calibration curve. Sufficient time should be allowed for the reading to come to equilibrium (no change for two minutes).
NOTE: Between measurements, rinse the cell with deionized water and leave the cell soaking in virgin extract solution. Never use a dry cell as this is bad technique.

5.2.2.4 Using the linear relationship formed in 5.2.1.6, determine the concentration of sodium chloride corresponding to the conductivity reading. Use the equation given below to determine the total micrograms of sodium chloride equivalence per square centimeter (µg NaCl Eq./cm²)

Using the nomogram:

\[
\text{Concentration of Unknown} \times \text{Volume of Extract Solution (liter)}
\]

\[
\frac{\text{Extracted Surface Area (cm²)}}{\mu \text{g NaCl Eq./cm²}}
\]

5.2.2.5 If the conductivity of the unknown solution is outside of the bounds represented on the existing nomogram, then continue the technique used to generate the nomogram (see 5.2.1) until the bounds contain the conductivity of the unknown solution.

5.3 Measurement – Static ROSE Tester Method

NOTE: This section was developed using an Omegameter 600SMD with a 10,000 mL cell. Make appropriate changes to the procedure to accommodate other static ROSE testers.

5.3.1 Perform a system verification check.

5.3.2 Set the instrument to an appropriate amount of solvent volume. A target solution level should be 1.5 mL for one cm² of board surface. It is not necessary to cover the spray jets (if applicable). If the lid is on the test cell, the CO₂ mixing is minimized.

5.3.3 Enter the appropriate surface area into the instrument.

5.3.4 To allow for the volume of solvent that is to be added, the instrument setup volume will be set at the minimum volume (e.g., 2300 mL) plus the volume of solution in the extraction bag (e.g., 100 mL).

Dwell time or run time: 2 minutes
Pass / Fail Value: None
Begin the test and follow the test prompts.
Remove the cell cover.

5.3.5 Carefully open the test bag and quickly pour the extract solution into the test cell. To minimize CO₂ absorption, the addition should be made as quickly as possible and the cell cover quickly replaced.

5.3.6 The instrument should very quickly reach equilibrium (10 - 15 seconds) and then should remain essentially unchanged for the remainder of the two minute run.

5.3.7 Log the reading in total µg of sodium chloride equivalence per cm².

5.3.8 Static ROSE Calculation Example:
Testing a bare board, 10 cm x 20 cm [3.9 in x 7.9 in]
Surface area is 10 cm x 20 cm x 2 = 400 cm² [62 in²]
Bag size should be about 15 cm x 30 cm [5.9 in x 12 in] or larger
Extract solution would be about 620 mL
ROSE volume input to 4620 mL (4000 mL to cover sprays and 620 mL from extraction)
ROSE tester cell volume set to 4000 mL.
Run time - 2 minutes

5.4 Measurement – Dynamic ROSE Tester Method

5.4.1 Perform a system verification check.

5.4.2 Program the instrument with the appropriate surface area of the board.

5.4.3 Cycle the instrument to the beginning cleanliness point.

5.4.4 Carefully open the test bag and quickly pour the extract solution into the test cell. To minimize CO₂ absorption, the addition should be made as quickly as possible and the cell cover quickly replaced.

5.4.5 When the instrument completes the test, log the reading in total µg of sodium chloride equivalence per cm².

6 Notes

6.1 The background for this test method may be found in technical papers:

6.3 This method may also be known as the modified-ROSE test. This test, due to its longer extraction time and higher extraction temperature, has demonstrated better correlation with the total ion determination by ion chromatography than IPC-TM-650, Test Method 2.3.25, Detection and Measurement of Ionizable Surface Contaminants by Resistivity of Solvent Extract (ROSE) Method. However, as a bulk contamination measurement method, it cannot distinguish individual ion species.

6.4 From an analytical standpoint, the dip probe method is preferred as more repeatable than the automated ROSE testers and avoids many of the test inaccuracies (e.g., CO₂ absorption from spray agitation) inherent in those instruments. It should be stressed that the dip probe method is an electrolytic conductivity measurement and must be temperature-compensated.

6.5 The dip probe calibrations can be run at multiple temperatures and a family of curves generated, widening the test window for use with this method. Higher temperatures, however, will lead to a faster 2-propanol evaporation rate. The test can also be run with more dilute concentrations, prepared by series dilution.

6.6 Conductivity cells have a "constant" value. Measured readings must be multiplied by this constant. Exposure to harsh chemicals may alter the constant, making a re-calibration necessary. Do not allow the probe used for this procedure to contact sticky, oily, or resinous liquids (e.g., flux).

6.7 This procedure is intended to be a process control aid and as such, no pass-fail criteria is stated. It is expected that the fabricator/assembler will determine, with their customer, the necessary pass-fail criteria for their product by this method.

6.8 This method is best suited for monitoring and control of a previously optimized process and should not be used to generate acceptance data unless part of a larger correlation study. Values generated with this method should be correlated to acceptable electrical performance if used for acceptance.

6.9 Kapak™ 500 Series Bags can be obtained from:
Kapak Corporation
5305 Parkdale Drive
Minneapolis, MN 55416
800-527-2557
www.kapak.com

A secondary source of Kapak™ or Scotchpak™ polyester bags or pouches can be obtained from:
VWR International
1310 Goshen Parkway
West Chester, PA 19380
Orders: 1-800-932-5000
Web Orders: www.vwrsp.com

If an alternative to the Kapak™ bag or Scotchpak™ is desired, the bag must have the following characteristics:
• No extractable ionic material in 75% 2-propanol / 25% DI water at 80°C [176°F] for 60 minutes
• 0.01 cm [0.0039 in] wall thickness minimum
• Heat sealable or mechanical seal

6.10 There is some concern regarding ROSE tester cell size. Testing a 2 cm x 2 cm [0.79 in x 0.79 in] board in a 20,000 mL cell causes such a severe dilution as to cause the signal to be lost in the noise. A recommended cell size is 5000 mL or less. Smaller cell volumes will allow for a more measurable result. If a smaller cell, or running with a smaller test volume, are not an option, then the number of bare boards can be increased, all extracted separately, and the extract solutions all tested at once.

6.11 When testing hybrids or microelectronics, be aware that 2-propanol stored in glass containers can leach out materials such as sodium, borates, and silica. 2-propanol stored in plastic containers does not have such a leaching problem.
1.0 Scope

The purpose of this test is to determine the mobile ion content remaining in a polymeric dielectric film after curing.

2.0 Applicable Documents

None

3.0 Test Specimen

4.0 Apparatus or Material

- Spin (spray, extrusion, etc.) coating equipment
- Virgin Si monitor or production grade wafers (w/Au release coating if required for self-priming materials)
- Hot plate or convection oven drying apparatus
- Non-contact exposure tool (photosensitive compositions only)
- Curing furnace
- (4) 20ml capacity digestion bombs with PTFE liners
- Razor knife or blade
- Scissors
- ≥18 MR – CM deionized water
- Ion chromatograph

5.0 Procedure

5.1 General

5.1.1 This procedure assumes that the approximate weight of a cured coating of the material for a given wafer size and speed is known. If not, a spin speed curve and cured density or other cured film mass determination must be made. If the cured film mass in grams for the selected wafer size is mf, then N is (1/mf) rounded up to the nearest whole number.

5.1.2 The procedure further requires that films be prepared in such a way that they may be mechanically peeled from the wafer without excessive handling or damage. For materials that are not self-priming, this may simply mean omitting the use of an adhesion promoter. For self-priming materials, it may mean coating over a gold or other release layer on the surface of the wafer. Any release layer that cannot be guaranteed to be clean should not be used.

5.1.3 In order to obtain meaningful results, great care must be taken to assure that the films are not contaminated during their preparation. This requires that all wafers, etc., be handled with clean tweezers and gloves only and that all processing (coat, bake, exposure, cure) be done in a cleanroom that eliminates particulate accumulation on the film surface.

5.2 Test

5.2.1 Coat a layer of material onto 2xN wafer(s) at 2krpm for 30 seconds. This should be done in a cleanroom.

5.2.2 Softbake per the standard process for that material. This should be done in a cleanroom.

5.2.3 If the material is photosensitive and is negative working, blanket expose at a standard dose using a non-contact exposure method.

5.2.4 Cure all the wafers in a diffusion furnace or hot plate. This should be done in a cleanroom.

5.2.5 Tare two clean bomb assemblies to 0.01g (for bomb cleaning procedure see Section 6).

5.2.6 Peel the cured films from the wafers. Score the perimeter of the wafer with a clean razor blade if required. This should be done in a cleanroom.

5.2.7 Cut up the films using clean scissors and place N films in each of the bombs. This should be done in a cleanroom. Weigh the bombs to 0.01g and subtract the tares (see Section 4.5) to determine the exact sample mass in each bomb. Record these masses as ms1 and ms2.

5.2.8 Add approximately 10ml of DI water to the bombs and weigh the bombs to 0.01g. Subtract the weight from Section 4.7 to determine the mass of the water added. Record these masses as mw1 and mw2.

5.2.9 Seal the bombs and set aside.

5.2.10 Place approximately 10ml of DI water into each of two additional clean bombs. Seal the blank bombs.
5.2.11 Extract the films and the blank at 160°C for 20 hours in a box oven.

5.2.12 Remove the extract and analyze using an ion chromatograph. Calibrate and operate the instrument per the manufacturer’s instruction and other procedures.

5.2.13 Adjust for the background as indicated by the blanks as follows:

\[ [I_a] = ([I_{s1}] + [I_{s2}]) - ([I_{b1}] + [I_{b2}]) \]

where:

- \([I_a]\) = The average concentration of ion I in the extract due to the sample.
- \([I_{s1}], [I_{s2}]\) = The raw concentration of ion I in the extract from bombs 1 and 2.
- \([I_{b1}], [I_{b2}]\) = The raw concentration of ion I in the extract from blanks 1 and 2.

5.2.14 Correct the dilution during extraction to determine the levels of mobile ion species in the film:

\[ [I_f] = [I_a] \times \frac{m_{w1} + m_{w2}}{m_{s1} + m_{s2}} \]

Where:

- \([I_f]\) = The measured average concentration of ion I in the cured film.

5.3 Repeatability, Reproducibility, and Sensitivity

5.3.1 This method should give repeatability to ≤10% within a laboratory and reproducibility ≤20% between laboratories with proper calibration of instruments.

5.3.2 Ion chromatography should be run to give a nominal sensitivity of 0.01 ppm in the extract at 0.1 ppm in the film.

6.0 Notes — Bomb Cleaning Procedure

6.1 Method A

6.1.1 Add 40 ml of acetone to the bomb. Replace the lid and shake by hand. This should loosen any residue. Rinse any remaining residue with additional acetone. After all the residue has been removed, rinse the container and lid an additional three times with acetone.

6.1.2 Rinse the container and lid three times with DI water.

6.1.3 Add 10 ml to the container, seal, and extract at 160°C for 20 hours.

6.1.4 Empty the bomb and rinse three times with DI water.

6.1.5 Dry the container and lid for one hour in 100°C.

6.2 Method B

6.2.1 Add 40 ml of acetone to the bomb. Replace the lid and shake by hand. This should loosen any residue. Rinse any remaining residue with additional acetone. After all the residue has been removed, rinse the container and lid an additional three times with acetone.

6.2.2 Fill vessel with 1:1 HNO₃ and let soak for several hours.

6.2.3 Empty vessel and rinse the container and lid three times with DI water.

6.2.4 Add 10 ml to the container, seal, and extract at 160°C for 20 hours.

6.2.5 Empty the bomb and rinse three times with DI water.

6.2.6 Dry the container and lid for one hour in a 100°C oven.
1.0 Scope  
To quantify the residual rosin left from solder paste and/or wave soldering flux after the reflow and cleaning process.

2.0 Applicable Documents  
IPC-TR-580  Cleaning and Cleanliness Test Program Phase 1 Results

3.0 Test Specimen  
A printed circuit board assembly which has been cleaned after soldering.

4.0 Apparatus  
a) Ultraviolet spectrophotometer  
b) Balance capable of measuring 0.0001 grams  
c) Balance capable of measuring 500 grams  
d) 100 ml volumetric flasks (5)  
e) 250 ml volumetric flask  
f) 1000 ml volumetric flask  
g) Squeeze bottle  
h) Soxhlet Extraction Tube  
i) 500 ml round bottomed flask  
j) Friedrich condenser  
k) Heating Mantle capable of heating a 500 ml flask  
l) 250 ml Erlenmeyer flask

Materials:  
a) TEST SOLUTION—HPLC TEST SOLUTION with 1.0% v/v phosphoric acid and 0.1% v/v water added.  
b) Solder paste to be used on assembly line  
c) GLAD-LOCK recloseable freezer bags (7 inch x 8 inch x 2.7 mil)

5.0 Procedure  

5.1 Preparing the Standards  
First, analyze the components of the solder paste. To do this assemble a Soxhlet extraction apparatus. Set the round bottomed flask in the heating mantle and plug the mantle into a power regulator so that the temperature can be controlled. DO NOT TURN THE POWER ON AT THIS TIME. Hook the inlet of the condenser to a water supply, and the outlet to a drain.

Once the extraction unit is assembled, weigh a cotton cellulose thimble on an analytical balance to the forth decimal place. Record the weight.

Remove the top of the solder paste jar and use a spatula to stir the solder paste. Scoop about 25 grams of fresh solder paste and put it into the thimble. Immediately weigh the thimble and paste together to the fourth decimal place. Record that weight.

Carefully remove the round bottomed flask and the Soxhlet extraction tube from the condenser. Place the thimble containing the paste into the Soxhlet extraction tube and set it aside. Pour about 300 ml of TEST SOLUTION into the round bottomed flask. This amount is not critical. Reassemble the Soxhlet extraction tube and the round bottomed flask back together with the condenser and mantle.

Turn on the water supply to a slow but steady flow. Turn on the power to the mantle and gradually heat the TEST SOLUTION to a boil. As the solvent boils, vapors will condense in the coil and start dripping into the cellulose thimble containing the paste. As the condensate fills the Soxhlet tube, it will eventually fill to a point that a siphon will drain the condensate back down into the round bottom flask. Continued filling and draining of the Soxhlet tube will wash away the flux residues and leave only the solder in the thimble.

Allow the condensate to flush for two hours. At the end of the two hours, disconnect the Soxhlet and round bottom flask from the condenser. If TEST SOLUTION is not covering the paste already, add some so that the paste is covered by at least two inches. Using a long object such as a spatula, stir the solder paste to release any remaining trapped flux. Reassemble the tube and flask back together and let the solvent boil for another two hours.

After four hours of boiling, disconnect the Soxhlet and round bottomed flask from the condenser and turn off the water. Pick the thimble up and let the TEST SOLUTION drain back into the Soxhlet tube. Set the thimble on a paper towel to air dry for about one hour then place it in an oven at 150°F for two hours. Remove the thimble from the oven and let it cool to room temperature. Weigh the thimble and dry solder together to four decimal places and record the weight.

Pour the TEST SOLUTION that is in the Soxhlet tube into the round bottomed flask with the rest of the solvent. Place the
round bottomed flask in the mantle and bring the solvent back to a boil. Let the TEST SOLUTION evaporate until the volume is around 50 to 100 ml then remove it from the mantle. Weigh a 250 ml erlenmeyer flask to at least 2 decimal places and record the weight. Pour the solvent from the round bottomed flask two times to make sure all of the residue is in the erlenmeyer.

Set the erlenmeyer on a hot plate and evaporate the solvent dry. The flask will probably not go completely dry, but it will reduce to a thick, viscous looking solvent. Remove the flask from the heat and let it cool. When the flask is at room temperature, weigh the flask and residue together and record the weight.

Repeat this testing at least four times to get an average of each weight.

**CAUTION: SOLDER IS A HAZARDOUS MATERIAL. DISPOSE OF SOLDER AND SOLDER PASTE PROPERLY.**

5.1.1 Standards Calculations:
(Thimble + wet paste wt.) – thimble wt. = wet paste wt.
(Thimble + dry solder wt.) – thimble wt. = dry solder wt.
(Flask + residue wt.) – flask wt. = residue wt.

\[
\frac{100}{\text{wet paste wt.}} \times \text{dry solder wt.} = \% \text{ metal}
\]

\[
\frac{100}{\text{wet paste wt.}} \times \text{residue wt.} = \% \text{ residue}
\]

\[
\frac{\text{all } \% \text{ metals}}{\text{number of times run}} \times \text{average } \% \text{ residue}
\]

\[
\frac{\text{all } \% \text{ residues}}{\text{number of times run}} \times \text{average } \% \text{ residue}
\]

*Note: All % metals run and the amount listed in technical data sheets should be within 2% of each other. All % rosins run and the amount listed in technical data sheets should be within 1% of each other.

5.2 Standards: Making the Stock Solution Once the solder paste components have been verified, standards can be made.

Weigh a cotton cellulose thimble to the fourth decimal place and record the weight. Add about 25 grams of fresh solder paste to the thimble and weigh it immediately. Record the weight.

Put the thimble into the Soxhlet tube and assemble the extraction unit as described earlier. Turn on the water to the condenser and the power to the mantle. Gradually bring the solvent to a boil.

As done previously, let the paste flux for two hours then stir it with a spatula. Flux for another two hours. When flushing is complete, lift the thimble up and let the TEST SOLUTION drip back into the Soxhlet tube. Set the thimble on a paper towel and let it air dry for one hour. Place the thimble in an oven at 150°F for two hours. Remove the thimble from the oven and let it cool to room temperature. Weigh the thimble and paste together to the fourth decimal place and record the weight.

Pour the solvent remaining in the Soxhelt tube into the round bottom flask and let it boil down to about 100 ml. Remove the flask from the heat. Weigh a 500 ml volumetric flask to the second decimal place and record the weight. Pour the TEST SOLUTION from the round bottomed flask into the volumetric. Rinse the round bottomed flask with TEST SOLUTION at least twice to be sure all of the residue is in the volumetric. Rinse the inside of the volumetric down and continue to add TEST SOLUTION until the flask is about half full. Weigh the flask and the solvent together to the second decimal place and record the weight. Cap the flask and mix thoroughly.

5.2.1 Calculations
(thimble + paste wt ) – thimble wt. = paste wt.

\[\text{Example: } 32.8293 - 4.2686 = 28.5607\]

(thimble + dry solder wt.) – thimble wt. = metal wt.

\[\text{Example: } 29.6060 - 4.2686 = 25.3374\]

*this weight should be within 1% of your average metal wt.

paste wt. – metal wt. = flux wt.

\[\text{Example: } 28.5607 - 25.3374 = 3.2233\]

(volumetric flask + solvent wt.) – volumetric wt. = solvent wt.

\[\text{Example: } 175.22 = 199.96\]

flux wt. x average % residue = wt of residue in flask

\[\text{Example: } 3.2233 \times 0.55 = 1.77\]

\[
\text{residue wt.} = \frac{\% \text{ residue in stock solution}}{\text{solvent wt.}}
\]

\[\text{Example: } 1.77 = 0.00885 \text{ grams or 0.885%}\]

\[
\text{average } \% \text{ residue}
\]

\[
\text{number of times run}
\]

\[
\text{all } \% \text{ resins}
\]

\[
\text{average } \% \text{ residue}
\]

\[
\text{number of times run}
\]
5.3 Making the Standards from the Stock Solution

First, calculate the amount of stock solution you will need for each standard. Standards that will be used are 0.002%, 0.004%, 0.006%, 0.008% and 0.010%.

5.3.1 Calculations

To make 50 grams of 0.002% standard:

\[
\frac{0.002}{50} = \text{ wt. of stock solution to be used for standard}
\]

*Note: If the amount of stock solution to be taken from the 500 ml volumetric is less than one gram, dilute the concentration of the solvent. This will decrease your margin of error.

**Example:**

\[
\frac{0.002}{50} = 0.0001129 \text{ grams}
\]

So:

Dilute 10 grams of 0.885% = 190 grams TEST SOLUTION

\[
\frac{10 \times 0.885}{200} = 0.04425\%
\]

Now:

\[
\frac{0.002}{50} = 0.00226 \text{ grams}
\]

Calculate the rest of the standard using the same calculation, substituting the standard number for 0.002.

5.4 Making the Standards

Get five, 100 ml volumetric flasks and label them:

1) 0.002% residue
2) 0.004% residue
3) 0.006% residue
4) 0.008% residue
5) 0.010% residue

Weigh or zero the first volumetric labeled 0.002%. Add the amount of stock solution to the flask (Example: 2.26). Add TEST SOLUTION until the weight reaches 50 grams not including the weight of the flask. Cap the flask immediately and mix thoroughly.

Mix the rest of the standards using the different amounts of stock solutions calculated.

5.5 Procedure: Measuring the Standards

1) Turn on the spectrophotometer and let the system warm up.

2) Fill the sample cuvette (fill both cuvettes if your system is a double beam) with clean TEST SOLUTION. Place the cuvette(s) into the holder(s).

3) Go to 241 nm wavelength and zero or record the absorbance reading as the 0.00% standard. This is also known as the "Y intercept."

4) Remove the sample cuvette and dump the TEST SOLUTION. Fill the cuvette with the 0.002% standard and insert it back into the spectrophotometer. Record the absorbance reading.

5) Repeat step four until all of the standards have been measured. Rinse the cuvette at least two times with TEST SOLUTION between each standard. Be sure that the outside of the cuvette is clean and dry before each measurement.

6) When all of the standards have been measured, graph the absorbance readings versus the percent concentration. Draw a line that best fits the points plotted. Ideally, the line should run through all of the points plotted (see Figure 1). If it does not, a problem has occurred in either the standards or a data entry. Check the printout to see that all data was entered properly. Look at the graph to see if one of the data points is located off line with the others as in Figure 2. If all of the points seem to be scattered, there is probably something wrong with the stock solution and the whole process will need to be redone.

7) Calculate the slope of the line using the following calculation:

\[
\text{slope} = \frac{\text{change in concentration}}{\text{change in absorbance}}
\]

5.6 Procedure: Sample Analysis

1) Take a GLAD-LOCK bag and add exactly 100 ml of TEST SOLUTION. To reduce the chance of leaking, keep the sealing part of the bag as dry as possible when adding the solvent.

2) Handle the board being tested with gloved hands and insert it into the bag along with the TEST SOLUTION.

3) Remove as much of the air from the bag as possible then seal the top of the bag closed. Fold the top of the bag over twice to reduce the size of the bag and to add to the seal.
Figure 1

UV Abs @ 242nm

WATER - WHITE ROSIN IN ISOPROPANOL
+ 1% PHOSPHORIC ACID + 0.1% H₂O

CONCENTRATION (PPM)
4) Hold the folded top of the bag with one hand, and hold the board in place with the other. Damage to the bag is likely to occur if the board is allowed to shift around while shaking. Shake the bag containing the board for 10 minutes.

5) At the end of 10 minutes, REMOVE THE BOARD FROM THE BAG.

6) Again, rinse the sample cuvette at least twice with clean TEST SOLUTION. Fill the cuvette with a sample of TEST SOLUTION from the bag. Insert the cuvette into the sample chamber of the spectrophotometer and record the absorbance reading.

Note: In the case of the boards that have high levels of contamination, the absorbance reading will be off scale. In that case, add another 100 ml of TEST SOLUTION to the bag and shake it for a couple of minutes. Repeat step six. If it is still off scale, add another 100 ml until the absorbance readings are less than 3.000. Keep track of the amount of TEST SOLUTION that is added.

7) Convert the absorbance readings to concentration percent using the following calculation:

\[
\text{concentration \%} = \text{slope} \times \text{absorbance} + \text{Y intercept}
\]

8) Convert the concentration percent to parts per million (ppm) using the following calculation:

\[
\frac{\% \times 1,000,000}{100} = \text{ppm}
\]

9) To calculate the residual rosin in micrograms per square inch using the following calculation:

\[
\text{residual rosin micrograms/sq. in} = \frac{\text{ppm rosin} \times \text{X specific gravity of TEST SOL.} \times \text{ml TEST SOL. in bag}}{\text{Surface area of board}}
\]
1.0 Scope

1.1 This High Performance Liquid Chromatography (HPLC) procedure outlines the analysis of rosin flux residues remaining on a printed wiring board (PWB) after defluxing. This test can be used for the evaluation of processes used to clean rosin based soldering fluxes.

Applicable Documents


IPC-TR-580 “Cleaning and Cleanliness Test Program Phase 1 Results.”

3.0 Test Specimens

3.1 Printed wiring board (PWB) for extraction

4.0 Apparatus and Materials

4.1 HPLC systems with UV detection

4.2 Waters C18 Novapak column, or equivalent

4.3 Suitable extraction vessel, KAPAK\textsuperscript® bag, or equivalent, to extract PWB

4.4 Volumetric Flasks

4.5 Acetonitrile, HPLC grade

4.6 Deionized water, HPLC grade

4.7 Rosin Standards: abietic acid, dehydroabietic acid, neoabietic acid (Helix BioTech, 604-270-7468, Aldrich Chemical, Alltech Associates)

4.8 2-Propanol (IPA), HPLC grade

4.9 Sodium phosphate monobasic, NaH2PO4oH2O

4.10 Hot water bath, 80° ± 5°C

5.0 Procedure

5.1 Extraction

5.1.1 Record area of PWB. General rule on surface area is (length x width x 2)+10% for a populated PWB.

5.1.2 Place processed PWB in extraction bag, or equivalent

5.1.3 Prepare 75/25 (by volume), IPA/H2O solutions for the extraction.

5.1.4 Add 75-200 ml of IPA/H2O solution to extraction bag, enough to cover PWB.

5.1.5 Heat seal bag and place in water bath at 80° ± 5°C for 1 hour (cut vent hole in bag).

5.1.6 Dilute (with IPA/H2O solution) or concentrate extract to get approximately 100 ml of extract per 35 sq inch of PWB area.

5.1.7 Extract unprocessed PWB blank, in same manner as sample.

5.2 Standard and sample analysis

5.2.1 Set HPLC instrument conditions as follows:

- Wavelength ................................ 220 & 240 nanometers
- (The two wavelengths are needed to get optimum response from all constituents. See attached cromatograms.)
- Column temp ....................................................... 60°C
- Mobile phase ................................................. Acetonitrile/water 60/40 (…………………………………….. 25 millimolar Na2PO4H2O
- Flow rate .................................................. 2 milliliters/minute
- Sample size ...................................................... 10 microliters
- (Instrument conditions may be changed to optimize separation)

5.2.2 Prepare standards of known concentration

5.2.3 Establish retention times and areas of rosin standards
5.2.4 Prepare calibration curves for each of the identifiable peaks in the extract chromatogram.

5.2.5 Run extracts obtained in 5.1

5.3 Calculation of residue concentration

5.3.1 Concentration of material in solution

\[
\text{Concentration of material in solution (milligrams/liter)} = \frac{(A \times B \times C)}{(D \times E)}
\]

- \(A\) = Area of material peak
- \(B\) = Concentration of standard (milligrams/liter)
- \(C\) = Injection volume of standard (microliters)
- \(D\) = Area of standard peak
- \(E\) = Injection volume of sample (microliters)

Residual material (micrograms/inch squared) = \(\frac{(F \times G)}{H} \times 1000\) ug/mg

- \(F\) = Concentration of material in solution (milligrams/liter)
- \(G\) = Volume of extract solvent (liter)
- \(H\) = PWB surface area (square inch)
Figure 2

Chromatogram of IPA/H₂O Extract of a PWB at 240 nm

- Solvent System
- Neoabietic
- Abietic

Minutes
0 2 4 6 8 10 12 14
0 50 100 150 aufs
1.0 Scope

This test procedure is designed to measure the level of anionic contaminants on the surface of circuit boards by ion chromatography.

2.0 Applicable Documents


3.0 Test Specimens

3.1 Printed Wiring Board (PWB) for extraction

4.0 Apparatus and Material

4.1 Dionex 4000i (Ion Chromatograph) or equivalent. The system consists of a gradient pump and an anion column (AS4A-SC or equivalent), and a conductivity detector. A system which is operating properly should be capable of 50 ppb or better. The equipment and chemistry should be set up and standardized per manufacturers’ instructions.

4.2 Hot Water Bath capable of holding 80°C ±5°C.

4.3 Use a clean heat sealable bag, ie. KAPAK® 500 series or equivalent, with less than 250 ppb extractable contaminants. (Specify cleanliness level or manufacturers’ part number.)

4.4 Cleanroom vinyl gloves. (<3ppm of Cl)

4.5 Hi-purity deionized water 18.3 meg-ohm grade and chloride levels of less than 50 ppb.

4.6 Hi-purity chemicals for eluent and regenerant preparation.

4.7 NIST traceable standards

4.8 2-Propanol (IPA), Electronic grade

5.0 Procedure

5.1 Extraction

5.1.1 Record area of PWB. General rule on surface area is (length x width x 2) + 10% for a populated PWB.

5.1.2 Use clean gloves when handling the samples to be tested, and then place each sample in the extraction bag.

5.1.3 Prepare 75/25 IPA/H₂O solutions for the extraction.

5.1.4 Add 100-250 mls of the extraction solution to the extraction bag (enough to cover the PWB).

5.1.5 Heat seal the extraction bag and place in the 80°C water bath for one hour (cut a vent hole in the bag).

5.1.6 Measure solution volume after extraction.

5.1.7 Prepare unprocessed PWB as control.

5.2 Standard and Sample Analysis.

5.2.1 Inject solution into Ion Chromatograph (IC) and calculate against known standards.

5.2.2 Values from the IC are in the ppb in solution range.

5.2.3 Standards should be used per mfg. instruction. (Chloride levels of 100 ppb are recommended).

5.2.4 A calculation to take into account for surface area and evaporation must be done so as to compare all different sizes of circuit boards,

\[ \text{ug/cm}^2 = \left( \frac{\text{ppb value from IC} \times 1000}{\text{Surface Area (cm}^2)} \right) \]
1 Scope  This method describes the test procedure required to determine if flexible flat cable is flame retardant.

2 Applicable Documents  None

3 Test Sample

3.1  The number of production samples shall be determined by the manufacturer and/or user and shall be one production sample as a minimum.

3.2  The test sample shall be 6.1 m minimum. The 6.1 m sample shall be cut into a quantity of 12 specimens, each 508 mm long.

4 Apparatus

4.1  Test chamber of sheet metal 610 mm with 305 mm sides, open at the top and front to permit a flow of draft-free air, sufficient for complete combustion, and provided with the means for supporting the test specimen in a position that is a 45° angle from the horizontal (see Figure 1).

4.2  Burner (Terrill, Bunsen, etc.) having a bore of 9.5 mm and a length of 102 mm above the primary air inlets; and a supply of ordinary illuminating gas at normal pressure

4.3  Watch or other device capable of measuring the time in seconds

4.4  The test shall be made in a room generally free from drafts of air, but a ventilated hood may be used if air currents do not affect the flame.

5 Procedure

5.1  The test specimens of 3.2 shall be tested as stated in 5.1.1 through 5.1.4.

5.1.1  Hold a single, full-width strip of cable at a 45° angle from the horizontal, with the flat side down, and the flame applied to the underside of the cable (see Figure 1).

5.1.2  Hold a single, full-width specimen of cable held at a 45° angle from the horizontal, with the edge down, and the flame applied to the lower edge of the cable (see Figure 2).

5.1.3  Tape five full-width specimens together and otherwise tested as in 5.1.1 (see Figure 3).

5.1.4  Tape five full-width specimens together and otherwise tested as in 5.1.2 (see Figure 4).

5.2  During this test, as well as after the application of the flame, observations shall be made to determine the rate of burning of the sample within the marked 152 mm length and whether or not any burning particles fell from the sample.

6 Notes  This test procedure was extracted from Underwriters Laboratories Factory Inspection Procedure, Subject 758, Section G, Page 31, as modified by Underwriters Laboratories, Inc., for flexible flat conductor cable.
Figure 2  Flame Applied to Edge of Cable

Figure 3  Edge of Five Cables

Figure 4  Underside of Five Cables
1 Scope  
This test method is used to measure pH in anhydrous fluorocarbon azeotropes and blends in cleaning and defluxing equipment. This method does not work in the presence of organic acid acceptors normally present with chlorinated solvents, namely 1,1,1-trichloroethane and trichloroethylene.

2 Applicable Documents  
None

3 Test Specimen  
3.1 Approximately 25 ml samples of solvent are taken from the boiling sump and condensate rinse sump of the operating fluorocarbon vapor defluxer or degreaser and, for comparison purposes, from the virgin solvent supply.

4 Equipment/Apparatus  
4.1 pH indicator sticks TM “colorpHast”® cat. #9590 available from MCB Manufacturing Chemists Inc., 2909 Highland Ave., Cincinnati, OH 45212
4.2 Screw cap glass vials (50 ml, three or six required per test)
4.3 Graduated glass cylinders (50 ml, three required per test)

Caution: Plastic is sometimes attacked by solvents such as acetone, methylene chloride azeotropes.

5 Procedure  
5.1 Transfer 25 ml of virgin solvent to a clean vial using a clean, dry graduated cylinder, insert a “colorpHast”® plastic strip, and cap the vial.

5.2 Repeat 5.1, sampling the defluxer or degreaser boiling sump.
5.3 Repeat 5.1, sampling the condensate or rinse sumps.
5.4 Allow the test vials to stand 30 minutes.
5.5 Compare the colors on the test sticks with the “colorpHast”® color key and record the matching pH value.
5.6 Discard the “colorpHast”® indicator sticks and vials after emptying the solvent into the boiling sump.
5.7 Rinse the graduated cylinders with virgin solvent, empty into the boiling sump, and allow to dry for reuse.

5.8 With fluorocarbon/acetone and fluorocarbon/methylene chloride azeotropes or mixtures, which attack the indicator adhesive, repeat the above steps, but with two vials of each sample. Cut the bottom two color squares off three “colorpHast”® sticks and discard the remainder of the stick. Put one square of each color in samples from 5.1, 5.2, and 5.3 sources and complete steps 5.4 through 5.7.

5.9 Interpretation of Results  
If pH is above 5.5, this is an acceptable condition. If pH is less than 5.5, the solvent is contaminated by an accumulation of activated flux residues, organic acids, or thermal degradation products of the solvent. This requires inspection to establish the need for cleaning of the equipment and for recovery of the solvent.
1.0 Scope  This test method is designed to determine relative degree of cure in liquid U.V. curable materials such as etch resists, plating resists and solder masks. It is not applicable to dry film products nor to solvent-based thermal cure products.

2.0 Applicable Documents  None

3.0 Test Specimens  Test specimens are formed in the apparatus described below.

4.0 Apparatus

4.1 Degree of Fineness Gauge, Model PB-20

4.2 U.V. curing unit

4.3 Mold release

5.0 Procedure

5.1 Test Conditions  The cure unit shall be operated at 3 meters [10 feet] per minute conveyor speed with two focused lamps rated at 200 W/inch operating at full power.

5.2 Test Specimen Preparation  Clean the surface of the Degree of Fineness Gauge and apply a thin coat of mold release. Remove excess release. One release application should last through several tests.

Place a quantity of the material to be tested sufficient to fill the trough in the deep end of the trough. Level with the straight edge supplied. Repeat in the second trough.

5.3 Cure  Place the gauge on the conveyor belt. Allow it to pass through the machine. Orient the long axis of the gauge parallel to the long axis of the cure unit. See notes for precautions.

5.4 Results and Evaluation  Remove the gauge from the cure unit’s conveyor. Carefully remove the cured films from the troughs beginning at the deep end. Use a small, thin blade (microspatula) to aid removal.

Examine the bottom surface of the film and the trough surface. Record the following points using the gauge markings starting from 0 (zero) mils:

a. The last point at which the film’s bottom surface is dry and tack free and last point at which the trough shows no residue;

b. The last point at which the film’s bottom surface is tacky and/or soft but not wet and at which the trough has a soft or tacky but not wet residue.

The regions of dry, tacky and wet are not always delineated by a straight line. At times, a finger of tacky or wet material will exist in the trough center with dry or tacky material, respectively, at the trough sides. Other materials will exhibit the opposite phenomena—tacky or wet residue on the trough sides surrounding a finger of a dry area or tacky residue, respectively, in the center. Therefore, for evacuation purposes, the point in (a) is taken as the point at which there is no residue across the width of the trough or the width of the film’s bottom surface. The point in (b) is the last point at which there is a dry or tacky but not wet residue across the film’s bottom surface or across the width of the trough.

The point in (a) represents the maximum depth of cure that can be expected with materials tested. This depth should be the minimum as specified or as agreed by the vendor and user.

6.0 Notes

6.1 Precautions  Some cure units have openings beneath the conveyor belt in the lamp section for air-flow or other considerations. If these openings are wide enough, the back of the gauge may cause the belt to deflect into this opening. This will raise the front end of the gauge—possibly jamming it against the housing. A few strategic metal strips to prevent large belt deflections or a large, thin piece of material under the gauge to distribute its weight will eliminate this problem.

6.2 Background  This test method is based on the chemistry of U.V. curing. As light enters the U.V. coating, it is absorbed by various molecular species. The most important are the photoinitiator molecules. Curing will not take place unless a sufficient number of these molecules absorb light to eventually yield free radicals. At some point below the surface of the coating, there is insufficient light intensity to convert photoinitiator molecules to free radicals or there are too few radicals for effective polymerization.
By holding the light intensity and the exposure time (i.e., conveyor speed) constant, while varying the applied thickness in the trough, the coating’s ability to make efficient use of light intensity and time can be evaluated. Thus, the dry tacky and wet regions on the cured film’s bottom surface represent the regions of good, poor and no cure.

6.3 References


6.4 Suppliers


1.0 Scope
This test method is designed to determine the removal effect the flux has (if any) on the bright copper mirror film which has been vacuum deposited on clear glass.

2.0 Applicable Documents
ASTM E104 Maintaining Constant Relative Humidity by means of Aqueous Solutions
LLL-R-626 Rosin, Gum, Rosin Wood and Rosin Tall Oil

3.0 Test Specimen
A minimum of 100 ml of liquid flux, a representative container of solder paste, reflowed solder-paste flux, extracted solder preform flux or extracted flux-cored wire.

4.0 Apparatus and Reagents
4.1 0.5L of control standard rosin flux, class A, type II, grade WW, of LLL-R-626.
4.2 0.5L of reagent grade (99% pure) 2-propanol.
4.3 A vacuum deposition system or the means to procure glass test panels having a copper mirror coating as described in paragraph 5 below.
4.4 0.5L of reagent grade 0.5% solution of ethylene diamine tetra acetic acid (EDTA).
4.5 0.5L of reagent grade ethanol or methanol.
4.6 100 ml medicine bottle with dropper.
4.7 Test cabinet capable of achieving 23 ± 2°C and 50 ± 5% relative humidity.
4.8 Glass slides
4.9 A relative humidity gauge having a ± 2% accuracy, or better, shall be used to continuously monitor the test environment. The gauge should be calibrated periodically.

5.0 Procedures
5.1 Preparation
5.1.1 Preparation of Control Standard Flux
Dissolve 35 g of Federal Specification LLL-R-626 rosin into 100 ml of reagent grade 99% 2-propanol and stir thoroughly.

5.1.2 Preparation of Temperature/Humidity Chamber
When acid or salt solutions, such as reported in ASTM E104, are used the environment shall be monitored for a minimum of 48 hours prior to exposing the copper mirror samples, to assure compliance with the 50% ± 5% relative humidity requirement.

5.1.3 Preparation of Copper Mirror Test Panels.
5.1.3.1 Apply by vacuum deposition, a film of copper metal on one surface of a flat sheet or clear, polished glass.
5.1.3.2 Apply a uniform thickness of approximately 50 nm and assure that the finished mirror permits 10 ± 5% transmission of normal incident light of nominal wave length of 500 nm. This may be determined using a suitable photoelectric spectrophotometer. Commercially available copper mirrors meeting the above specifications are acceptable. (See 6.2.)
5.1.3.3 Prevent oxidation of the copper mirror by storing in a closed container which has been flushed with nitrogen.
5.1.3.4 Immediately before testing, immerse the copper mirror in a 5 g/l solution of EDTA for copper oxide removal. Mirrors stored in a non-oxidizing environment, do not require cleaning with the EDTA solution prior to testing. The cleaning step must be used if test results are in dispute.
5.1.3.5 Rinse thoroughly in running water, immerse in clean ethanol or methanol and dry with clean, oil free air.
5.1.3.6 Carefully examine the mirror before testing. There must be no oxide.

5.2 Test
5.2.1 Place the copper mirror test panel on a flat surface, mirror side up, and protect from dust and dirt at all times.
5.2.2 Place one drop of test flux or extract to be tested (approximately 0.05 ml) on each copper mirror test panel. Do not allow the dropper to touch the test panel.
5.2.3 Solder-paste shall be applied directly to the mirror without scratching the copper mirror, with a volume approximating a 0.5 mm thickness and 8 mm diameter. (It has been determined that significant variations from this quantity have little effect for most materials.)

5.2.4 Immediately also place one drop of the control standard flux adjacent to the test flux. Do not allow drops to touch.

5.2.5 Place test panels in a horizontal position in the dust free cabinet at 23 ± 2°C and 50 ± 5% relative humidity for 24 ± 1/2 hours.

5.2.6 At the end of the 24 hour period, remove the test panels and remove the test flux and control standard fluxes by immersion in clean 2-propanol.

5.3 Evaluation

5.3.1 Carefully examine each test panel for possible copper removal or discoloration.

5.3.2 If there is any complete removal of the copper film as evidenced by the background showing through the glass, the test flux has failed the L category. Complete removal of the copper only around the perimeter of the drop defines the flux as M. Complete removal of the copper places the flux in the H category. (See Figure 1).

5.3.3 If the control flux fails, repeat the entire test, using new copper mirror test panels.

5.3.4 Discoloration of the copper film due to a superficial reaction or only a partial reduction of the copper film thickness is not considered a failure.

5.3.5 A number of chemicals can cause failure of copper mirror: free halides, stronger organic and inorganic acids and free amines.

6.0 Notes

6.1 Safety Observe all appropriate precautions on MSDS for chemicals involved in this test method.

6.2 Sources for prepared copper mirrors

6.2.1 Evaporated Metal Films, Inc., Ithaca, NY 14850.

6.2.2 Clausing PA Co., 8038 Monticello Ave., Skokie, IL, 708/267-3399
1.0 Scope  This test method is designed to determine the presence (if any) of chlorides and bromides in soldering flux by visual examination after placement on test paper.

2.0 Applicable Documents  None

3.0 Test Specimen  A minimum of 100 ml of liquid flux, a representative container of solder paste, reflowed solder paste flux, extracted solder preform flux or extracted flux-cored wire.

4.0 Apparatus and Reagents

4.1 Six pieces of silver chromate test paper 51 mm x 51 mm

4.2 0.25L of reagent grade 2-propanol.

5.0 Procedures

5.1 Preparation

a. The silver chromate paper is extremely light sensitive and must be stored in a closed container away from light until used for testing.

b. To avoid contamination, the paper must be handled with forceps and must never be touched with bare hands.

5.2 Test for Liquid Flux or Flux Extract Solution

5.2.1 Place one drop of test flux or flux extract (approximately 0.05 ml) on each piece of silver chromate test paper. Allow the droplet to remain on each test paper for a minimum of 15 seconds.

5.2.2 After the 15 seconds, immediately immerse each test paper in clean 2-propanol to remove the residual organic materials.

5.2.3 Allow each test paper to dry for 10 minutes, then examine for color change.

5.3 Test for Paste Flux or Solder Paste Flux as Obtained from the Supplier

5.3.1 Clean a glass microscope slide with 2-propanol and air dry.

5.3.2 Moisten a piece of silver chromate reagent paper of suitable size with deionized water.

5.3.3 Apply the wet paper to the glass slide and remove the excess water with blotting paper.

5.3.4 Using a spatula, apply a thin coating of the paste flux or solder paste flux directly to the moist reagent paper.

5.3.5 Allow the paste flux or solder paste flux to remain in contact with the paper for 1 minute, then remove the flux with 2-propanol without disturbing the paper.

5.4 Evaluation  Carefully examine each test sheet for possible color change. A change to off-white or yellow-white indicates the presence of chlorides or bromides. See Figure 1.

5.4.1 Interferences  A number of chemicals besides free halides may cause test failures. (Representative examples are, but are not limited to, amines, cyanides, isocyanates, etc.)

Figure 1 Chlorides and/or bromides test results
5.4.2 Certain acidic solutions may react with the reagent paper to provide a color change similar to that obtained with chlorides and bromides. When a color change is observed, it is advisable to check the acidity of the affected area by means of a pH indicating paper. If pH values of less than 3 are obtained, the presence of chlorides and bromides should be verified by other analytical means.

6.0 Notes

6.1 Safety Observe all appropriate precautions on MSDS for chemicals involved in this test method.

6.2 Source For Silver Chromate Test Paper

6.2.1 Quantek, PO Box 136, Lyndhurst, NJ 07071, (201) 935-4103
1.0 Scope  
This test method is designed to determine the residual solids content of the liquid flux after evaporation of the volatile chemicals from within the liquid flux; typically 15% by weight minimum.

2.0 Applicable Documents  
None

3.0 Test Specimen  
A minimum of 6 grams by weight per test of liquid flux or flux extracted from solder paste, solder preforms or flux-cored wire.

4.0 Apparatus and Reagents
1. A circulating air drying oven capable of maintaining 85 ± 5°C.
2. An analytical balance capable of weighing to the 4th decimal of a gram.
3. Glass pipettes
4. Glass petri dish, 30 ml capacity
5. Silica gel desiccant, or equivalent, in a glass desiccator
6. Analytical balance capable of 0.001 g. Carry out the following procedures in triplicate.

5.0 Procedures

5.1 Preparation
5.1.1 Dry 3 empty glass petri dishes in the drying oven, then cool in the desiccator to room temperature.
5.1.2 Weigh each dish to the nearest 0.001 gram.

5.2 Test
5.2.1 Pipette approximately 6 grams (see 6.1) by weight of test flux specimen into each specimen dish and weigh to the nearest 0.001 gram.
5.2.2 Heat in the drying oven for one hour, then reweigh after allowing the sample to come to room temperature.
5.2.3 Repeat heating and drying procedure until the weight is constant to within 0.005 gram.

5.3 Evaluation  
Calculate the residual solids as follows:
\[
\frac{100 \times m_2}{m_1}
\]
where:
\(m_2\) = the mass of residual after drying, in grams
\(m_1\) = the mass of original test flux specimen, in grams

6.0 Notes

6.1 Sample Size  
Larger sample sizes may be required to obtain accurate data on low solids (<15%) fluxes.

6.2 Safety  
Observe all appropriate precautions on MSDS for chemicals involved in this test method.
1.0 Scope  This test method provides a measurement of the flux percentage on flux-coated and/or in flux-cored solder.

2.0

J-STD-006  Requirements and Test Methods for Electronic Grade Solder Alloys and Fluxed and Non-fluxed Solid Solders for Electronic Soldering Applications

3.0 Test Specimen  Use approximately 200 grams of flux-coated and/or flux-cored solder. For fluxes whose flux percentage is expected to be 1% or more, the test specimen may be approximately 100 grams. For fluxes whose flux percentage is expected to be 2% or more, the test specimen may be approximately 50 grams.

4.0 Apparatus

4.1 One hot plate capable of being set to 50+5/-0°C above the liquidus temperature of the solder sample alloy.

4.2 One suitably sized pyrex or equivalent beaker.

5.0 Test Procedure

5.1 Preparation for Test

5.1.1 Determine the liquidus temperature of the solder specimen alloy from J-STD-006.

5.1.2 Weight solder sample to the nearest 0.01 gram (W1).

5.1.3 Carefully pack the solder sample as tightly as possible in the bottom of the beaker. Weigh the beaker and solder sample to the nearest 0.01 gram (W2).

5.2 Test

5.2.1 Preheat the hot plate to 50+5/-0°C above the liquidus temperature of the solder specimen alloy.

5.2.2 Place the beaker with the solder sample on the hot plate. Remove the beaker as soon as all of the solder melts and allow it to cool at room temperature for about 30 minutes.

5.2.3 Using reagent grade 2-propanol, or other suitable solvent recommended by the solder manufacturer, slight agitation, and gentle heat, thoroughly extract the flux residues from the beaker. Decant the extraction solution through coarse filter paper taking care that no solder escapes the beaker. Repeat the extraction procedure as necessary to remove all traces of flux residue. Evaporate the remaining solvent from the beaker by warming under a gentle stream of air until the residue in the beaker is completely dry.

5.2.4 Weigh the beaker and melted solder metal to the nearest 0.01 gram (W3).

5.2.5 Repeat the flux residue extraction procedure until a constant final weight W3 is obtained.

5.3 Evaluation  Calculate the flux percentage using the following formula.

\[ \%F = 100 \times \frac{W3 - W2}{W1} \]

6.0 Safety  Observe all approximate safety precautions. Consult MSDS sheets for safety precautions for chemicals involved in this test method.
1.0 Scope

This test method is designed to determine the halide content of fluxes attributable to chlorides and bromides. The halide content is reported as the weight percentage of chloride to the solid (non-volatile) portion of the flux or as milliequivalent per gram of flux solids. A sample of flux or flux extract is titrated to an end-point and the percentage chloride or meq/g of halides is calculated.

2.0 Applicable Documents:
None

3.0 Test Specimen:
A minimum of 100 ml of liquid flux, 10-50 ml flux extract of known solids content from solder paste, solder preforms or flux-cored wire.

4.0 Apparatus and Reagents:

(1) Hot plate with magnetic stirrer.
(2) Analytical balance capable of reading to 0.001 g.
(3) Pipettes
(4) Burettes
(5) 100 ml beakers, Pyrex
(6) 125 ml separatory funnel
(7) 125 ml Erlenmeyer flasks
(8) 1000 ml volumetric flasks
(9) Reagents
   a. 0.1N silver nitrate, standardized: dissolve 17.000 g silver nitrate in deionized water and dilute to 1000 ml in a volumetric flask.
   b. 1M sodium hydroxide: 40.0 g of sodium hydroxide diluted to 1000 ml with deionized water in a volumetric flask.
   c. 0.2M nitric acid: add 12.6 ml concentrated (16M) nitric acid to deionized water and dilute to 1000 ml in a volumetric flask.
   d. 1M Potassium chromate: 194 g diluted to 1000 ml using deionized water in a volumetric flask.
   e. 0.03M phenolphthalein solution. (Reagent Grade)
   f. Chloroform (Reagent Grade)
   g. Deionized water

5.0 Procedures

5.1 Sample Preparation

5.1.1 For Rosin/Resin Fluxes

5.1.1.1 In a tared 100 ml beaker, accurately weigh about 3-5 g of flux sample on an analytical balance.

5.1.1.2 Quantitatively transfer the flux sample to a 125 ml separatory funnel using three 10 ml aliquots of chloroform.

5.1.1.3 Add 15 ml of deionized water to the funnel and shake the funnel for 10 seconds.

5.1.1.4 Allow the funnel to stand until the layers completely separate.

5.1.1.5 Draw off the bottom (chloroform) layer into a beaker and save for the next extraction.

5.1.1.6 Transfer the top (water) layer to a 125 ml Erlenmeyer flask.

5.1.1.7 Transfer the chloroform layer from the beaker to the funnel and repeat the extraction with 15 ml of water two more times, each time adding the water extract portion to the flask.

5.1.1.8 Heat the water extract in the Erlenmeyer flask using a steam bath to expel any chloroform which may be present.

5.1.1.9 Do not heat above 80°C. Allow for solution to cool to room temperature.

5.1.2 For Organic and Inorganic Fluxes

5.1.2.1 In a tared 125 ml Erlenmeyer flask, accurately weigh about 3-5 g of flux sample on an analytical balance.

5.1.2.2 Add 50 ml deionized water.

5.1.2.3 Add 2 drops of 0.03 M phenolphthalein solution to the Erlenmeyer flask (from step 5.1.1.9 or 5.1.2.2).

5.1.2.4 Add 1 M sodium hydroxide until the solution turns red. Add 0.2 M nitric acid dropwise until the red color is just completely discharged.
5.1.2.5 Dulute to about 60 ml with deionized water.

5.1.2.6 Add 6 drops of 1 M potassium chromate and titrate with standardized 0.1N silver nitrate to the red-brown end point.

5.1.3 For extracted preforms and extracted cored-wire follow the procedure in paragraph 5.1.1 if the extract contains a rosin or resin; follow the procedure in paragraph 5.1.2 if the extract is water soluble.

5.2 Calculations

5.2.1 Calculate the percentage of halides as chloride based on flux solids content, using the following formula:

\[
\text{Halides, as } \% \text{ chlorides} = \frac{3.55 \times V \times N}{m \times S} \times 100
\]

5.2.2 Calculate halides milliequivalent per gram of flux solids (non volatiles) using the following formula:

\[
\text{Halides, meq/g solids} = \frac{V \times N}{m \times S} 
\]

Where:

- V is the volume of 0.1N silver nitrate in ml.
- N is the normality of silver nitrate solution.
- m is the mass (weight) of flux sample in gram.
- S is the percentage of solids (non-volatiles) of the flux.

6.0 Notes

6.1 Safety: Observe all appropriate precautions on MSDS for chemicals involved in this test method.
1.0 Scope  This test method is designed to determine the presence (if any) of fluoride(s) in soldering flux by visual examination after placement of a drop of liquid test flux in a zirconium - alizarin purple lake.

2.0 Applicable Documents  None

3.0 Test Specimen

3.1 A minimum of 10 ml of first article or production specimen of liquid flux, solder paste flux, paste flux, or extracted flux from preform or wire furnished in a new clean glass container.

3.2 For paste flux or solder paste flux dilute the sample in 2-propanol or another suitable solvent.

Note: The solvent used in dilution/extraction must be watermiscible.

4.0 Apparatus and Reagents

4.1 Apparatus

4.1.1 White spot plate

4.1. Glass droppers

4.2. Glass rods

4.2 Reagents:

4.2.1 Zirconium nitrate solution: 0.05g dissolved in 50 ml of deionized water.

4.2.2 Sodium alizarin sulfate solution: 0.05g dissolved in 50 ml of deionized water.

5.0 Procedure

5.1 Preparation

5.1.1 Prepare a fresh zirconium - alizarin purple lake in three spots of the white spot plate by adding 1 drop each of zirconium nitrate and sodium alizarin sulfate solutions.

5.2 Test

5.2.1 Add one drop of the test flux to each of the spots.

5.2.2 Mix each spot with a clean glass rod.

5.2.3 Examine for any color change.

5.3 Evaluation  A change in color of the lake from purple to yellow is an indication of the presence of fluoride(s).

6.0 Notes

6.1 Safety  Observe all appropriate precautions on MSDS for chemicals involved in this test method.
1.0 Scope  This test method is used to determine the concentration of fluorides in soldering flux. The fluoride content is reported as the weight percentage of fluoride to the non-volatile portion of the flux. Ion specific electrodes are used for the determination. This method uses Orion equipment and solutions.

2.0 Applicable Documents  None

3.0 Test Specimen

3.1 A minimum of 100 ml of first article or production specimen of liquid rosin flux or prepared flux solution furnished in a new clean glass container.

3.2 For paste flux and solder paste flux 100 ml of the diluted material.

3.3 For preform and cored wire 100 ml of the extracted material.

4.0 Apparatus and Reagents

4.1 Apparatus

4.1.1 Autocalibrating ion analyzer (Orion EA 920 or equivalent)

4.1.2 Fluoride specific electrode (Orion 94-09-00 or equivalent)

4.1.3 Double junction reference electrode (Orion 90-02 or equivalent)

4.1.4 Magnetic stirrer and stir bars

4.1.5 250 ml and 500 ml beakers, glass or polypropylene

4.1.6 Funnel stand and funnel

4.1.7 50 ml graduated cylinders

4.1.8 100 ml and 1000 ml volumetric flasks

4.1.9 10 ml and 100 ml pipets

4.1.10 Analytical balance capable of 0.001 g

4.2 Reagents

4.2.1 Deionized water

4.2.2 Sodium fluoride, reagent grade

4.2.3 Chloroform, reagent grade

4.2.4 Orion TISAB II #940909 or equivalent

4.2.5 Whatman #41 ashless filter paper

5.0 Procedure

5.1 Sample Preparation—Water Soluble Flux  Depending on the expected concentration of fluoride, use the following amount of sample and deionized water.

<table>
<thead>
<tr>
<th>ppm Fluoride</th>
<th>Sample ml</th>
<th>DI Water ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1–1.0</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>1.0–10.0</td>
<td>5</td>
<td>50</td>
</tr>
</tbody>
</table>

5.1.1 Tare the beaker and add sample, record the weight of the flux to 0.001 gram

5.1.2 Add DI water and mix with stirrer for 10 minutes. Stop mixing and allow to stand for 5 minutes

5.1.3 Pour solution through filter paper in funnel into a clean beaker. Allow sample to drain completely

5.2 Sample Preparation—Non-water Soluble Flux

5.2.1 Depending on the expected concentration of fluoride, use the following amount of sample and chloroform.

<table>
<thead>
<tr>
<th>ppm Fluoride</th>
<th>Sample ml</th>
<th>Chloroform ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1–1.0</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>1.0–10.0</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

5.2.2 Tare the beaker and add sample, record the weight of the flux to 0.001 gram
5.2.3 Add chloroform and 50 ml DI water and mix with stirrer for 10 minutes. Stop mixing and allow to stand for 5 minutes.

5.2.4 Carefully decant the water solution through filter paper in funnel into a clean beaker. Allow sample to drain completely.

5.2.5 Standard Solutions

5.2.5.1 10 ppm fluoride (0.001%)—This standard can be purchased ready-to-use from Orion, catalog #040908. Alternately, a solution can be prepared. Weight 0.0221 gram (dried to 140°C) reagent grade NaF. Add 500 ml DI water. Dilute to one liter in a volumetric flask with Orion catalog #940909 TISAB (total ionic strength adjustment buffer).

5.2.5.2 1.0 ppm fluoride (0.0001%)—This standard can be purchased ready-to-use from Orion, catalog #040906. Alternately, a solution can be prepared. Weigh 0.0023 gram (dried to 140°C) reagent grade NaF. Add 500 ml DI water. Dilute to one liter in a volumetric flask with Orion catalog #940909 TISAB.

5.2.5.2.1 Another method is to dilute 100 ml 10 ppm fluoride standard with 450 ml DI water and dilute to one liter in a volumetric flask with Orion catalog #940909 TISAB (0.00001%)—This standard is prepared by diluting 100 ml, 1.0 ppm fluoride standard with 450 ml DI water and dilute to one liter in a volumetric flask with Orion catalog #940909 TISAB.

5.2.5.2.2 Another method is to dilute 10 ml, 10 ppm fluoride standard with 495 ml DI water and dilute to one liter in a volumetric flask with Orion catalog #940909 TISAB.

5.2.6 Double Reference Electrode Filling Solutions

Inner chamber filling solution (green). Solution saturated with AgCl, Orion catalog #900002.

Outer chamber filling solution. 10% KNO3 - Orion catalog #900003.

5.3 Test For accurate results, allow all samples and standards to reach the same temperature before attempting a measurement. Stir the samples and standards while a measurement is being made.

Prepare two standards that differ in concentration by a factor of 10. The standards should bracket the expected sample concentration. Select concentration mode and STD 1 function. Significant digit selection is accomplished by pressing the X10 key the required number of times.

Dilute 50 ml of the two standard solutions, each with 50 ml of DI water.

While stirring with a magnetic stirrer, immerse electrodes in the more dilute standard solution. Adjust the display using arrows or X10 keys to the correct value. When “Ready” illuminates, press “Enter.” The display automatically proceeds to “STD 2.”

Remove and rinse electrodes with DI water. Immerse electrodes in the more concentrated standard solution. Adjust the display to read the correct value for STD 2. When “Ready” illuminates, press “Enter.” The display automatically proceeds to “Sample” function.

To the sample prepared per instructions for water soluble flux, add 25 ml TISAB. While stirring, immerse electrodes. When display indicates “Ready,” record indicated value.

5.4 Evaluation The indicated value is equal to the parts per million (ppm) fluoride. To obtain weight % of fluoride as percentage of the non-volatile content, use the following formula:

Fluoride % of Solids = \( \frac{I}{(MS)100} \)

Where:
I is indicated value in ppm
M is mass of the flux sample in grams
S is the percentage of solids (non-volatile chemicals) of the flux

6.0 Notes

6.1 Standardization and Limits Restandardization should be done every few hours to compensate for electrode drift.

Reproducibility is typically ±2% obtainable with hourly recalibration. Temperature fluctuation, drift and noise will limit reproducibility.

Detection limits are 0.02 ppm minimum and no known maximum. A list of possible interfering ions has not yet been determined for this electrode method.

6.2 Safety Operator should be trained and familiar with the hazards inherent to the chemicals being used and analyzed. Proper personal safety equipment, such as safety glasses,
gloves and splash apron, and adequate ventilation should be used.

Using the same batch of DI water for dilutions will eliminate the need to run blanks.
1 Scope
This test is a method for determining acid acceptance of chlorinated solvents.

Acid acceptance is applicable for evaluating the condition of the following inhibited chlorinated solvents.

- Perchloroethylene
- 1,1,1-Trichloroethane
- Methylene Chloride
- Trichloroethylene

2 Applicable Documents


3 Test Specimen

3.1 25 ml of solvent (see 5.1 for sampling procedure)

4 Apparatus

4.1 One flask, Erlenmeyer, 100 ml, with glass stoppers (see 6.5)

4.2 Two flasks, Erlenmeyer, 250 ml, with glass stoppers (see 6.5)

4.3 Two flasks, Volumetric, 1000 ml, with glass stoppers (see 6.5)

4.4 Two pipets, 25 ml, with bulb (see 6.5)

4.5 One pipet, graduated (calibrated), with bulb (see 6.5)

4.6 One eye dropper (see 6.5)

4.7 One balance, analytical (see 6.5)

4.8 Two pieces of weighing paper (see 6.5)

4.9 Sodium hydroxide 0.1 N in C.P. anhydrous methanol (5.2.1 & 6.5)

4.10 Hydrochlorination reagent, 0.1 N Hydrochloric acid in anhydrous isopropanol (see 5.2.2 & 6.5)

4.11 Bromothymol blue indicator, 0.1% solution

Note: Make sure all glassware is clean and dry.

5 Procedure

5.1 Sampling Procedure

5.1.1 Securely tie a cupper wire around the neck of a 100 ml Erlenmeyer flask. Carefully lower, allow to fill, stopper, and store in cool, dark place.

5.1.2 Since a representative sample is desired, sampling should be done when the tank is half full. Most tanks (or hoses from them) have sampling points. From here, fill a 100 ml Erlenmeyer flask, stopper, and store in a cool, dark place.

5.1.3 See 6.3 for safety and handling and 6.4 for first aid.

5.2 Reagent Preparation

5.2.1 Sodium Hydroxide Solution Preparation

5.2.1.1 Weigh 4.0 g reagent grade NaOH.

5.2.1.2 Pour approximately 500 ml C.P. anhydrous methanol into a 1 liter volumetric flask.

5.2.1.3 Add NaOH and swirl until dissolved.

5.2.1.4 Dilute solution to exactly 1 liter with methanol and stopper. See 6.3 for safety and handling information and 6.4 for first aid information.

5.2.2 Hydrochlorination Reagent Preparation

5.2.2.1 Pour about 500 ml anhydrous isopropanol into an 1 liter volumetric flask.

5.2.2.2 Bulb pipet exactly 8.50 ml 37% HCl into the flask, then swirl.
5.2.2.3 Dilute solution to exactly 1 liter and stopper. See 6.3 for safety and handling information and 6.4 for first aid information.

5.3 Test Procedure

5.3.1 Measure specific gravity of sample using ASTM Method D 2111-95.

5.3.2 Bulb pipet exactly 25 ml sample into a 250 ml Erlenmeyer flask.

5.3.3 Bulb pipet exactly 25 ml hydrochlorination reagent into sample, stopper, then mix thoroughly.

5.3.4 Let sit 15 to 20 minutes for complete reaction. During reaction time, a blank may be run (see 5.3).

5.3.5 When reaction time is complete, add five drops of bromothymol blue 0.1% solution with an eye dropper.

5.3.6 Titrate the sample to endpoint with 0.1 N NaOH solution. The endpoint is reached when solution color changes from yellow to blue.

5.4 Blank

5.4.1 Bulb pipet exactly 25 ml hydrochlorination reagent into a 250 ml Erlenmeyer flask.

5.4.2 Add five drops bromothymol blue 0.1% solution with an eye dropper.

5.4.3 Titrate blank to endpoint with 0.1 N NaOH solution. The endpoint is reached when solution color changes from yellow to blue.

5.5 Disposal of Solutions

5.5.1 0.1 N NaOH in Methanol, Unused This solution is dilute and readily soluble in water, hence it can be safely poured down the sink. Flush with excess water.

5.5.2 All Other Solutions DO NOT POUR DOWN THE SINK. Place the solutions in appropriate, labeled, metal containers to be buried or burned in accordance with local, state, and federal regulations.

5.6 Cleaning Glassware Use soap and water to clean any glassware. Rinse well with excess water.

5.7 Safety and Handling, First Aid See 6.3 and 6.4.

6 Notes

6.1 Calculations:

\[
\frac{(B-A) \times 0.4}{\text{ml sample} \times \text{specific gravity} (1)} = \text{Total Acid Acceptance as % of NaOH}
\]

where:

\(A = \text{ml of 0.1 N NaOH used to titrate sample}\)

\(B = \text{ml of 0.1 N NaOH used to titrate blank}\)

(1) See sale specification for specific gravity of solvent choice.

6.2 Interpreting Test Results*

<table>
<thead>
<tr>
<th>Chlorinated Solvent</th>
<th>Within Normal Range</th>
<th>Solvent is Borderline</th>
<th>A) Discard</th>
<th>B) Remove, distill blend with virgin solvent at 4 parts virgin solvent, 1 part distilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene Chloride</td>
<td>&gt;0.08%</td>
<td>0.04%-0.08%</td>
<td>&lt;0.04%</td>
<td></td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>&gt;0.04%</td>
<td>≤0.04%</td>
<td>&lt;0.04%</td>
<td></td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: These guidelines have been established using inhibited chlorinated solvents from the Dow Chemical Company. The solvent manufacturer should be consulted for particular interpretation.

6.3 Safety and Handling

6.3.1 Sampling Procedure Wear safety goggles and neoprene or neoprene-coated gloves. Have adequate ventilation. Avoid sparks or flames.

6.3.2 Laboratory Procedure There are no unusual hazards inherent in this method, but good ventilation and normal laboratory safety precautions should be employed. When preparing reagents, mixing should be employed in a hood and chemical goggles should be worn. Keep away from any sparks or flames.
OSHA recommended exposure limits for chlorinated solvents (all in parts per million).

<table>
<thead>
<tr>
<th>Chlorinated Solvent</th>
<th>OSHA TWA*</th>
<th>ACGIH TLV</th>
<th>ACC^2</th>
<th>AMP^3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perchloroethylene</td>
<td>100</td>
<td>50</td>
<td>200</td>
<td>300/5 min. in any 3 hrs.</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>100</td>
<td>50</td>
<td>200</td>
<td>200/5 min. in any 2 hrs.</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>350</td>
<td>350</td>
<td>450^a</td>
<td>1000/5 min. in any 2 hrs.</td>
</tr>
</tbody>
</table>

Chloride

<table>
<thead>
<tr>
<th>Chlorinated Solvent</th>
<th>OSHA TWA*</th>
<th>ACGIH TLV</th>
<th>ACC^2</th>
<th>AMP^3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene</td>
<td>500</td>
<td>100</td>
<td>1000</td>
<td>2000/5 min. in any 2 hrs.</td>
</tr>
</tbody>
</table>

a. No limits established by OSHA. ACGIH recommends a short term exposure limit (STEL) of 450 ppm.

(1) TWA—Time Weighted Average
(2) ACGIH—American Conference of Governmental Hygienists
(3) ACC—Acceptable Ceiling Concentration
(4) AMP—Acceptable Maximum Peak

6.4 First Aid

6.4.1 Eye Contact Rinse eyes with running water for at least 30 minutes. Prompt medical attention is essential.

6.4.2 Skin Contact Flush the area thoroughly with water. Wash clothing before reusing it.

6.4.3 Oral Ingestion DO NOT INDUCE VOMITING. Call a physician or transport the worker to an emergency facility.

6.4.4 Inhalation Remove the worker to fresh air if the worker starts feeling dizzy or light-headed. Contact a physician or transport the worker to a medical facility. If breathing stops, give mouth-to-mouth resuscitation. Administer oxygen when breathing starts (see 6.3.2 for chlorinated solvent exposure limits).

6.4.5 Additional Help For any additional chemical related medical help, call Chemtree Emergency at 800) 424-9000. In Canada call (collect) Canutel (613) 996-6666.

6.5 All equipment and chemicals used were purchased from Van Waters and Rogers standard lab supply catalog.

6.6 This test is designed for the base chlorocarbons only; therefore, discretion should be used when testing bipolar solvents.

6.7 Specific Questions Any specific questions can be referred to Dow Chemical U.S.A., Inorganic Chemicals Department, Technical Service and Development, Midland, Mich. 48640.
1 Scope  The purpose of the two test methods is to provide means for determining the volatile content of adhesive coated dielectric films used in the manufacture of flexible printed wiring. Method A is a weight loss procedure. Method B is a headspace gas chromatography procedure.

2 Applicable Documents  None

3 Test Specimen

3.1 Method A  The test specimens shall be squares of adhesive coated dielectric film. The specimens shall be 10 cm x 10 cm. This method is to be used for non-aqueous solvent systems only.

3.2 Method B  Three specimens shall be prepared: One specimen shall be cut from the center of the material and one each from each edge of the material. Specimens shall be cut no closer than 25.4 mm from the edge of the material.

4 Equipment/Apparatus

4.1 Method A

4.1.1 Analytical Balance  Analytical balance capable of weighing to the nearest milligram (0.001 gram).

4.1.2 Test Chamber  Circulating air oven maintained at 150°C ± 2.8°C.

4.2 Method B1

4.2.1 Analytical Balance  Analytical balance capable of weighing to the nearest 0.1 milligram (0.0001 gram).

4.2.2 Sample Vials  It is essential that the septa are placed with the Teflon® side toward the sample and that the vials are sealed tightly enough that it is not possible to turn the lid by hand.

4.2.3 Test Device  A gas chromatograph fitted with a Headspace Sampler and a data acquisition/manipulation system capable of recording and quantitating gas chromatograms.

4.2.4 Chromatography Conditions

- Tenax column 6.35 mm O.D. 1.8 m long.
- Injector temperature: Product dependent
- Oven temperature: Product dependent
- Isothermal
- Flame Ionization Detector:
  - Carrier gas is Nitrogen at kg/cm²
  - Adjust equipment conditions for specific product being tested.

4.2.5 Headspace Conditions  Temperature and dwell time dependent on product tested.

5 Procedure Method A

5.1 Preparation

5.1.1 Condition each specimen at 50% ± 5% relative humidity (RH) and 23°C ± 2°C for a minimum of three hours.

5.1.2 Weigh each specimen to the nearest milligram (0.001 gram) \([W_1]\).

5.1.3 Subtract out substrate weight by calculating the area x the density of the substrate under test \([W_s]\).

5.1.4 Hang each specimen from a metal hook in the circulating air oven at 150°C ± 2.8°C for 15 ± 1 minutes.

5.1.5 Remove each specimen from the chamber and place in a stabilization environment of 50% ± 5% RH and 23°C ± 2°C for a minimum of three hours.

5.1.6 Reweigh each specimen to the nearest milligram \([W_f]\).

5.1.7 Subtract out substrate weight by calculating the area x the density of the substrate under test \([W_s]\).
5.1.2 Evaluation  The volatile content of each specimen is calculated as follows:

\[
\text{Volatile Content (\%)} = \frac{(W_I - W_S)(W_F - W_S)}{(W_I - W_S)} \times 100
\]

5.1.3 Report  The results should be documented and contain the following:

1. Certification that the test was performed in accordance with this test method.
2. Identification of specimens tested.
3. Volatile content % for each specimen tested and the average.

Procedure Method B

5.2 Calibration

5.2.1 Prepare two liquid calibration mixtures as directed per vendor instructions. The mixtures do not need to have these exact amounts but the amount of each ingredient should be measured precisely to within 0.0002 grams. The mixture should be stored in a suitable container with a resealable septa lid. Calibration mixtures should be appropriate for volatiles present in product tested.

5.2.1.2 Make sure the mixtures are each well mixed, then determine the density of the mixtures by any acceptable method.

5.2.1.3 From each of the mixtures inject a minimum of four different amounts (0.5 to 3.0 microliters each) into separate, previously prepared, empty, sealed vials.

5.2.1.4 Allow each vial to equilibrate in the headspace unit, then inject each into the chromatography column and obtain an area for each sample.

5.2.1.5 Plot the areas vs. the amount (in milligrams) of each ingredient. The eight points should all lie on the same straight line.

5.2.1.6 Determine the response factor Rf (milligrams/area unit) for each ingredient. If the plot above is not linear or does not pass through the origin, then it might be necessary to have different Rf at different amounts.

5.2.2 Sample

5.2.2.1 Cut and weigh a 25.4 mm square sample of material to be tested. Place into sample vial and seal tightly. Equilibrate sample in the headspace unit and then inject onto the chromatography column. Allow the chromatogram to run for eight minutes.

Note 1: Appropriate time and temperature dependent on product tested.

5.2.2.2 Calculate the amount of each calibrated peak using the following equation.

\[
\text{Volatile \% (i)} = \frac{(\text{Area (i)} \times \text{Rf (i)} \times 100)}{(\text{Wt} \times F)}
\]

where:

- Area (i) = area generated for ith calibrated peak
- Rf (i) = response factor for ith peak
- Wa = weight of sample (not including substrate—subtract out substrate weight by calculating the area x the density of the substrate under test (Ws) and subtracting the value from the total sample weight (Wt). Wt – Ws = Wa)
- F = fraction of ingredient in film that reaches the chromatography relative to the same fraction of pure liquid.

5.2.3 Determination of F

5.2.3.1 Determination of F\_liq  Prepare a mixture of ingredients to be tested. Inject 1 to 2 microliters of the mixture into a sealed vial. Equilibrate in the headspace unit, then inject into the chromatograph and obtain the area for each peak of interest.

5.2.3.1.1 Immediately after the injection is complete, vent the vial by means of a small syringe needle and replace the vial to allow it to equilibrate again. Again after equilibration inject the vial into the chromatograph.

5.2.3.1.2 Vent the vial a second time and equilibrate and inject again. There should have been three injections, each preceded by an equilibration and two ventings, one immediately after the first injection and the other immediately after the second injection.

5.2.3.1.3 Calculate F\_ret\_liq and F\_liq for each ingredient as follows.

\[
\text{F\_ret\_liq} = \frac{\text{square root (area3/area2)} + \text{area2/area1}}{2}
\]

\[
\text{F\_liq} = 1 - \text{F\_ret\_liq}
\]
5.2.3.2 Determination of F__film  
Prepare a film sample in a vial as standard. Make three injections with venting between injections and equilibration before each one, just as in the case of the liquid. The F__ret__film and F__film are calculated in exactly the same way as F__ret__liq and F__film, except that the areas used are generated by the film sample.

5.2.3.3  F__liq and F__film are determined at least eight times, preferably over a period of several days. Approximately the same number of liquids as films are tested each day. The values of F__liq and F__film are averaged separately.

5.2.3.5  Once determined, F should not change unless the ingredients change or unless the equilibrium conditions change.

5.2.3.6  Different materials will have different values of F.

6 Notes
1.0 Scope  This test method is for use in determining if organic, non-ionic contaminants are present on bare printed wiring board, and completed assembly surfaces in the production area by limited technical personnel. Although the test fluid is also capable of dissolving very small amounts of various inorganic compounds, their presence would generally be masked by the much higher levels of the organic contaminants.

1.2 The test will neither identify the contaminants present nor separate contaminant mixtures into the individual constituents (see Test Method 2.3.39). The present visual limit of organic contaminant detection by this method is approximately 10 micrograms/cm².

2.0 Applicable Documents


IPC-TM-650 Test Method 2.3.39, Surface Organic Contamination Identification Test (Laboratory Analytical Method.)

3.0 Test Specimens  A bare printed wiring board or test coupon with a surface area of at least 35cm².

4.0 Apparatus or Material

4.1 The test fluid; Spectro or High Pressure Liquid Chromatography (HPLC) grade acetonitrile. Other appropriate solvents may be used as agreed upon by user and vendor.

4.2 Microscope slides, 25 mm x 75 mm, glass.

4.3 Disposable glass medicine dropper with rubber squeeze bulb.

4.4 60 ml (2 oz.) capacity rubber squeeze bulb fitted with glass medicine dropper tube.

4.5 Lint free gloves.

5.0 Procedure

5.1 Preparation

5.1.1 Pre-clean microscope slide by rinsing the slide with test fluid, drying it as described in paragraph 5.2, and establishing that it is free from residues as described in paragraph 5.4.

5.1.2 Hold the test specimen by the edges at an angle above the pre-cleaned microscope slide. The specimen should not touch the slide.

5.2 Test

5.2.1 Slowly drip 0.25 to 0.50 ml of test fluid onto the test specimen, allowing it to wash across a small area of the surface of the specimen and drip onto the microscope slide. Do not allow medicine dropper to touch test specimen. See Figure 1.

5.2.2 Evaporate the test fluid with a gentle stream of dry, oil-free air or nitrogen in a well-ventilated fume hood. If the compressed air or nitrogen specified above is not available, a gentle air stream may be generated using a large rubber squeeze bulb and glass tube.

5.2.3 Rapid evaporation of the test fluid must be avoided, to prevent evaporative cooling of the glass slide and subsequent moisture condensation from the air onto the slide.

5.2.4 Application of sufficient heat to evaporate the water may volatize part or all of the residue and invalidate the results.
5.2.5 Repeat until $3 \pm 0.5$ ml of test fluid washings per 10cm$^2$ of washed specimen surface area have been accumulated on the slide.

5.3 Control Slide

5.3.1 Dispense the same quantity of test fluid onto a duplicate pre-cleaned microscope slide and allow to evaporate.

5.3.2 Examine the slide as described in paragraph 5.4. No residue should be seen.

5.3.3 If residues are seen, the test fluid is not pure enough to use in this test.

5.3.4 A faint outline of the test fluid may be seen on the slide. This does not necessarily indicate the presence of contamination.

5.4 Evaluation

5.4.1 Hold the test slide on the edges and tilt so over-head incident light is reflected from the surface. The residues (if present) washed from the test specimen will be readily visible.

6.0 Notes

6.1 Test fluid from Fisher Scientific Co. (FSC19C). High Pressure Liquid Chromatography (HPLC) grade acetonitrile was used to develop this test method. Equivalent material from other suppliers may be used, provided no residue remains after evaporation as described in this test method. (Residue after evaporation is less than 1 part per million.)

6.2 The American Conference of Governmental and Industrial Hygienists has adopted a 40 ppm (v/v) Threshold Limit Value (TLV) for acetonitrile. It is recommended that the application and evaporation of test fluid be carried out in a well-ventilated fume hood. Rubber gloves and safety glasses should be provided for the person(s) running the test.

6.3 Fisher Scientific Co. plain glass microscope slides, catalog number 12549, were used to develop this test. Equivalent slides may be used for testing.

6.4 Fisher Scientific Co. straight medicine droppers, catalog number 13700, were used to develop this test. Equivalent droppers or disposable pipettes may be used.

6.5 Fisher Scientific Co. 60 ml (2 oz.) capacity rubber squeeze bulbs, catalog number 14070D (or equivalent), are suitable for this use when fitted with a straight glass medicine dropper.

6.6 The actual identification of the contaminant(s) may be accomplished using IPC Test Method 2.3.39. If identification is to be performed, the specimen can be transferred to an Infrared Analysis plate. See paragraph 5.3.1 of IPC Test Method 2.3.39.
1.0 Scope

1.1 This infrared spectrophotometric analysis test method is for use in identifying the nature of non-ionic organic contaminants present on printed wiring board surfaces or on the contaminated microscope slide used in the solvent extraction procedure defined in IPC-TM-650, Test Method 2.3.38, by use of the Multiple Internal Reflectance (MIR) Method. This test should be performed only by an experienced spectroscopist.

2.0 Applicable Documents

IPC-TP-383 Organic Surface Contamination—Its Identification, Characterization, Removal, Effects on Insulation Resistance and Conformal Coating Adhesion

IPC-TM-650 Test Method 2.3.38, Surface Organic Contaminant Detection Test (In-House Method)

IPC-TM-650 Test Method 2.3.42, Identification of Solder Mask Products Using Fourier Transform Infrared Spectroscopy (FTIR)

3.0 Test Specimens

3.1 A bare printed wiring board or test coupon with a surface area of at least 35 cm².

3.2 The contaminated microscope slide used in the solvent extraction procedure defined in IPC-TM-650, Test Method 2.3.38.

4.0 Apparatus & Materials

4.1 An infrared spectrophotometer capable of scanning the from 2.5 micron to at least 15 micron range.

4.2 A multiple internal reflectance (MIR) attachment with a KRS-5 or ZnSe plate. Other techniques such as Attenuated Total Reflectance (ATR) or reflection absorption using micro FTIR can be used in lieu of the MIR techniques. (See 6.10)

4.3 The test fluid is Spectro or High Pressure Liquid Chromatography (HPLC) grade acetonitrile. Other appropriate solvents may be used as agreed upon by user and vendor.

4.4 Disposable glass medicine dropper with rubber squeeze bulb or 2 ml capacity glass syringe.

5.0 Procedure

5.1 Clean an MIR plate by moistening a soft tissue with test fluid, then gently wiping the surface of the plate until all residues have been removed. Since the KRS-5 plate scratches easily, stubborn stains may be removed by ultrasonic cleaning in acetone.

5.2 Obtain the contaminated microscope slide specimen prepared in Test Method 2.3.38, or the printed board specimen.

5.3 Test Hold the test specimen by the edges at an angle above the clean MIR plate. The specimen should not touch the plate.

5.3.1 Transfer the residue from the test specimen. Slowly drip 0.25-0.50 ml. of test fluid onto the contaminated test specimen, allowing it to wash across the surface and drip onto the MIR plate. (See Figure 1)

5.3.2 Evaporate the test fluid with a gentle stream of dry, oil-free air or nitrogen in a well-ventilated fume hood.

Figure 1 Contaminant Transfer to MIR Plate

 IPC-2339-01
5.3.3 Place the MIR plate in the MIR attachment. Generate an infrared spectrum of the residue according to the instrument manufacturer’s recommended procedure. Remove and clean the MIR plate.

5.4 Evaporate the same amount of test fluid on clean MIR plate to obtain a control specimen.

5.5 Evaluation

5.5.1 Compare the test and control spectra for evidence of organic contamination.

5.5.2 The chemical class for the contaminant may be determined from the major bands in the spectrum in Table 1.

5.5.3 See Figures 3 and 4, comparative examples of spectrum graphics.

6.0 Notes

6.1 A Perkin Elmer Model 283 infrared Spectrophotometer was used to develop this test method. Equivalent instruments from other manufacturers should be satisfactory if they have provision for a multiple internal reflectance (MIR) attachment.

6.2 This test may also be performed using IPC-TM-650, Test Method 2.3.42, “Identification of Solder Mask Products Using Fourier Transform Infrared Spectroscopy (FTIR)”.

6.3 The test fluid Fisher Scientific Co. High Pressure Liquid Chromatography (HPLC) grade acetonitrile was used to develop this test method. Equivalent material from other suppliers may be used, provided no residue remains after evaporation as described in this test method. Other solvents may be required to dissolve specific residues.

6.4 Fisher Scientific Co. straight medicine droppers, catalog number 13-700, were used to develop this test. Equivalent droppers or disposable pipettes may be used.

6.5 The American Conference of Governmental and Industrial Hygienists has adopted a 40 ppm (v/v) Threshold Limit Value (TLV) for acetonitrile. It is recommended that the application and evaporation of acetonitrile be carried out in a well-ventilated fume hood. Rubber gloves and safety glasses should be provided for person(s) running the test.

6.6 Modified procedures permit detection and identification of contaminants residues containing carboxylic acid, carboxylic acid salts, ester, hydroxyl, amide, or nitrile (cyano) functional groups. For example, dicyandiamide (“dicy”), dehydroabietic acid, unpolymerized bisphenol-A type epoxy resins, rosin and long chain amides have also been identified on printed wiring surfaces.

6.7 Although the test fluid is also capable of dissolving very small amounts of various inorganic compounds, their presence would generally be masked by the much higher levels of the organic contaminants.
6.8 Rapid evaporation of the acetonitrile must be avoided to prevent evaporative cooling of the MIR plate and subsequent moisture condensation from the air onto the plate. Application of sufficient heat to evaporate the water may volatilize part or all of the residue and invalidate the results. The present limit of detection of arylalkyl polyether residues by this method is 10 micrograms/cm².

6.9 The maximum organic surface contamination levels that will still permit reliable end-use operation of printed wiring assemblies of differing component densities and conductor line spacings have not been established for the various contaminants.

6.10 The present limit of detection can be easily extended by an order of magnitude using more sophisticated instrumentation and computer enhanced spectra. (See Figures 3 and 4)

6.11 The KRS-5 plate is very toxic; it should be handled only with gloved hands, and should be polished with recommended polishing compound to minimize generation of hazardous dust.
Figure 4 Typical Spectrum Comparison
1.0 Scope  This test method establishes a procedure for determining the thermal decomposition temperature of organic films using thermogravimetric analysis (TGA).

2.0 Applicable Documents
ASTM D 618  Standard Practice for Conditioning Plastics and Electrical Insulating Materials for Testing
ASTM D 3850  Standard Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials by Thermogravimetric Analysis

3.0 Test Specimen  The free films are cut to fit into the TGA sample pan giving an initial weight of nominally 2-20 mg.

4.0 Apparatus or Material  Thermal gravimetric analysis equipment equipped with air, nitrogen purge, capable of maintaining 5°C heating rate from ambient to 800°C, such as TA Instruments or Perkin Elmer TGA instruments.

5.0 Procedure
5.1 The test specimens should be conditioned at 23 ± 2°C and 50 ± 5% relative humidity for not less than 24 hours prior to testing. Refer to ASTM D 618 and ASTM D 3850.

5.2 Follow the manufacturer’s recommendations for equipment startup and calibration.

5.3 Set the dry nitrogen purge rate at 55 cc/min.

5.4 Allow the instrument to purge for 30 min.

5.5 Heat at a rate of 5°C/min from ambient to 150°C.

5.6 Hold the temperature for 15 min to remove any moisture from the specimen.

5.7 Heat at a rate of 5°C/min to 800°C.

5.8 Record the temperature at which 5% additional weight loss occurs based on the weight after the 150°C hold.

5.9 Repeat steps 5.3-5.6 with dry air instead of nitrogen using a new sample.

5.10 Report the thermal decomposition temperature, T_{max}, in degrees Celsius (°C), followed by the evaluation criteria (e.g., 5% wt. loss), and the atmosphere under which the test was conducted (e.g., nitrogen), e.g. 185°C (5% wt. loss, nitrogen).

6.0 Notes
6.1 Calibration of the instrument must be carried out according to the manufacturer’s recommendations. The rate of flow of the gas in the cell will have a significant effect on the calibration, therefore the instrument must be calibrated with the same flow rate used during the test. After the instrument has been calibrated, the flow rate should not be changed.

6.2 The surface area of the test specimen will affect the results. If two specimens of the same material are tested, one with a large surface area and one with a small surface area, both of the same mass, the specimen with the smaller surface area will normally lose weight at a slower rate.

6.3 The specimen may initially gain weight due to buoyancy effects.
1.0 Scope  This test method uses pressure sensitive tape to
determine the adhesion quality of platings, marking inks or
paints, and other materials used in conjunction with Printed
Boards.

2.0 Applicable Documents

Commercial Item Description (CID) A-A-113  Tape, Pres-
sure Sensitive, Adhesive.

3.0 Test Specimens  Any preproduction, first article, or
production printed board. A minimum of three tests should be
performed for each evaluation.

4.0 Apparatus or Material

4.1 Tape  A roll of pressure sensitive tape 3M Brand 600
1/2 inch wide or a tape as described in (CID AA-113), Type 1,
Class B, except that the tape may be clear.

5.0 Procedure

5.1 Test  Press a strip of pressure sensitive tape, 50mm
[2.0 in] minimum in length, firmly across the surface of the test
area removing all air entrapment. The time between applica-
tion and removal of tape shall be less than 1 minute. Remove
the tape by a rapid pull force applied approximately perpen-
dicular (right angle) to the test area. An unused strip of tape
must be used for each test.

5.2 Evaluation  Visually examine tape and test area for evi-
dence of any portion of the material tested having been
removed from the specimen.

5.3 Report  The report should note any evidence of material
removed by this test.

6.0 Notes

6.1 If plating overhang breaks off (slivers) and adheres to the
tape, it is evidence of overhang but not an adhesion failure.

6.2 If foreign material (oil, grease, etc.) is present on the test
surface the results may be affected.
1 Scope  This test method is used to determine the adhesion quality of marking paints and inks on the laminate surface and/or metal surfaces of finished PWBs.

2 Applicable Documents


3 Test specimen

3.1 Any finished PWB having the marking under test applied to its surface. A minimum of three tests should be performed for each evaluation.

4 Equipment/Apparatus

4.1 Tape  A roll of pressure sensitive tape 3M Brand 600 13 mm wide, or a tape as described in CEDAA-1 13, Type 1 Class 3, except that the tape may be clear

5 Procedure

5.1 Test

5.1.1 Press a strip of pressure sensitive tape 13 mm wide and 5 cm long firmly across the surface of the board, covering the marking on both the laminate and metal conductors.

5.1.2 Rapidly remove the tape by manual force applied approximately perpendicular to the markings and board surface. Fresh tape must be used each time.

5.2 Evaluation

5.2.1 Visually examine the tape and specimen for evidence of any portion of the markings having come off the surface of the board, as evidenced by particles of markings adhering to the tape.

6 Notes

6.1 Failure of the marking to properly adhere to either the laminate or metal conductors constitutes a failure of the test.
1.0 Scope
This method is to determine the adhesion or bonding quality of conductors on hybrid substrates.

2.0 Applicable Documents
None

3.0 Test Samples
Test samples shall be x thickness 25.4 mm x 25.4 mm [1 in x 1 in] on which the conductor test pattern is applied. Sufficient samples should be made to provide at least 15 data points. Measuring bond strength of three conductor lands on each of five substrates will provide the required data points.

4.0 Apparatus

4.1 Equipment
A power-driven test machine with fixed and movable gripping devices and an instrument for recording maximum tensile force shall be used. The movable gripping device should travel at a uniform rate of 1.2 cm [0.5 in]/minute. The range of the recording instrument should be such that adhesion values will always be between 15 and 85% of rated capacity.

4.2 Lead wires
AWG #20 gauge tinned copper wire 0.081 cm [0.032 in] diameter. The wire should be free of oil, grease and tarnish.

5.0 Test

5.1 Preparation

5.1.1 Soldering the Lead Wire
A lead wire is placed across the surface of each column of conductor lands as shown in Figure 1. The end of the wire should be bent around the edge of the substrate to hold the wire in place temporarily until the solder boards are formed.

5.1.2 The sample is fluxed, preheated and soldered using standard soldering techniques. One method is to immerse the samples into molten solder for 5 to 10 seconds.

5.1.3 Bending the Wire Leads
Carefully place a straight-edge rule across the lead wire in line with the first row of wire bend marks in the test pattern. Bend one wire to a position perpendicular with the surface of the substrate 1.25 mm [0.050 in] from the edge of the conductor land (Figure 2).

IPA-24-1-2-1

Figure 1

IPA-2-4-1-2-2

Figure 2
After each wire is pulled the bending procedure is repeated with the next lead wire.

5.2 Procedure

5.2.1 Measuring Adhesion  Mount substrate in the stationary gripping fixture of the test machine.

5.2.2 Attach wire to the movable gripping fixture and turn on the machine.

5.2.3 After the bond failure, stop gripping fixture. Remove specimen and return fixture to its starting position.

5.2.4 The bending and measuring processes are repeated with the next wire. The practice is to measure bond strength of only one conductor land in each column; more may be measured if care is taken to avoid stressing neighboring conductor lands in a column.

5.3 Evaluation  The conductor square area should be examined with 10x to 30x magnification to determine failure mode. Each conductor land shall be classified into one of the following categories:

A. Failure at the conductor-substrate interface. Small amounts of conductor film may remain on the substrate surface. That provides a true measurement of conductor adhesion to the substrate.

B. Failure at the solder-conductor interface. That may indicate that the solder has not wet the conductor surface adequately.

C. Failure between the wire and the solder fillet.

5.4 Data Analysis  Average adhesion value, $\bar{x}$, standard deviation and coefficient of variation, $cv$, are calculated for n data points as follows:

$$\bar{x} = \frac{X_1 + X_2 + \cdots + X_n}{n} \text{ Newtons}$$

$$\sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2} \text{ Newtons}$$

$$cv = \frac{100 \sigma}{\bar{x}} \%$$
1.0 Scope  This test method is to determine the adhesion quality of resistive and capacitive materials on the substrate surface of finished hybrid circuits.


3.0 Test Specimen

3.1 Any finished hybrid circuit having the resistor under test applied to its surface. A minimum of three tests should be performed for each evaluation.

4.0 Apparatus

4.1 Tape  12.7 mm [1/2 inch] wide roll pressure sensitive tape (3m brand 600 transparent tape or equivalent per CID - AA113B Type 1; Class B)

5.0 Procedure

5.1 Test

5.1.1 Press a strip of pressure sensitive tape 12.7 mm [1/2 inch] wide and 2 inches long firmly across the surface of the board covering marking on both the laminate and metal conductors.

5.1.2 Rapidly move the tape by manual force applied approximately perpendicular to the markings and board surface. Fresh tape must be used each time.

5.2 Evaluation

5.2.1 Visually examine the tape and specimen for evidence of any portion of the resistor having come off the surface of the hybrid circuit as evidenced by particles of resistors adhering to the tape.

6.0 Note

6.1 Failure of the resistive material to properly adhere to the ceramic substrate constitutes failure of the test.
1.0 Scope  This test method is to determine the adhesion quality of overglaze materials on the substrate surface of finished hybrid circuits.


3.0 Test Specimen

3.1 Any finished hybrid circuit having the overglaze under test applied to its surface. A minimum of three tests should be performed for each evaluation.

4.0 Apparatus

4.1 Tape 12.7 mm [1/2 inch] roll pressure sensitive (3m brand 300) transparent tape or equivalent per CID - AA113B Type 1; Class B) General Service Administration approved Commercial Item Description (CID) Standard AA113B, “Tape Pressure Sensitive Adhesive”, FSC 7510-551-982.

5.0 Procedure

5.1 Test

5.1.1 Press a strip of pressure sensitive tape 12.7 mm [1/2 inch] wide and 50.8 mm [2 inch] long firmly across the surface of the board covering the marking on both the laminate and metal conductors.

5.1.2 Rapidly move the tape by manual force applied approximately perpendicular to the markings and board surface. Fresh tape must be used each time.

5.2 Evaluation

5.2.1 Visually examine the tape and specimen for evidence of any portion of the overglaze having come off the surface of the hybrid circuit as evidenced by particles of overglaze adhering to the tape.

6.0 Note  Failure of the overglaze to properly adhere to the ceramic substrate constitutes failure of the test.
1.0 SCOPE

1.1 This procedure describes three methods to determine the level of treatment transfer for treated copper foil.

2.0 APPLICABLE DOCUMENTS


ANSI/IPC-CF-152 “Composite Foil Specification,” current revision

3.0 DEFINITION

3.1 Treatment An electro-mechanical or chemical process applied to one or both sides of copper foil to enhance the adhesion of the foil to the base laminate.

3.2 Treatment Transfer Any visible bond enhancement that has transferred from the surface of the copper foil to the laminate substrate.

4.0 EQUIPMENT

4.1 For the Tape Transfer method a sample of the foil to tested 152 mm x 152 mm.

4.1.1 3M Scotch Brand #600 Tape 19 mm wide.

4.2 For the Strip Transfer method a representative sample of foil, pressed to four plies of 7628 FR-4 prepreg to produce a 0.028 ml laminate, or as agreed upon by user and supplier.

4.2.1 Etching system capable of removing copper foil from base laminate.

4.3 For the Weight and Filter Paper method a sample of treated foil at least 203 mm x 51 mm.

4.3.1 #2 Filter Paper strips at least 76 mm x 25 mm.

4.3.2 A standardized weight of 250 grams with a 3/4 inch surface

4.4 Visual Acceptance Standards

4.5 White Background

5.0 TEST PROCEDURE

5.1 Tape Transfer Method

5.1.1 Each copper sample being tested will have tape 19 mm x 102 mm applied to the treatment side in the machine direction of the foil. The tape should be firmly applied by hand.

5.1.2 Remove the tape by quickly pulling on one end at an acute angle.

5.1.3 The tape should then be reaffixed, adhesive side down on standard white paper.

5.2 Strip Transfer Method.

5.2.1 Image a line on the laminate to a minimum of 1/8 inch wide.

5.2.2 Etch, clean and process using standard industry practices and equipment. If preferred, a cut or sheared sample may be used.

5.2.3 Pull the strip of foil back 1 inch to expose the area directly under the foil.

5.2.4 Visually examine this area by placing the laminate strip against a white background and comparing the amount of transfer with the standard.

5.3 Weight and Filter and Paper Method

5.3.1 Place the copper foil sample on a firm, flat surface with the treatment side up.

5.3.2 Place the #2 filter paper on the copper foil sample with the rougher side of the paper against the foil.
5.3.3 Place the proper surface of the weight on the filter paper.

5.3.4 Grasping one end of the filter paper, pull the paper and the weight across the surface of the foil (going in the transverse direction, across the grain) for a distance of 6".

6.0 EVALUATION

6.1 The specimen is evaluated for treatment transfer as follows:

1. No transfer
2. Very slight transfer
3. Slight transfer
4. Transfer

6.2 The grading scheme listed above will be based on visual comparison of an acceptance standard agreed upon by user and supplier.
1.0 Scope  This test method establishes a procedure for
determining whether the adhesion of a polymer coating to an
inorganic or ceramic substrate is above an adequate level.
The substrate may or may not have an oxide layer on the sur-
face. The test can be inverted and used for determining the
adhesion of a metal coating to a polymer film.

2.0 Applicable Documents
ASTM D 3330  Test Method for Peel Adhesion of Pressure-
Sensitive Tape of 180° Angle
ASTM D 3359  Standard Test Methods for Measuring Adhe-
sion by Tape Test

3.0 Test Specimen  The test specimen shall consist of the
coated substrate. A control should also be prepared using a
mutually agreed upon material whose results from this test are
known, preferably a material with an adhesion classification of
5. At least 3 test specimens should be prepared for each
material of interest.

4.0 Apparatus or Material
4.1 25 mm [1.0 in] wide semitransparent pressure sensitive
tape with an adhesion strength of 43 ± 6 g/mm [38 ± 5 oz/in].
The adhesion should not change more than 6.5% of its mean
value within 12 months. 3M Scotch brand #600 tape has
been found to be acceptable for this test.

4.2 Rubber eraser on end of pencil.

4.3 A light source is helpful in determining if the cut has
been made all the way through the polymer to the substrate.

4.4 A closed boiling water bath.

5.0 Procedure
5.1 Preparation of test specimen. Refer to ASTM D 3330
and ASTM D 3359.

5.1.1 Prepare and clean the substrate according to the
manufacturer’s recommended procedure.

5.1.2 Prime the surface with the manufacturer’s recom-
mended adhesion promoter, if required.

5.1.3 Apply a 10 µm to 25 µm (measured after processing
is complete) coating onto the surface of the substrate using
the manufacturer’s recommended procedure.

5.2 Pattern Coating  The coating should be patterned
according to the procedures outlined in section 4.2.5 of IPC-
DD-135. The pattern consists of a 10 x 10 grid of 1 mm x 1
mm squares separated by 100 µm wide lines or pattern fea-
tures, as illustrated in Figure 1. At least two complete grids
must be patterned on the specimen, one for the initial test and
one for the 3 hour test.

5.3 Test
5.3.1 Remove two complete laps of tape and discard.
Remove an additional length at a steady (not jerked) rate and
cut a piece approximately 75 mm [3.0 in] long.

5.3.2 Place the center of the tape over one of the grid pat-
terns and smooth into place by a finger. Rub the tape firmly
with the eraser on the end of the pencil to ensure good con-
tact between the tape and the film. The color under the tape
is a good indicator of contact between the tape and the film.

![Figure 1](2.4.1.6-01)
5.3.3 Within 90 seconds of applying the tape, remove the tape with a steady motion by pulling at a 180° angle.

5.3.4 Inspect the lattice pattern under illumination for removal of coating from the substrate. Rate the adhesion in accordance with the following scale illustrated in Figure 2:

- **5** The edges of the line patterns are completely smooth; none of the squares of the lattice are detached.
- **4** Small flakes of the coating are detached at the intersection of the lattice; less than 5% of the area is affected.
- **3** Small flakes of the coating are detached along the edges and at intersections of the lattice. The area affected is 5 to 15% of the lattice.
- **2** The coating has flaked along the edges and on parts of the squares. The area affected is 15 to 35% of the lattice.
- **1** The coating has flaked along the edges of the line patterns in long ribbons and whole squares have detached. The area affected is 35 to 65% of the lattice.
- **0** Greater than 65% of the lattice has detached.

5.3.5 Place the test specimens in a boiling water bath and stress the samples for 3 hours. The water in the boiling water bath must completely cover the test specimens for the entire 3 hours. A closed system that returns the steam as condensation is preferred.

5.3.6 Remove the test specimens from the boiling water bath or environmental chamber and allow to cool to room temperature.

5.3.7 Wipe sample dry. Repeat steps 5.3.1-5.3.4 on the second (unused) grid pattern.

5.3.8 Report adhesion results for both the initial and 3 hour tests.

6.0 Notes None
1 Scope  Ductility values are determined by measuring the bulge height on a Mullen bulge tester or equivalent. Measurements are made in mm.

2 Applicable Documents  None

3 Test Specimen  Three clean, smooth pieces of copper foil 10 cm x 10 cm area or any non-overlapping equivalent areas.

4 Apparatus  Mullens Bulge Tester by B. F. Perkins & Son, Inc., Model A to be 10 RPM at large shaft between gear box and diaphragm, or equivalent.

5 Procedure

5.1 Preparation  Raise upper clamping ring by rotating the hand wheel. Place a 10 cm x 10 cm by 0.15 mm thick steel plate that is perfectly flat over the diaphragm and lower the upper clamping ring applying sufficient pressure to prevent slippage. Zero the dial indicator. Raise the upper clamping ring and remove the 10 cm x 10 cm by 0.15 mm steel plate.

NOTE: The above operation should be done once every eight-hour shift.

Start the motor and move the ball-handled control lever to the right to be certain that the diaphragm is returned to its starting position.

5.2 Test

5.2.1 Place a sample of the copper foil to be tested over the diaphragm with the matte side up.

5.2.2 Lower the clamping ring, applying sufficient pressure to prevent slippage of the sample between the plates.

5.2.3 Move the ball-handled control lever to the left. The operator should keep his hand on the lever in readiness to stop or reverse the machine at any time during the test and when the test is complete. During the test, the operator should be watching the dial indicator and, at the instant bursting occurs, should note the reading on the dial indicator and the ball-handled control lever should be moved as far to the right as it will go and be released. This will return the diaphragm to its starting position and automatically shut off the pump.

5.3 Evaluation

5.3.1 Record the reading from the dial indicator.

5.3.2 Rotate the hand wheel to raise the clamping ring and remove the sample. Avoid overlapping of the clamping areas and disregard any single reading that is not reasonably consistent with those taken in neighboring areas, and repeat the test.
1.0 Scope  With this test method the flexural fatigue life for any given bend radius, the flexural fatigue behavior and the ductility in percent deformation after tensile failure can be determined.

Note: The indirect determination of foil 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
Method 2.4.18, Tensile Strength and Elongation, Copper Foils

3.0 Test Specimen  Foil of sufficient size to permit cutting of three 3.2 mm (1/8 inch) wide specimens of at least 50.8 mm (2 inches) in length. Specimens must be clean cut and free of burrs and nicks.

4.0 Apparatus

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

4.2 Sample cutter, punch or tensile cut router. Note 6.4.

4.3 Micrometer tool capable of measurement to the nearest 0.0025 mm (0.0001 inch).

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

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

4.6 Microscope

5.0 Procedure

5.1 Preparation of Samples

5.1.1 The samples should be smooth and undistorted (wrinkle free).

5.1.2 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.

5.1.3 Use the micrometer to determine the specimen thickness, \( t \), in center of each specimen to the nearest 0.0025 mm (0.0001 inch). If one or both specimen surfaces are rough, it is necessary to determine the core thickness, \( t_{\text{M}} \), from a microsection (see Figure 1).

Note: Thickness is a critical parameter in the determination of fatigue ductility. A 10% error in \( t_{\text{M}} \) results in a 14% error in \( D_f \).

Note: The core thickness, \( t_{\text{M}} \), 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 \( t_{\text{M}} \) is to be made once on a batch or lot basis, and this fractional value of \( t_{\text{M}}/t \) is then multiplied by all other micrometer, \( t \), values to achieve core values for all samples.

Note: Care must be taken that during thickness measurements the specimens are not compressed or surface roughness crushed, producing false low thickness readings.

5.1.4 Attach test specimen to the ends of 2 sample holders with adhesive tape and clamp 84 grams (3 ounce) foil weight (not the 8 ounce weight shown in Figure 2) to the free ends of the sample holders to form a loop (See Figure 2).
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 inch] (shim provided) between rollers and mandrels.

Note: For the ductility test, it is important that the specimens fail between 30 and 500 cycles. Mandrels with 2.0 or 1.0 mm [0.079 or 0.040 inch] diameter are suggested but for some samples, mandrel diameters different from these diameters might be necessary. Larger mandrel diameters result in longer cyclic life and smaller diameters in shorter life.

5.2.2 Mount test specimen between mandrels, attach relay leads with alligator clips to foil weight wing nut to form “slip-off” electrical connections, plug relay leads into relay jacks, set counter to zero, and start flex tester.

5.2.3 Complete separation of the foil specimen constitutes failure and the flex tester stops automatically when the dropping foil weight dislodges the alligator clips from the wing nut.

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:

\[
N_f^{-0.6}D_f^{-0.75} + 0.9 \frac{S_u}{E} \left[ \exp(D_f) \right]^{0.36} \left( \frac{10^7}{N_f} \right)^{0.1785 \log_{10} N_f^2} - \frac{2t_M}{2r+h} = 0
\]

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
- \( r \) = mandrel radius of curvature, inch within 0.005 mm [0.0002 inch]

Note: Determine \( S_u \) as per Test Method 2.4.18 of IPC-TM-650. 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 determination of \( E \) foils is not a straightforward procedure. It is therefore suggested that for specification purposes standard values of \( E \) be adopted. For copper foil such standard values might be: \( E(CF-E) = 12 \times 10^6 \) psi for electrodeposited foil, \( E(CF-W) = 16 \times 10^6 \) psi for wrought (rolled) foil.

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 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 mandrels 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 Manon-Coffin plot log \( \Delta \varepsilon = \frac{2t_M}{2r + t} \) 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 mandrel radius can also be obtained by evaluating the ductility formula for the flex life in cycles-to-failure using the fatigue 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 (IPC-TP-204).


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 Tool & Machine Inc., 171 Coit St., Irvington, NJ 07111; 201-374-4400.

6.4.2 JDC Precision Sample Cutter, Model JDC 125-N or equal.
1 Scope To determine the number of flexes to failure of etched flexible printed wiring circuit patterns.

2 Applicable Documents None

3 Test Specimen The test specimen shall consist of an etched conductor pattern in accordance with Figure 1. A minimum of six specimens with the long dimension of the conductors oriented in the transverse direction of the material shall be prepared using standard commercial practices.

For double-sided clad constructions, a separate sample specimen shall be prepared for each side. The opposite (untested) side shall be completely etched of copper.

3.1 The thickness designator in the specification refers to the total thickness of dielectric, copper, and adhesive.

4 Apparatus Flexural Endurance Tester (see Figure 2) or equivalent.

5 Procedure

5.1 Attach a short length of insulated wire to the extreme ends of the conductor pattern of each of the six specimens.

5.2 Using the flexure equipment, Figure 2, mount the specimen so that the inside diameter of the loop is 6.4 mm ± 0.4 mm and connect the two wires to the relay.

5.3 Test three specimens per clad side with the conductor on the inside of the loop. The reciprocating travel should not exceed 10 cycles per minute. The loop shall travel at least 25.4 mm.

5.4 The number of cycles to failure is when discontinuity of the conductor occurs.

5.5 Examine the conductor fracture for evidence of process anomalies (such as pin holes and nicks), which could cause premature fracture. If such anomalies are found, the sample shall be discarded and a new sample tested.

5.6 Report the average number of cycles to failure for the three specimens tested per clad side.

6 Notes Prints of test fixture are available from the IPC office.
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).

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](image)

**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](image)

**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:

\[ N_f^{0.6}D_f^{0.75} + 0.9 \left( \frac{S_u}{E} \right)^{0.1785 \log \left( \frac{10^D}{N_f} \right)} - 2 \frac{t_m}{2} = 0 \]

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
- \( \rho \) = 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 \( D_f \) is kept below 20% if

\[ \left[ \frac{t_m}{t_m - 1} \right]^2 \frac{E_{\text{substrate}}}{E} \leq 0.1 \]

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

**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 \( D_f \) is kept below 20% if

\[ \left[ \frac{t_m}{t_m - 1} \right]^2 \frac{E_{\text{substrate}}}{E} \leq 0.1 \]

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 \( \log \Delta \epsilon = \log \left( \frac{2t_m}{2t + t} \right) \) 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.


6.4 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.
1 Scope With this test method, the flexural fatigue life for any given bend radius, the flexural fatigue behavior, and the ductility of the metal cladding in percent deformation after tensile failure can be determined.

Note: The indirect determination of cladding 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.

Note: Processing may change the original mechanical properties of the conductor metal.

2 Applicable Documents
2.1.1 Microsectioning
2.4.18 Tensile Strength and Elongation, Copper Foil
IPC-D-330 IPC Design Guide

3 Test Specimen Foil/dielectric laminate of sufficient size to permit cutting of three 3.2 mm wide specimens of at least 50.8 mm in length. Specimens must be clean cut and free of burrs and nicks.

4 Equipment/Apparatus
4.1 Ductility Flex Tester, Universal Mfg., Model FDF or 2FDF or equivalent (see 6.4 and Figure 1)
4.2 Sample cutter, punch or tensile cut router (see 6.4.2)
4.3 Micrometer tool capable of measurement to the nearest 0.0025 mm
4.4 Hewlett-Packard, HP-67, Programmable Calculator or equivalent
4.5 Sample holders, 203.2 mm x 12.7 mm, of very flexible material (e.g., epoxy impregnated glass cloth, paper, etc.)
4.6 Microscope – capable of 200X

5 Procedure
5.1 Preparation of Samples
5.1.1 The samples should be smooth and undistorted (wrinkle free).

5.1.2 Use the sample cutter to cut the 3.2 mm-wide test specimen. Examine each specimen for nicks, cuts, or curled edges. Discard any specimen with defects.

5.1.3 Use the micrometer to determine the specimen thickness, t, in the center of each specimen to the nearest 0.0025 mm. In the case of single sided specimens the core thickness, t_M has to be determined also (see Figure 2).

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: The second 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.

5.1.4 Connect all conductors to be tested and monitored in series and attach thin relay leads to the two free ends.

5.1.5 Attach test specimen to the ends of two sample holders with adhesive tape and clamp 224 grams circuit weight to the free ends of the sample holders to form a loop (see Figure 1).

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

5.2 Test Procedure

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

Note: For the ductility test, it is important that the specimens fall between 30 cycles and 500 cycles. Suggested mandrel diameters are 19.05 mm for double-sided laminate and 6.35 mm for single-sided laminate, but for some samples, mandrel diameters different from the above suggested may be necessary. Larger mandrel diameters result in longer cyclic life and smaller diameters in shorter life.

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

5.2.3 Electrical discontinuity constitutes failure; 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:

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

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
- \( \rho \) = mandrel radius of curvature, within 0.005 mm

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

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

IPC-D-330 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.

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 Manon-Coffin plot $\log \Delta \varepsilon = [2t_M/(2t + t)]$ versus $\log N$ allows interpolation and extrapolation to other bend radii or fatigue lives.

6 Notes  For further technical details, reference the material given in 6.1 through 6.3.

6.1 IPC-TP-204  Engelmaier, W., A New Ductility and Flexural Fatigue Test Method for Copper Foil and Flexible Printed Wiring, April, 1978


6.4 Test Equipment Sources  The equipment sources given in 6.4.1 and 6.4.2 represent those currently known to the industry. Users of this test method are urged to submit additional source names as they become available, so this list can be kept as current as possible.

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

6.4.2 JDC Precision Sample Cutter, Model JDC 125-N or equivalent.
1.0 Scope  This test is designed to determine the flexural strength of laminates of thicknesses greater than, or equal to, 0.51 mm [0.020 in] by applying a specific load to a specific size and shaped specimen.

2.0 Applicable Documents


IPC-TM-650

Methods 2.3.6, Etching Ammonium Persulfate
Method 2.3.7, Etching Ferric Chloride
Method 2.3.7.1, Cupric Chloride Etching

3.0 Test Specimens

3.1 Size and Configuration  Dimensions of the specimens shall be as shown in Table 1. Edges of the specimens shall be free of fractures, delamination, or roughness by means of sanding or equivalent means (do not radius the edges.)

3.2 Quantity and Sampling  Unless otherwise specified, four specimens shall be tested, two in the lengthwise and two in the crosswise direction of the sample sheet or panel.

4.0 Apparatus or Material

4.1 Tester  A standard tension and compression test apparatus which can be operated at a constant rate of crosshead movement shown in Table 1. The error in the load measuring system shall not exceed ± 1%. The loading nose and supports shall have cylindrical surfaces. The radius of nose and supports shall be in accordance with ASTM-D-790 (in order to avoid excessive indentation).

4.2 Etching system capable of complete removal of the metallic cladding.

4.3 Measuring devices capable of determining specimen widths to the nearest 0.025 mm [0.001 in] and specimen thickness to the nearest 0.0025 mm [0.0001 in].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 When applicable, chemically etch off all metallic cladding in accordance with standard industry etching practices. For referee purposes, etching shall be in accordance with 2.3.6, 2.3.7, or 2.3.7.1.

5.1.2 Cut specimens to the size as shown in Table 1 and smooth the edges of specimens. Measure and record specimen width to the nearest 0.025 mm [0.001 in] and thickness to the nearest 0.0025 mm [0.0001 in].

5.2 Measurement

5.2.1 Set tester for the required span and crosshead vertical speed as specified in Table 1.

5.2.2 Align the loading nose and supports so that the axis of the cylindrical surfaces are parallel and the loading nose is midway between the supports.

| Table 1 |
|------------------|------------------|------------------|------------------|------------------|
| Specimen Dimensions | Test Parameters |
| Nominal thickness\(^1\) mm [inches] | Width\(^2\) mm [inches] | Length\(^3\) mm [inches] | Span mm [inches] | Speed of testing mm [inches] per min. |
| 0.79 [0.031] | 25.4 [1.0] | 63.5 [2.5] | 15.9 [0.625] | 0.51 [0.020] |
| 1.57 [0.062] | 25.4 [1.0] | 76.2 [3.0] | 25.4 [1.0] | 0.76 [0.030] |
| 2.36 [0.093] | 25.4 [1.0] | 88.9 [3.5] | 38.1 [1.5] | 1.02 [0.040] |
| 3.18 [0.125] | 25.4 [1.0] | 101.6 [4.0] | 50.8 [2.0] | 1.27 [0.050] |
| 6.35 [0.250] | 12.7 [0.5] | 152.4 [6.0] | 101.6 [4.0] | 2.03 [0.080] |

1.) Nominal thicknesses other than those listed shall be prepared and tested in accordance with the next greater nominal thickness.
2.) Width as cut and smoothed to within 5% of nominal shown.
3.) Length as cut (not necessary to smooth) to within 10% of nominal shown.

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5.2.3 Specimens shall be at room temperature. Center the specimen on the supports with the long axis of the specimen perpendicular to the loading nose and supports.

5.2.4 Apply the load at the speed of testing from Table 1 until the specimen breaks. The load at breakage shall be recorded in pounds. (P).

5.3 Calculation and Report

5.3.1 Calculate the flexural strength for each specimen using the formula below:

\[ S = \frac{3PL}{2bd^2} \]

\( S \) = Flexural strength in psi

\( P \) = Load at breaking (pounds)

\( L \) = Span, inch

\( b \) = Width of specimen

\( d \) = Thickness, inch

5.3.2 Average the flexural strengths and record in psi.

5.3.3 Report the specimen thicknesses, individual psi values, and average psi for each direction; note the orientation of the sample panel or sheet associated with the direction of the specimen.

6.0 Notes

6.1 Additional information and background useful to the performance of the test may be found in ASTM-D-790.
1.0 Scope  
This test method is designed to determine the flexural strength of laminates of the thicknesses greater than, or equal to, 0.51 mm [0.020 in] by applying a specific load to a specified sized and shaped specimen at elevated temperature.

2.0 Applicable Documents

ASTM-D-790  Flexural properties of unreinforced and reinforced plastics and electrical and insulating materials.

IPC-TM-650  Method 2.3.6, Etching Ammonium Persulfate  
Method 2.3.7, Etching Ferric Chloride  
Method 2.3.7.1, Cupric Chloride Etching  
Method 2.4.25, Glass Transition Temperature and Cure Factor by DSC

3.0 Test Specimens

3.1 Size and Configuration  
Dimensions of the specimens shall be as shown in Table 1. Edges of the specimens shall be free of fractures, delamination, or roughness by means of sanding or other equivalent means (do not radius the edges).

3.2 Quantity and Sampling  
Unless otherwise specified, four test specimens shall be cut from the lengthwise direction of the sample sheet or panel.

4.0 Apparatus or Material

4.1 Tester  
A standard tension and compression test apparatus, which can be operated at a constant rate of crosshead movement shown in Table 1. The error in the load measuring system shall not exceed ± 1%. The loading nose and supports shall have cylindrical surfaces. The radius of nose and support shall be at least in accordance with ASTM-D-790 (in order to avoid excessive indentation).

4.2 Test chamber designed to shroud the specimens, test jaws and movable shafts as an integral part of the tester, or equivalent. Chambers must be capable of maintaining the test temperature as shown in Table 2 to within ± 3°C [5.4°F].

4.3 Etching system capable of complete removal of metallic cladding.

4.4 Measuring devices capable of measuring specimen width to the nearest 0.025 mm [0.001 in] and specimen thickness to the nearest 0.0025 mm [0.0001 in].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 When applicable, etch off all metallic cladding in accordance with accepted industry practices. For referee testing, etching shall be in accordance with 2.3.6, 2.3.7, or 2.3.7.1

5.1.2 Cut specimens to the size as shown in Table 1 and smooth the edges of specimens. Measure and record specimen width to the nearest 0.025 mm [0.001 in] and specimen thickness to the nearest 0.0025 mm [0.0001 in].

Table 1

<table>
<thead>
<tr>
<th>Specimen Dimensions</th>
<th>Test Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal thickness 1 mm [inches]</td>
<td>Width 2 mm [inches]</td>
</tr>
<tr>
<td>0.79 [0.031]</td>
<td>25.4 [1.0]</td>
</tr>
<tr>
<td>1.57 [0.062]</td>
<td>25.4 [1.0]</td>
</tr>
<tr>
<td>2.36 [0.093]</td>
<td>25.4 [1.0]</td>
</tr>
<tr>
<td>3.18 [0.125]</td>
<td>25.4 [1.0]</td>
</tr>
<tr>
<td>6.35 [0.250]</td>
<td>12.7 [0.5]</td>
</tr>
</tbody>
</table>

1.) Nominal thicknesses other than those listed shall be prepared and tested in accordance with the next greater nominal thickness.

2.) Width as cut and smoothed to within 5% of nominal shown.

3.) Length as cut (not necessary to smooth) to within 10% of nominal shown.
5.2 Measurement

5.2.1 Set tester for the required span and crosshead vertical speeds, as specified in Table 1.

5.2.2 Align the loading nose and supports so that the axis of the cylindrical surfaces are parallel, and the loading nose is midway between the supports.

5.2.3 Condition specimens within the test chamber, for one hour at the temperature specified (see Table 2, or the applicable specification).

5.2.4 Center the specimen on the supports with the long axis of the specimen perpendicular to the loading nose and supports and stabilize for 2 minutes at temperature.

5.2.5 Apply the load at the speed of testing from Table 1 until the specimen breaks. The load at breakage shall be recorded in pounds (P).

5.3 Calculation and Report

5.3.1 Calculate the flexural strength for each specimen using the formula below:

\[
S = \frac{3PL}{2bd^2}
\]

- \(S\) = Flexural strength in Psi
- \(P\) = Load at breakage (pounds)
- \(L\) = Span, inch
- \(b\) = Width of specimen
- \(d\) = Thickness

5.3.2 Average the flexural strengths and record in psi.

5.3.3 The specimen thicknesses, average Psi, and test temperature shall be reported.

6.0 Notes

None

6.1 Additional information and background useful to the performance of the test may be found in ASTM-D-790.
1 Scope  This method is used to determine the mechanical and electrical behavior of flexible printed wiring materials after exposure to two cycles of folding.

2 Applicable Documents  None

3 Test Specimen

3.1 A random sample of the flexible material at least 61 cm long by the width

4 Apparatus

4.1 Two metal plates, the upper plate having sufficient weight to apply 206 KPa to the specimen, as calculated from the length of fold and width of specimens

4.2 Electrical test equipment to measure continuity and dielectric strength after cycling

5 Procedure

5.1 Test

5.1.1 Fold the specimen 180° transversely along a 45° angle to the conductors and press between two metal plates with a pressure of 206 KPa for 15 minutes.

5.1.2 Unfold specimen and reapply pressure for another 15 minutes.

5.1.3 Repeat cycle one more time.

5.2 Evaluation After the two complete cycles, examine specimen for separation, cracks, discontinuity or breaks, and perform an electrical test.
1 Scope  This test method is designed to determine the resistance of the conformal coating to cracking and crazing when the coating is exposed to flexing.

2 Applicable Documents

IPC-CC-830  Qualification and Performance of Electrical Insulating Compound for Printed Board Assemblies

FED-STD-141  Method 2012

3 Test Specimens

3.1  Four tin panels in accordance with FED-STD-141, Method 2012. Electroplated tin is also acceptable.

4 Apparatus

4.1  Tin panels coated with conformal coating according to the coating supplier’s recommendations.

4.2  Mandrel, 0.3 cm [0.12 in] diameter

4.3  Magnifying apparatus, capable of supplying 10X magnification

5 Procedure

5.1  Place the tin panel on a flat surface.

5.1.1  Place the 0.3 cm [0.12 in] mandrel, in a stationary position, in the center of the test panel.

5.1.2  Select one end of the test panel and within one second bend the panel 180° over the mandrel.

5.2 Evaluation

5.2.1  Following the folding procedure, the test panel shall then be examined with 10X magnification for cracking and crazing.
1.0 Scope  The determination of lamination bond quality by immersion in an oil stabilizing high temperature bath.

2.0 Applicable Documents  None

3.0 Test Specimen  Use each of the four IPC test pattern specimens H in Figures 1 through 7 shown in part 5.8.3 of this publication. Any other sample of the production boards may be used by mutual agreement between the vendor and the customer.

4.0 Apparatus

4.1 Test Oil  Commercial grade oil having a boiling and flash point higher than 300°C (572°F).

4.2 Container  Heating container capable of heating oil to 300° ± 10°C (572°F).

4.3 Stopwatch

4.4 Chamber  Circulating air chamber capable of attaining 200°C (392°F).

5.0 Procedure

5.1 Preparation

5.1.1 Saw the four coupons from specimen H. Do not cut coupons so as to introduce any shearing, bending, or breaking stresses.

5.1.2 Condition specimens by suspending in a circulating chamber at 135° ± 15°C for one hour.

5.2 Test

5.2.1 Specimens must be tested within two minutes after removal from the chamber to preclude ambient moisture from returning to specimens before flotation.

5.2.2 Remove the specimens one at a time and float on the surface of the hot oil bath, preset at 260° ±6° –3° for 20 seconds +1 –0 seconds.

5.2.3 After removal from the hot oil and cooling, immerse specimens in chloroethene-NU or trichlorethylene for a few seconds, then dry with compressed air.

5.2.4 Rinse in clean isopropyl alcohol and again blow dry before examination.

5.3 Evaluation  Examine each specimen for measling, blistering or delamination.
1 Scope  This method is designated for use in determining the ease of machining of plastic materials and the effect of such machining on the cutting tools and plastic.

2 Applicable Documents  None

3 Test Specimen

3.1 Any rigid printed wiring material on a finished board (conventional, multilayer or flush)

4 Apparatus

4.1 All typical production machine tools normally used in the fabrication of finished printed wiring boards

5 Procedure

5.1 Machining  The machining must be performed by a skilled mechanic. The technique shall be as standard as possible for all materials in order that comparisons between materials may be made.

5.2 Evaluation  After machining (i.e., drilling, sawing, and machining in all directions), check for cracking, splitting, delaminating, or other adverse effects. The cutting tools should show reasonable tendency to dull, nick, or overheat.
1.0 **Scope**  This test method is designed to determine the peel strength of metallic cladding when tested in the following conditions, "as received," after thermal stress, and after exposure to processing chemicals; and to evaluate the base laminate material after the peel strength test is completed for degradation due to the conditioning.

2.0 **Applicable Documents**

IPC-TM-650

Method 2.4.8.1, Peel Strength, Metal Foil (Keyhole Method for Thin Laminates)

Method 5.8.3, Peel Strength Test Pattern

3.0 **Test Specimens**

3.1 **Size and Configuration**  Specimens shall be 50.8 mm x 50.8 mm [2.0 x 2.0 in] by the thickness of the laminate. Cladding test strips shall be as specified (see 5.1.2).

3.2 **Quantity and Sampling**  At least 2 specimens per clad side per each test condition (see 5.2) shall be taken at random from the laminate lot. They may be taken from samples used for other QA testing or inspection. One specimen per side shall be used for crosswise and one specimen per side for lengthwise testing.

4.0 **Apparatus or Material**

4.1 **Tensile Tester**  A tensile strength tester equipped with a load cell, capable of measuring to the nearest 0.0045 kg [0.01 lbs], and light load wire or chain and clamp at least 457 mm [18.0 in] long (its weight is included in the load cell calculation). The clamp jaws must cover the entire width of each peel strip. Any equipment or apparatus having the described accuracy, precision, and reproducibility may be used.

4.2 **Solder Pot**  A solder bath or pot capable of maintaining solder at the specified temperature when measured 25.4 mm [1.0 in] below the surface. Type Sn60 or Sn63 solder shall be used.

4.3 **Specimen Hold-down**  A suitable hold-down clamping system equivalent in performance as that defined in IPC-TM-650, Method 2.4.8.1.

4.4 **Chemicals**  A minimum of two ounces of the following processing solutions:

4.4.1  Organic chemical stripper, such as Methylene Chloride, or equivalent

4.4.2  Sodium Hydroxide 10 gr/liter

4.4.3  Boric Acid 30 gr/liter and Sulfuric Acid 10 gr/liter

4.4.4  Organic degreaser, such as isopropyl alcohol, or equivalent.

4.5  Hot fluid bath, capable of being maintained at the specified temperature, when measured 25.4 mm [1.0 in] below the surface.

4.5.1  Dow Silicone Fluid No. 704, or equivalent.

4.6  Dow Silicone Grease, Compound 4, or equivalent.

4.7 **Data Collection**  For qualificationtesting, a recording system capable of permanent data retention must be incorporated into the test apparatus.

4.8  Etching system capable of complete removal of metallic cladding.

4.9  Measuring device capable of measuring from 0.000 to 12.7 mm [0.5 in] to within ± 0.0025 mm [0.0001 in].

4.10 **Etch Resist Materials or Systems**

4.10.1  Platers tape, or equivalent, to act as etch resist for strip formation of the specified widths (see 5.2.1.1, 5.2.2.1, and 5.2.3.1).

4.10.2  Photoresist system (printing, developing, and stripping).

5.0 **Procedure**

5.1 **Specimen Preparation**
5.1.1 Cut the specimens from the laminate sample. Specimens shall be taken no closer than 25.4 mm [1.0 in] from the edge of the laminate sheet as manufactured.

5.1.2 Specimens shall be prepared with at least four resist strips of the width specified (see 5.2.1.1, 5.2.2.1, 5.2.3.1), etched, cleaned and processed using standard industry practices and equipment. For qualification and referee testing the specimen shall be photomized in accordance with the artwork shown in Method 5.8.3 of IPC-TM-650 except that tab ends are optional. Specimens shall be etched so that the conductor strips on one specimen are in one direction per Figure 1. Double clad laminate shall have each side tested using separate specimens. The opposite side cladding shall be either fully removed or left fully clad. For referee testing the cladding on the opposite side shall remain. Separate specimens for both the warp and fill directions are required for each side.

5.1.3 Thin specimens may be provided with support by bonding them to a rigid substrate base, or may be tested with the aid of the keyhole fixture (see Figure 2). For referee testing of laminates less than 0.51 mm [0.020 in], the specimens shall be bonded to a rigid substrate or laminate.

Note: Peel values can be affected by the adhesive used to bond the specimen to the rigid substrate. It is imperative that the best adhesive be found for the type of materials being bonded to least influence the true peel strength value.

5.1.4 For referee testing and qualification, specimens shall be preconditioned by baking at 125°C [257°F] for 4 ± 0.5 hours.

5.2 Measurements

5.2.1 Condition A Peel Strength: As Received

5.2.1.1 A minimum of two 3.18 mm [0.125 in] test strips per specimen shall be peeled. For qualification testing four 3.18 mm [0.125 in] strips per specimen shall be peeled.

5.2.1.2 Adjust the measurement system to compensate for the weight of the wire and clamp.

5.2.1.3 Peel the test strip back at the tab end (if present) no more than 12.7 mm [0.5 in]. Attach the clamp to the peeled back end of the test strip.

5.2.1.4 Fasten specimen with hold down fixture so that an unencumbered vertical pull can be exerted. The end of the test strip should be in a vertical position ready for testing. The wire connecting the clamp to the tensile tester must be free to pull vertically within ± 5° angle.

5.2.1.5 Start tester and apply force in the vertical direction at the rate of 50.8 mm [2.0 in]/minute, until at least a 25.4 mm [1.0 in] peel is completed (see Note 6.1).

5.2.1.6 Observe and record the minimum load as defined by Figure 1. Measure the actual width of the test strip and record with the minimum load.

5.2.1.7 If the full width of the test strip does not peel, the results shall be discarded and another strip tested.

5.2.2 Condition B Peel Strength: After Thermal Stress

5.2.2.1 A minimum of two 3.18 mm [0.125 in] test strips per specimen shall be peeled. For qualification testing four 3.18 mm [0.125 in] strips per specimen shall be peeled.

5.2.2.2 Apply a thin coating of silicon grease to specimens and float on solder maintained at 288°C ± 5.5°C [550°F ± 10°F] for 10 seconds, +1, -0.

5.2.2.3 Cool specimens to laboratory ambient temperature, Clean the grease off and perform steps 5.2.1.2 through 5.2.1.7.

5.2.3 Condition C Peel Strength: After Exposure to Processing Chemicals

5.2.3.1 A minimum of two 0.79 mm [0.032 in] test strips per specimen shall be peeled. For qualification and conformance four 0.79 mm [0.032 in] strips per specimen shall be used.

5.2.3.2 Immerse in organic stripper as specified in 4.4.1 for 75 ±5 seconds at 23 ±2°C [73.4 ±3.6°F].

5.2.3.3 Dry specimens 15 ± 5 minutes at 125 ± 5°C [257 ± 9°F].

5.2.3.4 Immerse in a solution of 10 gr/liter sodium hydroxide at 90 ± 5°C [194 ± 9°F] for 5 ± 1 minutes.

5.2.3.5 Rinse in hot tap water at 50–55°C [122–131°F] for 5 ± 1 minutes.

5.2.3.6 Immerse for 30 ±5 minutes in a solution of 10 gr/liter sulfuric acid (sp. gr. 1.836) and 30 gr/liter boric acid solution at 60 ± 5°C [140 ± 9°F].
5.2.3.7 Rinse in hot water at 55 ± 5°C [131 ± 9°F] for 5 ± 1 minutes.

5.2.3.8 Dry for 30 ± 5 minutes at 125 ± 5°C [257 ± 9°F].

5.2.3.9 Immerse in a hot oil bath maintained at 220 ± 5°C [428 ± 9°F] for 40 ± 5 seconds.

5.2.3.10 Immerse in degreaser as specified in 4.4.4 at 23 ± 2°C [73.4 ± 3.6°F] for 75 ± 5 seconds to remove hot oil.

5.2.3.11 Air dry specimens and perform steps 5.2.1.2 through 5.2.1.7.

5.2.4 Determination of Degradation Examine the specimens using normal or corrected 20/20 vision. Record and report the presence of any base laminate degradation, including loss of surface resin, discoloration, resin softening, delamination, blistering, propagation of imperfections, measing, crazing, or voids.

5.3 Calculation and Report

5.3.1 Calculate the peel strength as per the formula:

\[
\text{lbs/in} = \frac{L_M}{W_S}
\]

where:

- \(L_M\) = Minimum Load
- \(W_S\) = Measured width of peel strip

5.3.2 Record and report each individual peel strength value. Average the individual peel strength values for each side and each grain direction of the laminate sampling. For example, if the sampling plan calls for one specimen per side and per grain direction, there will be at least two values to be averaged from four different specimens.

5.3.3 Report any presence of laminate degradation as observed in 5.2.4

6.0 Notes

6.1 Test strip breakage may be caused by either a bond greater than the tensile strength of the foil, or foil brittleness. Where superior bond is shown (value at break above specification) the value at break may be used instead of minimum peel. The average reported shall indicate that the value is greater than average.

6.2 For metallic cladding less than one oz thickness, copper plating or solder coating may be used to build up to 0.035 ± 0.0035 mm [0.0014 ± 0.00014 in] to provide strip strength.

6.3 Environmental aspects of chemicals as specified in 4.4.1 and 4.4.4. Based on industry and government policies toward chemicals which are hazardous to worker health or of concern for ozone depletion, previous requirements for use of Methylene Chloride and 1,1,1 Trichloroethane have been replaced with equivalents.
1 Scope  This method is designed to determine the peel strength of metal foil when bonded to thin laminates. Peel strength is determined for specimens as received or after conditioning, such as solder immersion or elevated temperature exposure.

2 Applicable Documents

2.4.8  Peel Strength of Metallic Clad Laminates

3 Test Specimen  Bonded metal foil with peel strength test patterns 3 mm wide and up to 76 mm long (each specimen is about 60 mm to 76 mm long)

4 Apparatus

4.1 Force gage or testing machine capable of a travel speed of 5 cm per minute with a range of 1 kg to 1.4 kg and 4.5 g minimum scale divisions

4.2 Keyhole test plate per Figure 1, or equivalent

4.3 Keyhole horizontal base fixture per Figure 2

4.4 Chain 61 cm to 71 cm

4.5 Surgical hemostat

4.6 Cylindrical spring paper clips (Boston clip No. 4, Hunt Mfg. Co.)

4.7 Chain to hemostat adapter, per Figure 3 (approximately 76 mm long)

4.8 Scalpel

5 Procedure

5.1 Preparation

5.1.1 Cut specimens from a laminated or bonded and etched panel and trim to the edge of the peel tabs.

5.2 Conditioning  If specimens are to be conditioned, the conditions in IPC-TM-650, Method 2.4.8, shall be used. Other conditions of specifications working this method as applicable may be used.

5.3 Test

5.3.1 Place the specimen on the base fixture, metal foil side up, and center the peel strip on the base.
5.3.2 Place the keyhole plate over the peel strip with the tab in the large hole and the strip centered in the slot.

5.3.3 Clamp the keyhole plate to the base with the paperclips, making sure the alignment is not disturbed.

5.3.4 Attach the hemostat to the tab so the peel will be 90° to the strip (the hemostat should be attached to the chain with the adapter and hanging from the tester jaws or force gage so that the tab can be clamped without excessive bending or damage).

5.3.5 Start the vertical pull (5 cm per minute) with the test head and initiate a chart recorder or visually observe the minimum and pull force.

5.3.6 Lower the head or force gage to position for starting the next peel strip and repeat starting at 5.2.1.
5.4 Evaluation

5.4.1 Calculate the peel strength per mm of width by measuring the strip width in mm, using the following formula:

\[
\text{peel strength/} \text{mm width} = \frac{1 \text{ mm}}{\text{measured strip width in mm}} \times \text{observed pull force}
\]

6 Notes

6.1 Peel strength is usually the minimum peel strength observed.
1.0 Scope  This test method defines the procedure for determining the bond strength of copper foil clad flexible dielectric material.

2.0 Applicable Documents  None

3.0 Test Specimens  If a statistically sound evaluation by a given supplier can prove that die cut and etched specimens differ, the preparation giving the lower measurement can be the only preparation tested. In case of conflict, the die cut sample will be used as the referee method. The sample preparation will be the same for as received, after solder and after aging.

3.1 Type A—Etched Specimen

3.1.1 The test specimen shall consist of an etched conductor pattern in accordance with Figure 1. Note: Conductors are 3.2 mm wide x 228.6 mm long [0.125 inches wide by 9.0 inches long].

3.1.2 A minimum of four specimens, two from the machine direction and two from the transverse direction, shall be prepared for each of the procedure Methods A, C, E. If a statistically sound evaluation by a given supplier can prove that MD and TD measurements differ, the direction giving the lower measurement can be the only direction tested. If the two directions are the same, only the MD direction needs to be tested. In the event a test specimen tears during testing, another test specimen will be prepared to replace it.

3.1.3 For double clad laminate, a separate sample unit shall be prepared and tested for each side.

3.2 Type B—Die Cut Specimen

3.2.1 The test specimen shall consist of a strip of clad flexible material 12.7 mm wide by 228.6 mm long [1/2 inch wide by 9 inches long].

3.2.2 A minimum of four specimens, two from the machine direction and two from the transverse direction, shall be prepared for each of the procedure Methods B, D, F. If a statistically sound evaluation by a given supplier can prove that MD and ID measurements differ, the direction giving the lower measurement can be the only direction tested. If the two direction are the same, only the MD direction needs to be tested.

3.2.3 For double clad laminate, a separate sample unit shall be prepared and tested for each side. The copper foil on the non-test side may remain to provide stability to prevent tenting of the specimen from the German Wheel (free wheel rotary drum).

4.0 Test Equipment

4.1 Testing Machine  Power driven testing machine, crosshead autographic type, or an equivalent constant speed drive machine.

4.2 Sample Cutter  Thwing Albert sample cutter, Model No. JDC-50, or equivalent.

4.3 Test Fixture  Free wheeling rotary drum (Figure 2), sliding plate (Figure 3), or equivalent. The referee fixture will be a 152.4 mm [6.0 in] free wheeling rotary drum.

---

Figure 1  Type A peel strength test pattern
4.4 Solder Pot  An electrically-heated, thermostatically con- 
trolled solder pot of adequate dimensions to accommodate 
the specimen and contain no less than 2.25 Kg [5 pounds] of 
SN60 solder.

4.5 Automatic Temperature Cycling Chamber  (See 
5.5.3)

5.0 Procedure

5.1 Method A—As Received-Etched Specimen

5.1.1 Prepare Type A etched conductor test specimens in 
accordance with Figure 1 using standard commercial prac-
tices per paragraph 3.1.2.

5.1.2 Condition specimens for 24 hours at 23 ± 2°C (73.4 ± 
3.6°F) and 50 ±5 ° relative humidity. Stabilization time may be 
reduced if statistically sound evidence has been generated on 
the specific product line to support the shorter stabilization 
times.

5.1.3 Attach the specimen to the test fixture with double-
sided tape, cement, and/or mechanical clamps. The referee 
attachment technique will be double sided adhesive tape.

5.1.4 Peel the conductor at a rate (crosshead speed) of 
50.8 mm/minute [2 inches/minute]. The peel load shall fall 
within 15 to 85 percent of the range of the scale used on the 
testing machine. The peel load shall be continuously 
recorded, and the recorded load for the entire length of the 
peeled conductor shall be evaluated per paragraph 5.7.1. A 
minimum of 57.2 mm [2-1/4 inches] must be peeled, the first 
6.4 mm [1/4 inch] to be disregarded.

5.2 Method B—As Received—Die Cut Specimen

5.2.1 Cut Type B test specimens with the Thwing Albert 
sample cutter per paragraph 3.2.2.

5.2.2 Condition specimens for 24 hours at 23 ± 2°C (73.4 ± 
3.6°F) and 50 ± 5% relative humidity. Stabilization times may 
be reduced if statistically sound evidence has been generated on 
the specific product line to support the shorter stabilization 
times.

5.2.3 Attach the specimen to the test fixture with double-
sided tape, cement, and/or mechanical clamps. The referee 
attachment technique will be double sided adhesive tape.
5.2.4 Peel the foil at a rate (crosshead speed) of 508 mm/minute [2 inches/minute]. The peel load shall fall within 15 to 85 percent of the range of the scale used on the testing machine. The peel load shall be continuously recorded, and the recorded load for the entire length of the peeled conductor shall be evaluated per paragraph 5.71. A minimum of 57.2 mm [2-1/4 inches] must be peeled, the first 6.4 mm [1/4 inch] to be disregarded.

5.3 Method C—Solder Float—Etched Specimen

5.3.1 Prepare Type A etched conductor test specimen in accordance with Figure 1 using standard commercial practices per paragraph 3.2.1.

5.3.2 Dry the test specimens in an area circulating oven maintained at 135 ± 10°C (275 ± 18°F) for one hour.

5.3.3 Remove the specimen from the conditioning chamber and float each specimen, conductor side down, just beneath the surface of molten solder at 288 ± 6°C [550 ± 10°F] for at least 5 seconds. Agitate the specimen from side to side during immersion, then remove the specimen and tap the edge to remove excess solder. Suitable procedures must be used to ensure that solder does not remain on test specimen.

5.3.4 Repeat steps 5.1.2 through 5.1.4 as performed in Method A.

5.4 Method D—Solder Float—Die Cut Specimen

5.4.1 Cut Type B test specimens with the Thwing Albert sample cutter per paragraph 3.2.1.

5.4.2 Dry the test specimens in an air circulating oven maintained at 135 ± 10°C (275 ± 18°F) for one hour.

5.4.3 Remove the specimen from the conditioning chamber, apply solder stop (e.g. petroleum jelly) and float each specimen, conductor side down, just beneath the surface of molten solder at 288° ± 6°C [550 ± 10°F] for at least 5 seconds. Agitate the specimen from side to side during immersion, then remove the specimen and tap the edge to remove excess solder. Suitable procedures must be used to ensure that solder does not remain on test specimen.

5.4.4 Repeat steps 5.2.2 through Method B.

5.5 Method E—After Aging Etched Specimen

Figure 3 Sliding plate test fixture
5.5.1 Prepare Type A etched conductor test specimen in accordance with Figure 1 using standard commercial practices per paragraph 3.1.1.

5.5.2 Condition specimens for 24 hours at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5% relative humidity. Stabilization time may be reduced if statistically sound evidence has been generated on the specific product line to support the shorter stabilization times.

5.5.3 Expose each test specimen to five cycles at the time-temperature sequence: 1/2 hour at 150° +5° -0°C [302° ±9° -0°F], 1/4 hour at 23° ± 10°C [73.4° ± 18°F], 1/2 hour at -55° -5° +0°C [-67° -9° +0°F], 1/4 hour at 23° ± 10°C [73.4° ± 18°F].

5.5.4 Repeat steps 5.1.2 through 5.1.4 as performed in Method A.

5.6 Method F—After aging—Die Cut Specimen

5.6.1 Cut Type B test specimens with the Thwing Albert sample cutter per paragraph 3.2.1.

5.6.2 Condition specimens for 24 hours at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5% relative humidity. Stabilization time may be reduced if statistically sound evidence has been generated on the specific product line to support the shorter stabilization times.

5.6.3 Expose each test specimen to five cycles at the time-temperature sequence: 1/2 hour at 150° +5° -0°C [302° +9° -0°F], 1/4 hour at 23° ± 10°C [73.4° ± 18°F], 1/2 hour at -55° -5° +0°C [-67° -9° +0°F], 1/4 hour at 23° ± 10°C [73.4° ± 18°F].

5.6.4 Repeat steps 5.2.2 through 5.2.4 as performed in Method B.

5.7 Evaluation

5.7.1 Average the chart recordings for both specimens over the entire peel length if the mode of failure hasn’t changed. In the case of changes in failure mode, the average specimen peel strength shall be determined using the area of the chart associated with the failure mode producing the lowest peel strength number (see Figures 4, 5 and 6).
5.7.2 Measure and record the width of the etched conductor or peeled foil to the nearest 0.02 mm [0.001 inch].

5.7.3 Compute the peel strength using the following formula: Peel Strength (pounds/inch of width) = Average load per 5.7.1 conductor width per specimen.

6.0 Notes

6.1 The force required to bend the test conductor will affect the measured peel strength. The magnitude of this effect will increase as the conductor thickness increases.

6.2 In order to prevent tenting of the peel specimens, suitable support material may be applied to the back side of the test specimen. A referee support material will be a 0.25 mm [0.25 mil] glass epoxy material. Bonding during sample preparation should occur at conditions not exceeding 65.6°-9° +0°C [150° -10° +0°F] 1 hour cure @ 100 psi. In the event of a conflict, a backer will be used to prevent tenting. Note: The copper foil on the nontest side may remain to provide stability to prevent tenting of the specimen from the German Wheel.

6.3 Definition: Slipstick failure is a peel failure which propagates faster than the crosshead speed (also known as a zipper failure).
1 Scope  The purpose of this test is to characterize peel adhesion at ambient conditions.

2 Applicable Documents

IPC-3408  General Requirements for Anisotropically Conductive Adhesive Films.

3 Test Specimens

3.1 1 mm pitch (center-to-center) flex test circuits and 1 mm pitch (center-to-center) test boards

4 Apparatus

4.1 Soda-lime glass test slides or printed circuit boards

4.2 All other test materials listed in IPC-3408

4.3 'Instron-1122' tensile tester or equivalent, equipped with air-powered jaws and 50 kg load cell, adjustable to 10 kg full scale

4.4 Test fixture, mountable on lower stage of tensile tester

5 Procedure

5.1 Sample Preparation

5.1.1 Cut flex test circuits to the appropriate length (see Figure 1).

5.1.2 Use of new PCBs is recommended. If new boards are being used there should be no need for any special cleaning procedure. If used boards are to be used, they should be inspected to ensure that:

a) Protective metalization (Au or Pb-Sn) is intact,

b) FR-4 isn’t significantly discolored from prior high temperature exposure,

c) The board is free of any residue from previous tests.

5.1.3 Refer to IPC-3408 for proper bonding procedure.

5.2 Procedure

5.2.1 Prepare at least three, and preferably five, samples for each test point to be measured.

5.2.2 Confirm proper calibration of the tensile tester, and ensure proper full-scale setting.

5.2.3 Mount sample in test fixture. Secure the flex circuit tail into the air-powered jaws on the cross-head stage, being careful to place the jaws as close to and as square to the bond-line as possible.

5.2.4 Peel the sample at a rate of 2.5 mm/min., and record the peak adhesion value.

5.2.5 Repeat steps 3 and 4 for all additional samples. Compute the average adhesion value and record.

Figure 1  Sample Pattern
1 Scope  In order to assess the actual performance of any given lot of material, it is necessary to apply and thermally bond the material between the substrates of interest. This method describes the recommended procedure for both pre-tacking and bonding anisotropically conductive films (ACF). This method describes a fully manual procedure.

2 Applicable Documents

3 Test Specimens
3.1 Appropriate flex circuit and test substrate(s)

4 Apparatus
4.1 "Hot-Bar" type soldering station: Unitek PM-4 or equivalent
4.2 Thermode: 1.5 mm width minimum; sufficient length to span bond-line
4.3 Hot-Plate: Pace, Inc., ‘Hot Spot’ or equivalent (optional if hot bar bonder is used for tacking or if adhesive can be tacked without applied heat)
4.4 Razor blade
4.5 Cotton swab (optional; see 4.3)
4.6 One roll or sheet of conductive adhesive
4.7 Appropriate compliant material (as required)

5 Procedure
5.1 Sample Preparation
5.1.1 Allow the roll of adhesive to equilibrate at room temperature before handling.
5.1.2 Cut the flex circuit sample to the appropriate length and width for the given performance test.
5.1.3 Cut an adhesive sample to match the width and length of the bond area.

5.2 Procedure
5.2.1 Position the adhesive over the pads on the flex circuit, liner-side up.
5.2.2 If the adhesive requires heat to tack it, tack the adhesive in place on the flex circuit using the hot plate and cotton swab (alternatively, the adhesive can be tacked using an appropriately low setting of the hot bar equipment). The adhesive should be easily tackable with a three to five second exposure at 100°C. A cotton swab should be used to apply mild pressure in order to facilitate wetting. Allow the flex circuit to cool before handling further.
5.2.3 Peel the release liner away from the flex circuit in order to expose the adhesive. The adhesive may need pre-cutting (using a razor blade) to separate it from the liner along the starting edge.
5.2.4 Align the flex circuit to the test substrate. In instances requiring extreme accuracy of alignment, it is helpful to affix the flex circuit relative to the substrate to prevent misregistration prior to and during bonding. This can be accomplished with custom fixturing. Alternatively, a soldering iron can be brushed lightly along the bond-line in order to tackify the adhesive, thereby temporarily adhering the flex circuit to the test substrate.

Note: When a soldering iron is used, it should be powered through a Variac in order to provide temperature control. The temperature/time of the soldering iron should be just high enough to tackify the adhesive but not so high as to substantially cross-link the adhesive (i.e., 100°-130°C) and only a few seconds exposure to these temperatures.
5.2.5 Bond the flex circuit to the test substrate using the hot-bar soldering station. Apply a minimum of 20 kg and a maximum of 40 kg/sq. cm of total bond-line area (or as recommended by the adhesive vendor), then ramp the temperature to the set point. The thermode set point needs to be set to permit the adhesive layer to reach 180°C within 10 seconds (or as recommended by the adhesive vendor) of the time at which the thermode reaches its setpoint. The thermode should remain at the setpoint for a time sufficient to cure the adhesive according to vendor’s specification (typically 20 seconds). Some vendors may advise that the bond pressure...
should be maintained until the adhesive layer cools to 100°C. Allow the test sample to cool slightly before handling. The compliant material (if one is used) should be placed between the thermode and flex circuit prior to bonding.
1.0 Scope  
To test the adhesion of plating on printed wiring conductor patterns.

2.0 Applicable Documents

2.1 IPC-A-600A  Acceptability Guidelines

2.2 Federal Specification L-T-90  “Tape, Cellophane, Pressure Sensitive”

3.0 Test Specimen  
Use test specimen “B” of MLB Test Panel, section 5.8.3 of this publication, or a production board.

4.0 Apparatus  
Not applicable.

5.0 Procedure

5.1 Test

5.1.1 Firmly press a 1/2 in. strip of pressure-sensitive cellophane tape across the surface of the conductor pattern.

5.1.2 Remove the tape rapidly by manual force applied approximately perpendicular to the pattern.

5.1.3 The tape must be applied to, and removed from, three different locations on each printed wiring board tested.

5.1.4 Fresh tape shall be used for each test.

5.2 Evaluation  
Examine for any portions of the protective plating or the conductor pattern being removed, as shown by particles of the plating or pattern adhering to the tape. If overhanging metal breaks off (slivers) and adheres to the tape, it is evidence of overhang but not of plating adhesion failure.
1 Scope  This method covers the punch-type shear test to determine the shear strength of flexible dielectric substrate materials.

2 Applicable Documents
ASTM-D-732  Shear Strength

3 Test Specimen
3.1 Five specimens 5 cm x 5 cm or 5 cm diameter by the thickness.

4 Apparatus
4.1 Tinius-Olson Super “L” tester or equal, having constant speed capability and a load indicator. The shear tool must be constructed so that the specimen is rigidly clamped both to the stationary block and movable block so that it can not be deflected during the test. A suitable shear tool is illustrated in ASTM-D-732, although a typical production shear tool is acceptable.

5 Procedure
5.1 Test
5.1.1 Place the specimen in the shear tool and fasten tightly, then assemble the shear tool into testing machine.
5.1.2 Set the crosshead speed to 1.3 mm per minute, measured when the machine is running idle.
5.1.3 Operate the testing machine and remove the specimen for evaluation.

5.2 Evaluation
5.2.1 Calculate the shear strength in KPa, by dividing the load by the area of the sheared edge, which shall be taken as the product of the thickness of the specimen by the circumference of the punch.
5.2.2 Report the individual and average values.

6.0 Notes  For further technical information on Super “L” tester, write Tinius-Olson Co., Willow Grove, Penn.
1.0 Scope This method is used to determine the solderability of copper foil, copper clad laminate, and printed boards. This method does not specifically relate to the solderability of the internal plating in holes.

2.0 Applicable Documents None

3.0 Test Specimen

Boards Specimen can be a scrap edge, a finished product or a specially prepared specimen processed with a group of production boards, as mutually determined between vendor and user.

Copper Foil A representative sample of copper foil that is 25 mm [1 in] wide and of sufficient length to dip approximately 50 mm [2 in] into the solder.

4.0 Apparatus

4.1 Solder Pot An electrically heated thermostatically controlled pot of sufficient size to accommodate the specimen containing no less than five pounds of solder.

4.2 Dipping Device A device as shown in Figure 1 shall be used. A similar device may be used if:

1. the rate of immersion, dwell time and rate by withdrawal are within the test limits described in the procedures;
2. the board and solder remain perpendicular within five degrees and
3. wobble, vibration and other extraneous movements, are eliminated.

4.3 Flux Nonactivated rosin flux having a nominal composition of 25% by weight of water white gum rosin in a solvent of isopropyl alcohol 99%. The specific gravity of the flux shall be 0.843 ± 0.005 at 25°C (77°F), and free of additional activators.

4.4 10% HCL by volume

5.0 Procedure

5.1 Preparation

5.1.1 The specimen shall be checked in an “as received” condition from the vendor and care must be exercised to prevent contamination (by grease, perspirants, etc.) of the surface to be tested.

5.1.2 Preclean the specimen using a 15 second immersion in 10% HCL (by volume) followed by water rinsing. The HCL shall be maintained at 60 ± 5°C [140 ± 10°F]. Dry the specimen quickly to avoid excess oxidation of the sample. Use of an air blower or isopropyl alcohol to expedite the drying is permitted.

5.1.3 Dip the specimen into the described flux and allow to drain for 60 seconds before proceeding with the solder dip.

5.2 Test

5.2.1 Stir, and skim the surface of the molten solder with a clean stainless steel paddle to assure that the solder is of a uniform composition and a temperature of 245 ± 5°C (473 ± 9°F).

5.2.2 Immerse the specimen edgewise into the molten solder. The insertion and withdrawal rates shall be 1 ± 0.025 inches per second, with a dwell time of 4 seconds ± 0.5 seconds.

5.2.3 Upon withdrawal, the solder shall be allowed to solidify by air cooling while the specimen is in the vertical position.

5.2.4 Thoroughly remove the flux and examine.

5.3 Evaluation

5.3.1 Examine specimen for a new uniform adhering coating of solder.

5.3.2 An area of 3.2mm [0.125 in] width, approximately, from the edge of the specimen shall not be evaluated.

6.0 Notes

6.1 As an aid to evaluation of the test results, see Figure 2. This aid to be used primarily to illustrate types of defects rather than percentage of area covered.

6.2 No quenching or other means of accelerating cooling shall be used.

Figure 1  Suggested Dipping Device
<table>
<thead>
<tr>
<th>Number</th>
<th>Subject</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4.12</td>
<td>Solderability, Edge Dip Method</td>
<td>6/91</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2  Aid to Evaluation**

- **Preferred Wetting**
- **Small Amount of Dewetting**
- **Complete Dewetting**
- **Nonwetting**
1 Scope  This test method establishes and defines the procedures for determining the solder float resistance of copper foil clad and bare flexible dielectric material.

2 Applicable Documents
J-STD-004  Requirements for Soldering Fluxes

3 Test Specimen
3.1 Two specimens, approximately 50 mm x 50 mm per clad side.
3.2 For double clad laminate, a separate specimen unit shall be prepared and tested for each side. The copper foil shall be etched from the reverse or non-test side of each specimen using standard commercial practices. Bare dielectric material shall be tested bare.

4 Apparatus
4.1 Test Chamber  A circulating air chamber capable of maintaining a uniform temperature of 135°C ± 10°C.
4.2 Solder Pot  An electrically-heated, thermostatically-controlled solder pot of adequate dimensions to accommodate the specimen and containing no less than 2.25 Kg of solder.
4.3 Cutter template and cutter to prepare approximately 50 mm x 50 mm specimens of copper clad dielectric material.
4.4 Solder float test fixture as per Figure 1.
4.5 Sn60, Sn62, or Sn63 solder conforming to J-STD-004.

5 Procedure
5.1 Prepare two specimens, clean the copper foil, then precondition the test specimen in an air circulating oven maintained at 135°C ± 10°C for one hour. Specimens may then be held in a room temperature desiccator.
5.2 Remove the specimens from the conditioning chamber.
5.3 Attach the specimens to the solder float test fixture with a thumb tack or other low mass holding device (Figure 1) prior to floating the sample. Float the specimen, foil side down, on the surface of the molten solder, maintained at the temperature specified in Table 1, for 10 seconds.

Table 1 Solder Float Temperatures

<table>
<thead>
<tr>
<th>Method</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>260°C ± 5°C</td>
</tr>
<tr>
<td>B</td>
<td>288°C ± 5°C</td>
</tr>
</tbody>
</table>

5.4 Float the specimen on the surface, then remove the specimens and tap the edges to remove excess solder.

5.5 Evaluation  Thoroughly clean each specimen and visually examine for blistering, delamination or wrinkling. For bare dielectric films, examine for blistering, shrinkage, distortion or melting.

6 Notes
6.1 For materials that absorb moisture, the preconditioning in this method is required to remove absorbed moisture from the materials. Absorbed moisture can volatilize and cause delamination and blistering because of the rapid temperature rise experienced in the solder bath. Drying may not be required for materials with low moisture absorption characteristics.
1.0 Scope  
This test method is designed to determine the thermal integrity of unclad or metallic clad laminates using short-term solder exposure.

2.0 Applicable Documents
Method 2.1.1, Microsectioning  
MIL-F-14256 Flux, Soldering, Liquid (Rosin Base)

3.0 Test Specimens
3.1 Size and Configuration  
Unless otherwise specified, specimens shall be 50.8 mm x 50.8 mm ± 0.75 mm [2.00 x 2.00 in ± 0.30 in] by the thickness of the laminate. Metallic clad laminate shall include specimens which are completely clad and fully etched.

3.2 Quantity and Sampling  
Unless otherwise specified, for each clad side and for each test condition, three specimens shall be used for qualification testing and two specimens for lot acceptance testing. Specimens may be cut from anywhere in the sheet of material except no specimen shall be taken closer than 25.4 mm [1.0 in] from any edge as laminated.

4.0 Apparatus or Material
4.1 Oven  
Air circulating oven capable of maintaining a temperature of 125 ± 2°C [257 ± 3.6°F].

4.2 Solder Bath  
Electrically heated solder pot; thermostatically controlled; containing at least 1.0 kilograms of solder; and capable of maintaining the specified temperature. Unless otherwise specified, the temperature shall be 288 ± 5.5°C [550 ± 10°F]. Type Sn60 or Sn63 shall be used.

4.3 Temperature Indicator  
Thermocouple or other device capable of measuring the solder temperature at a depth of 25.4 mm [1 in] below the surface and capable of measuring to within ± 2°C [3.6°F] at the solder temperature specified.

4.4 Desiccator  
A desiccation chamber capable of maintaining an atmosphere less than 30% RH at 23°C [73.4°F].

4.5 Optical Magnification
4.5.1 Microscope  
Range 100 to 200 X (for referee testing only).

4.5.2 Magnifier  
Magnifying loupe, or equivalent, capable of magnification of 4X to 10X.

4.6 Timer  
Stop watch, or equivalent, capable of measuring to within 0.2 seconds.

4.7 Water White Rosin Flux  
Type R per MIL-F-14256.

4.8 Cutting Apparatus  
Diamond saw, shear or other device capable of cutting to the specified size without excessive damage or stress on the material.

4.9 Etching System  
Etching system capable of complete removal of metallic cladding.

4.10 Flux Cleaning Solvent  
Isopropyl alcohol, flux thinner, or equivalent.

5.0 Procedure  
Specimens shall be tested in accordance with the following procedure.

5.1 Specimen Preparation
5.1.1 Etching  
One-half of the metallic clad laminate sampling shall be completely etched in accordance with standard industry practices.

5.1.2 Cutting  
The specimens shall be cut to size from the unetched and etched samples by suitable means. The edges shall be cleaned and smoothed by light sanding.

5.1.3 Conditioning  
For referee or qualification purposes, specimens shall be placed in an air-circulating oven maintained at 125° ± 2°C [257 ± 3.6°F] for 4 to 6 hours. After removal from the oven, place specimens in a desiccator and allow to cool to room temperature.

5.2 Measurement
5.2.1 Fluxing  Immediately after removal from the desiccator, metal surfaces shall be cleaned by light abrasion, or other suitable methods. Flux with rosin flux conforming to type R, MIL- F-14256. Let drain in a vertical position.

5.2.2 Stressing  Within 10 minutes of removal from desiccator, float the specimen for 10 + 1, –0 seconds on the surface of a solder bath maintained at the specified temperature, measured at a depth of 25.4 mm [1.0 in] below the surface. The specimens shall be kept in intimate contact with the solder surface and agitated by gentle downward pressure using tongs or equivalent.

Note: Very thin laminates, typically under 0.5 mm [0.020 in] thick, are prone to bowing or curling upon contact with solder. The following handling instructions apply:

a. For etched specimens, mount each specimen using staples to a piece of corrugated board (‘‘cardboard’’) approximately 75 x 75 mm [3.0 x 3.0 in].

b. For unetched single-clad specimens, mount each specimen to a 75 x 75 mm [3.0 x 3.0 in] piece of corrugated board (‘‘cardboard’’) by slipping two opposite edges into slits cut parallel and 38.1 mm [1.5 in] apart in the cardboard.

c. Unetched double-clad specimens including those of unequal cladding thicknesses, do not require mounting.

5.2.3 The specimens shall be removed from the bath and allowed to cool to room temperature. Mounted specimens may be removed from the supporting cardboard. Clean the flux from the specimens using appropriate solvent.

5.3 Evaluation

5.3.1 Etched or Unclad Specimens  Examine the specimens by normal or corrected 20/20 vision, using backlighting if necessary. Record the presence of charring, surface contamination, loss of surface resin, resin softening, delamination, blistering, weave exposure, propagation of imperfections, measling, crazing, or voids.

Determine the number and dimension of any voids using 4X minimum magnification; for referee purposes, 10X magnification shall be used.

5.3.2 Clad Specimens  The specimen shall be examined for any evidence of blistering, delamination or other damage. During the solder exposure, any apparent event that is evidence of damage, such as the specimen exhibiting a ‘‘bump’’ felt through the tongs, shall be recorded as a sign of possible delamination.

5.3.3 For referee purposes, the etched or unetched specimens shall then be microsectioned in accordance with IPC-TM-650, Method 2.1.1 (except there are no plated-through holes). The microsections shall be examined for degradation (see 5.6.1) at a magnification of 100X and referee inspection at 200X.

5.4 Report  Any observed degradation to the unetched or etched or unclad specimens shall be reported. The number and location of voids shall be reported for each specimen. Results of referee microsection examination will take precedence over visual examination.

6.0 Note  Automatic (gang mounting) microsectioning techniques may be used.

6.1 Desiccator Conditions  The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.
1 Scope  The purpose of this test is to determine the solderability of printed circuit boards (PCBs) that are to be joined by a soldering operation employing rosin flux and immersion in molten solder or by use of a soldering iron.

2 Applicable Documents
ASTM-B32  Solder
ASTM-D509  Flux
IPC-A-600  Acceptability of Printed Boards

3 Test Specimen
3.1  The specimens shall be representative of the manufactured product, consisting of three land strips from a printed wiring panel with a conductor pattern 0.64 cm wide by 5 cm in length.
3.2  When the printed wiring panels being tested contain circuit paths 0.64 cm wide, these may be used in lieu of the land strips.
3.3  The test specimens may also be terminal areas and conductor paths that are used for making electrical connections on production printed wiring panels or individual PWBs.

4 Equipment/Apparatus
4.1  An electrically heated, thermostatically controlled solder pot containing at least 1 kg of the required solder and of sufficient size to accommodate the required sample test specimens (0.64 cm x 5 cm). The temperature control shall be capable of maintaining the solder at a temperature of 232°C ± 6°C.
4.2  The solder shall meet the requirements of Alloy Grade 60B per ASTM-B32 - nominal composition 60% tin and 40% lead for Procedure A, B, and D. For Procedure C, the solder shall be as specified.

4.3 Flux  The flux shall be 25% by weight of Grade WW rosin per ASTM-D509 and 75% by weight of 99% isopropyl alcohol.
4.4  Stop watch
4.5  A microscope capable of examining specimens at 10X

5 Procedure
5.1 Test
5.1.1  Immerse the test samples described above in flux to a depth of 2.5 cm to 5 cm for five seconds.
5.1.2  Withdraw the samples from the flux and air dry for one minute in a vertical position. Then lower specimen until the bottom edge contacts the molten solder in the bath.
5.1.3  Hold this position for one to two seconds and immerse the specimen at a rate of approximately 1.3 cm per second to the depth that was fluxed. Keep in the solder for two seconds and withdraw at 1.3 cm per second.
5.1.4  Allow the samples to drain and cool in a vertical position.

5.2 Evaluation
5.2.1  After the specimens have been solder dipped and thoroughly cleaned of flux, they should be examined with at least a 10X lens.
5.2.2  Photographic standards in IPC-A-600A may be used in evaluating solderability, for PWBs and flat metal surfaces.
1 Scope  This document is intended to provide a recommended test method, which may be used by both vendor and user to determine solderability of PWBs, with or without surface coatings, which will be soldered by wave soldering machine methods or other soldering devices.

The solderability determination is made to verify that the printed wiring fabrication processes and storage have had no adverse effect on the solderability of the PWB. This is determined by evaluating the ability of those portions of the PWB normally soldered to be wetted by a new coat of solder. Determination is judged visibly by non-destructive methods.

The standard does not specifically relate to the solderability of the walls of plated-through holes (PTHs) but may be used for that purpose.

This standard shall not be construed as a production procedure for preparing and soldering PWBs.

1.1 Definitions

1.1.1 Solderability    The ability of a metal surface to be wetted by solder.

1.1.2 Wetting    The formation of a relatively uniform, smooth, unbroken, and adherent film of solder to a base metal.

1.1.3 Dewetting    A condition that results when the molten solder has coated the surface tested and then receded, leaving irregularly shaped mounds of solder separated by areas covered with a thin solder film; base metal is not exposed.

1.1.4 Not-Wetting    A condition that results when the molten solder has coated the surface tested and then receded, leaving irregularly shaped mounds of solder separated by areas covered with a thin solder film where some areas of the base metal are exposed.

2 Applicable Documents

J-STD-003    Solderability Tests for Wave Soldered PWBs
QQ-S-571    Solder Specification

3 Test Specimens
4.3.2 Flux  A non-activated rosin flux having a nominal composition of 25% by weight of water white gum rosin in a solvent of isopropyl alcohol (99% shall be used). The specific gravity of the flux shall be 0.843 ± 0.005 at 25°C. Other fluxes as agreed to between supplier and user may be used.

4.3.3 Flux Remover The flux remover shall be either isopropyl alcohol or other suitable solvent.

WARNING: Do not use chlorinated solvents on silicone base materials, as delamination and damage to finish may occur.

5 Procedure

5.1 Preparation

5.1.1 The PWBs shall be checked in an “as received” condition from the vendor and care shall be executed to prevent contamination (by grease, perspirants, etc.) of the surface to be tested.

5.1.2 The test samples are to be flux coated and preheated before proceeding with the solder application in accordance with the process agreed to by vendor and user. While fluxing may be done manually, it will generally be applied as part of the machine system.

5.2 Application

5.2.1 Wave/Machine Solder The process is to be agreed to between vendor and user. Note: Usually the manufacturing process generated by the user for wave soldering consists of a board holder, conveyor, flux applicator, preheater, solder unit, and operating instructions, which include machine settings, machine process controls on conveyor speed, conveyor incline, preheat temperature, solder temperature, fixture description, etc.

5.2.2 The solder composition shall be analyzed periodically for conformance with QQ-S-571.

5.3 Cleaning After the solder has been solidified, residual flux shall be removed from the specimens to facilitate inspection. Flux removing material shall be as specified in 4.3.2. Flux removal may be done manually or by machine.

5.4 Evaluation

5.4.1 After the sample parts have been wave soldered and thoroughly cleaned of flux, the parts shall be examined using the type of equipment specified in 4.2.

5.4.2 The criteria for acceptable solderability is a relatively uniform adhering coating of solder, which covers a minimum of 95% of the surface being tested. The balance of the surface may contain only small pinholes, dewetted areas, and rough spots, provided such defects are not concentrated in one area. For less critical applications, a smaller percent coverage may be determined by vendor and user. Solder build up or drainage on circuit areas where the circuit leaves the solder wave is acceptable. The PTH wall portion shall be partly wetted with solder, but need not be filled with solder.

5.4.3 A width of approximately 3.15 mm from the edge of each test specimen should not be evaluated.

5.4.4 Aids to Evaluation As an aid to evaluation of the test results, see Figure 1. This aid is to be used primarily to illustrate types of defects, rather than determine the percentage of area covered.
Figure 1 Types of Defects
1.0 Scope  This test prescribes the recommended test method for assessing the activity of liquid fluxes using a wetting balance.

2.0 Applicable Documents
ISO 1634

3.0 Test Specimen
3.1 The test specimen shall be a copper coupon complying with ISO 1634-CU-ETP Condition HA. The width shall be 6.0 ±0.25 mm wide; the length should be 25.0 ± 1 mm long or as appropriate to the test equipment. The thickness shall be 0.5 ±0.05 mm.

4.0 Apparatus and Reagents
4.1 Apparatus
4.1.1 A meniscus force measuring device (wetting balance) which includes a temperature-controlled solder pot containing solder maintained at 245 ±3°C. Note: Reaction rate is very sensitive at this temperature.
Solder composition shall be Sn60/Pb40 or Sn63/Pb37.
4.1.2 A chart recorder, data logger, or computer capable of recording force as a function of time with a minimum recorder speed of 10 mm/s.
4.1.3 A mechanical dipping device as shown in Figure 1 shall be used. This device shall be present to produce an immersion and emersion rate of 20–25 mm per second to a depth of 6.0 ±0.1 mm and a dwell time of 5.0 ±0.5 seconds.

5.0 Procedure
5.1 Preparation

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Figure 1 Wetting Balance Apparatus

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5.1.1 The test coupon should be cleaned (degreased) by immersion in a suitable solvent, then cleaned using a 10±1% fluoroboric acid dip.

5.1.2 The coupon shall then be washed with water and dried.

5.2 Test

5.2.1 After mounting the specimen in a suitable holder, the coupon should be immersed in the liquid flux at room temperature to a minimum depth of 10 mm.

5.2.2 Excess flux is to be immediately drained off by standing the specimen vertically on a clean filter paper for 1–5 seconds.

5.2.3 After partial drying, it should be mounted in the test equipment.

5.2.4 The surface of the molten solder shall be skimmed just prior to immersing the specimen in the solder.

5.2.5 The specimen in its holder shall be held for approximately 10±1 second, 3 mm above the solder pot. The test shall be started and the specimen immersed only once using an immersion and emersion rate of 20–25 mm per second to a depth of 5.0 ±0.1 mm and a dwell time of 5.0 ±0.5 seconds.

5.2.6 During the test, the wetting curve shall be recorded on a suitable device for use in the evaluation.

5.3 Evaluation Using the coupon as specified, fluxes which shall be evaluated for the following:

1. A wetting time (Tw) for the wetting curve to cross the corrected zero axis after the start of the test. (See Figure 2)

2. A maximum wetting force, Fmax, taken after correction for buoyancy (See 6.2).

6.0 Note This test method can be useful in requalifying materials that have exceeded the recommended shelf life. In addition, the method can help evaluate fluxing power prior to manufacturing operations on critical applications.

6.1 Safety Observe all appropriate precautions on MSDS for chemicals involved in this test method.

6.2 Correction for Buoyancy For the wetting balance to obtain wetting force values that are relatable to one another, it is necessary to correct for the variability in specimen sizes, in particular width and thickness. This is done by correcting for the volume of the sample immersed in the solder. The following formula may be used to calculate the buoyant force correction:

\[ P_b = \rho gV \]

\[ \rho = \text{Density of solder @ 245°C (8.15g/cm}^3) \]

\[ g = \text{Acceleration of gravity (9810 mm/s}^2) \]

\[ V = \text{Immersed volume of coupon (cm}^3) \]

\[ = \text{width x thickness x immersion depth} \]

When the buoyancy force is calculated it should be used to correct the zero axis. This correction is required to obtain both the proper measurement of wetting times as well as wetting forces. All measurements of wetting times and wetting forces must be made from the corrected zero axis. In the case of an upright curve, the new corrected zero axis will be below the instrument zero.

*For Sn60/Pb40 Alloy
Figure 2  Wetting Balance Curve

Note: The vertical force measured by the wetting balance is made up from two forces—the buoyancy force, and the wetting force caused by the contact angle changing from initial non-wetting to wetting.

The buoyancy force may be considered during the test, and is equal to the weight of the solder displaced, when the specimen is immersed into the solder.

The only changing force is the wetting force, caused by the changing contact angle, as the specimen solders.

The corrected zero (buoyancy) line is the force when the contact angle is 90°, or when the bath surface has returned to horizontal, having been initially depressed by the immersed sample.

The wetting balance curve is centered on the corrected zero (buoyancy) line since the only parameter that changes during the test is the contact angle. θ.

See equation 1:

\[ F = \gamma p \cos \theta - g \rho v \]  

Equation 1

Buoyancy = \( g \rho v \)  

Equation 2

where

\( F \) = The measured force in micronewtons

\( \gamma \) = Surface tension of molten solder (400 \( \mu \)N mm^{-1})

\( p \) = Specimen perimeter in mm

\( \theta \) = Contact angle

\( g \) = Gravitational acceleration (9.81 x 10^{-3} mm—sec^{-2})

\( \rho \) = Solder density (8000 \( \mu \)gm mm^{-3})

\( v \) = Immersed volume in mm^{3}

The corrected zero line (buoyancy) is a fixed reference point from which the force measurements should be taken. This line should also be used as a reference point for any time measurements.

Altering the specimen dimensions changes the immersed volume and hence the buoyancy, and so alters the position of the corrected zero line; but the wetting curve still remains centered on this line. Similarly, any change in immersion depth will also alter the immersed volume, with the same effect on the buoyancy.

Although use of the corrected zero line will cancel small variations in the specimen immersed volume and the immersion depth, large changes will affect the rate of heat transfer into the specimen, which will affect both \( T_w \), the time to recross the corrected zero (buoyancy) line and the time to reach \( F_{max} \).
1.0 Scope  A test method for measuring the geometric irregularities (roughness, waviness, etc.) of the surface of metal foils.

2.0 Applicable Documents  None

3.0 Test Specimen  Any sample of metal foil to be tested. Care must be taken to insure that there are no wrinkles or kinks in the sample.

4.0 Apparatus

4.1 Amplimeter, with range selector for measuring surface roughness in micro inches.

4.2 Piloior (electric) used to operate the tracer.

4.3 Tracer, for tracing and detecting surface irregularities.

4.4 Controlled Roughness Specimen

4.5 Surface Plate

5.0 Procedure

5.1 Test

5.1.1 Place the amplimeter on a rigid support such as a work bench, stand, or machine table with space beside it for the pilior that will be used.

Note: Do not connect the amplifier to a power line supplying heavy induction equipment such as induction furnaces, welders and induction motors. The starting and stopping of such equipment will cause fluctuations in the AC line voltage which may result in erroneous roughness readings.

5.1.2 Set the AA/RMS selector switch at AA (for arithmetical average), and turn on amplimeter.

5.1.3 Check setup for minimum vibration.

5.1.4 Set the roughness-width cutoff at 0.030 inch.

5.1.5 Set the “Range” selector switch.

5.1.6 Set the pilior stroke length between 1 in. and 1.5 in.

5.1.7 To make sure that the equipment in paragraph 4.0 is operating properly, take a reading of the rated roughness specimen.

Note: The controlled roughness specimen must be thoroughly cleaned before it is used. A dirty specimen will give erroneous readings.

5.1.8 If erroneous display readings are obtained, check the following conditions:

1. Amplimeter is turned on.
2. Tracer is connected to the amplimeter with all connections tight.
3. Tracer is moving over the work.
4. Tracer point is in contact with the work.
5. Check the tracer cable for wear and for open or short circuits.
6. Check for a blown fuse in the amplimeter.

5.2 Evaluation  Record roughness readings in micro inches using Arithmetical Average (AA). A minimum of 3 areas per sample should be taken for determining the surface roughness.
1.0 Scope This method covers the determination of the force required to initiate tearing in flexible insulating materials. It is based on ASTM D-1004-66 (1970).

2.0 Applicable Documents


3.0 Test Specimens

3.1 The specimens shall be prepared using flexible dielectric material from which the copper foil has been etched using standard commercial practices.

3.2 Ten specimens, five transverse and five longitudinal, shall be cut from the sample material.

3.3 The test specimens shall conform to the dimensions shown in Figure 1 and shall not vary by more than 0.5 percent from these dimensions.

4.0 Test Equipment

4.1 Testing Machines A power driven machine of either of the two following types shall be used:

4.1.1 Static Weighing Constant rate of grip separation type, negligible movement of the upper jaw.

4.1.2 Pendulum Weighing Constant rate of grip motion type, constant rate of lower jaw movement, variable upper jaw movement. Either maximum load indicating devices or recorders are permissible in the testing machine. The applied load, as indicated by a recorder, dial or scale, shall be accurate to within 12 percent. If an indicating device is used, the indicator shall remain at the point of maximum load after rupture of the test specimen.

4.2 Grips A gripping system that minimizes both slippage and uneven stress distribution on the specimen shall be used.

4.3 Thickness Measuring Devices Suitable micrometers, or thickness gages, reading to 0.0025 mm [0.0001 in] or less shall be used for measuring the thickness of the specimens.

4.4 Die A die having the dimensions shown in Figure 1 shall be used to cut all specimens. The 90° angle should be honed sharp with no radius or have a minimum practical radius. The cutting edge of the die shall have a 5° negative rake, and shall be kept sharp and free from nicks to avoid leaving ragged edges on the specimen. Cutting may be facilitated by wetting the surface of the sample and cutting edges of the die with water. The sample shall rest on the smooth, slightly yielding surface that will not injure the die blade. Lightweight cardboard or a piece of leather belting is suitable. Care should be taken that the cut edges of the specimen are perpendicular to its other surfaces and that the edges have a minimum of concavity.

4.5 Conditioning Apparatus Apparatus for maintaining laboratory atmospheric conditions of 23 ± 1°C (73.4 ± 1.8°F) and 50 ± 2 percent RH for conditioning prior to and during testing shall be used.
5.0 Conditioning

5.1 Conditioning  Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 percent relative humidity for not less than 24 hours prior to test.

5.2 Test Conditions  Conduct tests in the Standard Laboratory Atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 percent relative humidity.

6.0 Speed of Testing  A jaw separation of 25.4 mm [1 in] shall be used. The rate of travel of the power activated grip shall be 51 mm [2 in]/minute and shall be uniform at all times.

7.0 Procedure

7.1 Measure the thickness of the specimen at several joints to the accuracy limits of the measuring devices specified in 4.3. Record the average thickness in inches.

7.2 Place the specimen in the grips of the testing machine so that the long axis of the enlarged ends of the specimen is in line with the points of attachment of the grips to the machine.

7.3 Apply the load at 51 mm [2 in]/minute rate of grip separation. After complete rupture of the specimen, the maximum tearing load in grams (ounces) shall be noted from the dial scale or recorder chart and recorded. Data from specimens which break at some obvious flaw or which break in or at the edges of the grips shall be discarded and retests made.

8.0 Calculation  The average resistance to tearing shall be calculated from all specimens tested in each principal direction of orientation. Data shall be recorded as grams (ounces) of tearing resistance.

9.0 Report

9.1 Report the average thickness of all specimens.

9.2 Report the average transverse and the average longitudinal initiation tear strength.
1.0 Scope
This method is to determine the average force in grams required to propagate tearing through a specific length of the constant radius specimen. Because of the variation of materials and orientation of fibers, the method has been designed to compensate and derive acceptable data.

2.0 Applicable Documents
ASTM-D-689 Tear Strength

3.0 Test Specimens
At least five specimens from each direction are required to obtain an average result. They shall be cut as per Fig. 1. A Thwing-Albert Co. TA63 Sample Cutter, Catalog No. 98 may be used.

4.0 Apparatus
A Pendulum Impulse Tester from Thwing-Albert Co., or equal, having: stationary clamp, moveable clamp, stop catch, pointer and scale.

5.0 Procedure
5.1 Preparation
5.1.1 Cut specimens, adjust and calibrate apparatus paying particular attention to the pendulum to be certain it swings freely.

5.1.2 Separate clamps 0-10 in. apart and align the specimen in the plane perpendicular to the plane of the oscillation of the pendulum, with the edges of the jaws gripping the specimen in a horizontal line.

5.2 Test
5.2.1 Raise the pendulum to its top position, place specimen midway in the clamps so that its upper edge is parallel to the top of the clamps and the precut initial slit is at the bottom of and between the clamps at right angles to their top.

5.2.2 Release the stop latch and tear the specimen.

5.2.3 As the pendulum section completes its swing, catch it, being careful not to disturb the position of the pointer.

5.3 Evaluation
Examine specimen carefully. If torn through the constant-radius section within approximately 60° on either side of the vertical line of intended tear, record the pointer reading to the nearest 0.5 unit. If torn outside the 60°, disregard specimen and test a new piece. Calculate the tearing resistance in grams (R), as follows:

\[ R = \frac{S \times C}{n} \]

5.1.3 The clamping surface of the jaws must be at least 1 in. in width and 0.5 in. in depth.

6.0 Notes
Thwing-Albert Instrument Co. is located in Philadelphia, Pennsylvania.
1.0 Scope
This method covers the determination of the force necessary to propagate a tear in flexible insulating materials. It is based on ASTM D 1938-67 (1978).

2.0 Applicable Documents

3.0 Test Specimens
3.1 The specimens shall be prepared using flexible dielectric material from which the copper foil has been etched using standard commercial practices.

3.2 The specimens shall be of the single-tear type and shall consist of strips 75 mm [3 in] long by 25 mm [1 in] wide and shall have a clean longitudinal slit 50 mm [2 in] ± 2 percent long cut with a sharp razor blade (Figure 1) or the equivalent.

3.3 The thickness of the specimen below the slit (see Figure 1) shall be measured in several places and recorded in millimeters to the nearest 0.0025 mm [0.0001 in].

3.4 Enough specimens shall be cut to provide a minimum of five tear propagation force determinations each in the machine direction and in the transverse direction of the material being tested.

4.0 Apparatus
4.1 Film Testing Machine Must have weighing head that can measure the load applied to tear the specimen. It should be equipped with a device for recording the load carried by the specimen and amount of separation of the grips during the test. The testing machine shall be essentially free from inertia lag at the specified rate of testing and shall indicate the load with an accuracy of ± 2 percent of the indicated value or better. A device shall be included to control the grip separation rate at 250 mm [10 in] ± 5 percent/min.

4.2 Thickness Measuring Devices Suitable micrometers, or thickness gages, reading to 0.0025 mm [0.0001 in] or less shall be used for measuring the thickness of the specimens.

4.3 Cutter The cutter shall be a sharp razor blade or the equivalent.

4.4 Conditioning Apparatus Apparatus for maintaining laboratory atmosphere conditions of 23 ± 1°C (73.4 ± 1.8°F) and 50± 2 percent RH for conditioning prior to and during testing shall be used.

5.0 Conditioning
5.1 Conditioning Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 percent relative humidity for not less than 24 hours prior to test.

5.2 Test Conditions Conduct tests in the Standard Laboratory Atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 percent relative humidity.

6.0 Procedure
6.1 Secure tongue A (Figure 1) in one grip and tongue B in the other grip of the constant-rate-of-grip separation machine, using an initial grip separation of 50 mm [2 in]. Align the specimen so that its major axis coincides with an imaginary line joining the centers of the grips.

Figure 1  Single-tear specimens
6.2 Using a grip separation speed of 250 mm [10 in]/minute, start the machine and record the load necessary to propagate the tear through the entire unslit 25-mm [1 in] portion.

6.3 Test not less than five specimens in each of the principal film or sheeting directions.

7.0 Calculation

7.1 For thin films and sheeting that have load-time charts characterized by Figure 2, the average tear propagation force in grams (ounces) is obtained by averaging the load indicated on the chart over the time period, disregarding the initial and final portions of the curve. This can be done with an integrator or a planimeter. In some cases, a fairly accurate estimate can be made by eye.

7.2 For thin films and sheeting that have load-time charts characterized by Figure 3, the initial force to continue the propagation of the slit and the maximum force attained are obtained from the chart and reported in grams (ounces). The initial force may be more readily detected by placing a dot approximately 3 mm [1/8 in] in diameter at the base of the razor blade slit with a china marking wax pencil. As the load is applied to the sample, the dot area is observed. When the load is just sufficient to begin the extension of the slit, a “blip” is introduced on the chart (see Figure 3) by pushing the appropriate button on the recorder or the equivalent to mark this point. The maximum load is the highest reading on the chart as indicated. Both the initial load and the maximum load are reported in grams (ounces).

7.3 The average resistance to tearing shall be calculated from all specimens tested in each principal direction of orientation. Data shall be recorded as pounds of tearing resistance.

8.0 Report

8.1 Report the average thickness of all specimens.

8.2 For materials described in 7.1, report the average of the five average tear propagation determinations in grams (ounces) for the transverse and for the longitudinal direction of the material.

8.3 For materials described in 7.2, report the average of the five initial tear-propagation forces and the average of the five maximum tear-propagation forces in grams (ounces) for the transverse and for the longitudinal direction of the material.
1.0 **Scope**  To determine the tensile strength (in PSI) and the elongation (in percentage) of copper foil at ambient and elevated temperatures by mechanical force testing.

2.0 **Applicable Documents**

ASTM-E-345  Tensile Strength

3.0 **Test Specimens**  Copper foil sufficient in size to permit cutting or etching of five specimens 10 inches x ½ inch. Specimens must be clean cut and free of burrs and nicks.

4.0 **Apparatus**

4.1 Constant strain rate tensile tester capable of pulling at rate of 0.050 and 2.0 inches/minute.

4.2 JDC #50 sample cutter ½ inch wide x 10 inches long.

4.3 A shear to cut 10 inches long sample to 6 inches long.

4.4 Mettler Balance type P120 or equivalent.

4.5 Elevated temperature chamber or fixture, attachable to the tensile tester, capable of reaching and maintaining a temperature of 180°C ±10°C during sample testing.

5.0 **Procedure**

5.1 **Preparation of Samples**

5.1.1 The sample should be smooth and undistorted (wrinkle free).

5.1.2 Use the JDC #50 to cut five tensile specimens.

5.1.3 Cut the five 10 inches long specimens to 6 inches long.

*Note:* Accuracy is important in the ½ inch x 6 inches dimensions because it is used to determine foil thickness and cross-sectional area.

5.2 **Weighing Samples**

5.2.1 Weigh tensile sample to at least three places beyond the decimal point, in grams.

5.2.2 Record the weight and calculate the mean average cross-sectional area.

*Note:* The density of electrodeposited copper is 8.909 gm/cc (16.389 cc/in³ x 8.909 gm/cc = 146 gm/in³).

The density of rolled copper is 8.93 gm/cc (16.389 cc/in³ x 8.93 gm/cc = 146.35 gm/in³).

\[
\text{Mean avg. thickness} = \frac{\text{Weight of tensile sample in grams}}{\text{Area of Tensile sample in sq. inches} \times \text{The density of copper in gm/in}^3}
\]

\[
\text{Mean avg. cross-sectional area} = \frac{\text{Weight of tensile sample in grams}}{\text{Area of Tensile sample in sq. inches} \times \text{The density of copper in gm/in}^3}
\]

5.3 **General Test Information**

5.3.1 If the tensile tester is equipped with an area compensator, dial the mean average cross-sectional area into it. If not then the cross-sectional area has to be used to compute the tensile strength.

*Note:*

\[
\text{Tensile Strength} = \frac{\text{Load used to break sample in lbs.}}{\text{Mean average cross-sectional area}}
\]

If Tensile Tester is equipped with area compensator after the test is complete, the Tensile Strength can be read directly from the chart.

5.3.2 **Ambient Temperature Testing**

5.3.2.1 Select load range.

5.3.2.2 Place the sample in the jaws of the Tensile Tester.
being careful that it is properly centered and the axis aligned with the jaws.

5.3.2.3 Test Conditions

(1) Gage length 2.0 inches
(2) Crosshead speed 2.0 inches/min.
(3) Chart speed 20 inches/min.

Note: At a chart speed of 20 inches/min., a gage length of 2.0 inches and a crosshead speed of 2.0 inches/min., each one inch of chart paper equals 0.125% linear elongation.

5.3.3 Elevated Temperature Testing

5.3.3.1 Select load range.

5.3.3.2 Bring temperature chamber or fixture up to 180°C ±10°C.

5.3.3.3 Open temperature chamber and clamp foil sample between tensile jaws. (Note: Caution must be exercised to avoid excessive clamping pressures and to provide good sample alignment for testing.)

5.3.3.4 Close temperature chamber and monitor sample temperature with a thermocouple. Permit foil sample to dwell at 180°C temperature for 5 minutes prior to tensile test. Maximum time at temperature should not exceed 10 minutes.

5.3.3.5 Test Conditions

(1) Gage length 2.0 inches
(2) Crosshead speed 0.050 inches/min.
(3) Chart speed 20 inches/min.

Note: Temperature chamber contains normal ambient air. Inert gas atmosphere is not necessary, but may be used.

5.4 Evaluation

5.4.1 Activate crosshead to break sample and make calculations of tensile strength in pounds/in² and elongation in %.

5.4.2 Percent elongation may be determined by fitting the ends of the fractured specimen together carefully and measuring the distance between the original gage marks to the nearest 0.01 inch. Elongation is the increase in length of the gage length, expressed as a percentage of the original gage length.

Percent elongation = \[
\frac{\text{length at break} - \text{original gage length} \times 100}{\text{original gage length}}
\]

5.4.3 Average all five elongation readings.

6.0 Notes

6.1 For guidance, typical values for tensile strength and elongation are:

<table>
<thead>
<tr>
<th>TENSILE STRENGTH</th>
<th>Electrodeposited</th>
<th>Light cold rolled</th>
<th>Annealed</th>
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<tr>
<td>Oz/ft²</td>
<td>Standard or high ductility</td>
<td>As rolled</td>
<td>lb/in²</td>
</tr>
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<td>15,000</td>
<td>50,000</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>30,000</td>
<td>50,000</td>
<td>—</td>
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<tr>
<td>2 &amp; over</td>
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<td>50,000</td>
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<table>
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<th>ELONGATION</th>
<th>Electrodeposited</th>
<th>Light cold rolled</th>
<th>Annealed</th>
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<tr>
<td>Oz/ft²</td>
<td>Standard</td>
<td>High ductility</td>
<td>As rolled</td>
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<tr>
<td>1/2</td>
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<td>10</td>
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<tr>
<td>2</td>
<td>3</td>
<td>15</td>
<td>1</td>
</tr>
</tbody>
</table>
1.0 Scope
To determine the tensile strength in Mpa (PSI) and the elongation, in percentage, of electrodeposited copper plating at ambient temperatures by mechanical force testing.

2.0 Applicable Documents
ASTM E-345 Standard Test Methods of Tension Testing of Metallic Foil
IPC-TM-650 Method 1.7

3.0 Test Specimen
3.1 Plated copper samples prepared in sheet form for cutting or etching into the appropriate pattern, or pattern plating of the appropriate form.

3.2 Samples may be in the form of strips of 13 mm X 152 mm or in the form of “dogbone” samples as described in ASTM E-345, Type A. The thickness of the samples 0.05 mm to 0.1 mm. Testing shall be performed on 10 samples (5 lengthwise and 5 crosswise). Specimens must be wrinkle free, clean cut, and free of burrs and nicks.

4.0 Apparatus or Material
4.1 Constant strain rate tensile tester capable of pulling at rate of 0.05 to 0.5 mm/mm per minute of the length of the reduced section (or the distance between the grips for straight sided specimens).

4.2 Sample preparation equipment
4.3 Sample Size: 13 mm wide X 150 mm long.

4.4 A sample cutter capable of cutting samples to the appropriate size. See Note 6.1.

4.5 A phototool of tensile specimen of the appropriate size (strip or dogbone).

4.6 Stainless steel panel, type 304 or 321, 300 mm X 300 mm or of a size identical to that used to produce plated product. The panel surface must be free of pits, nicks, and scratches. Low carbon stainless steel performs best.

4.7 Weighing Balance capable of resolving to 1 mg.

4.8 Precision linear measuring device capable of measuring to the nearest 0.025 mm.

4.9 Precision micrometer capable of measuring to the nearest 0.0025 mm.

4.10 An oven capable of maintaining 125°C ± 5°C.

5.0 Procedure
5.1 Samples Preparation
Samples may be prepared using the phototool Method 5.1.1 or the cut Method 5.1.2.

5.1.1 Phototool Method
5.1.1.1 Clean the stainless steel panel using a standard acid or alkali cleaner (preferably reverse current) and verify by performing water-break test to insure cleanliness.

5.1.1.2 Apply negative resist to stainless steel plate.

5.1.1.3 Image plate with phototool and develop image using any acceptable method.

5.1.1.4 Inspect image for integrity.

5.1.1.5 Plate the imaged panel with a current density equivalent to production current density to a thickness of 0.05 mm to 0.1 mm.

5.1.1.6 Rinse and dry plate.

5.1.1.7 Remove specimens from the stainless steel by lifting a corner of the sample with a knife or razor exercising care not to bend or in any way damage the sample.

5.1.1.8 Inspect samples and discard those with nicks or pinholes in the gage length. Specimens should be smooth and undistorted without scratches from the plate in the gage length.

5.1.2 Cut Method
5.1.2.1 Clean the stainless steel panel using a standard acid or alkali cleaner (preferably reverse current) and verify by performing a water-break test to insure cleanliness.

5.1.2.2 Plate the panel with a current density equivalent to production current density to a thickness of 0.05 mm to 0.1 mm.

5.1.2.3 Remove the copper from the stainless steel by lifting a corner of the sample with a knife or razor exercising care not to bend or in any way damage the sample. Cut away and discard the outside 2.5 cm of the border of the sample.

5.1.2.4 Cut the specimens (5 lengthwise and 5 crosswise) using the sample cutter. Samples shall be smooth, undistorted (wrinkle free), and free of pinholes, nicks, and scratches.

5.1.2.5 Bake all specimens at 125°C ± 5°C for 4 to 6 hours, then allow the samples to cool to room temperature.

5.1.2.6 Mark (or otherwise note) a 50 mm gage length to the nearest 0.01 mm per ASTM E-345.

5.1.2.7 Weighing Samples Weigh tensile sample to at least the nearest milligram (0.001 gram). Record the weight and calculate the mean average cross-sectional area. Note: The density of electrodeposited copper is 8.909 g/cc or 8909 g/mm³.

Mean average thickness in millimeters =

\[
\frac{\text{Weight of tensile sample in grams}}{\text{Area of tensile sample in sq. mm}} \times \frac{\text{The density of copper in g/mm}^3}{\text{The density of copper in g/mm}^3}
\]

Mean average cross-sectional area in mm² =

\[
\frac{\text{Weight of tensile sample in grams}}{\text{Length of tensile sample in mm}} \times \frac{\text{The density of copper in g/mm}^3}{\text{The density of copper in g/mm}^3}
\]

5.2 General Test Information

5.2.1 If the tensile tester is equipped with an area compensator, dial the mean average cross-sectional area into it. If not then the cross-sectional area has to be used to compute the tensile strength.

Note:

\[
\text{Tensile Strength (Pa) =} \frac{\text{Maximum Load (N)}}{\text{Mean average cross-sectional area (m}^2)}
\]

or

\[
\text{Tensile Strength (Mpa) =} \frac{\text{Maximum Load (N)}}{\text{Mean average cross-sectional area (mm}^2)}
\]

or

\[
\text{Tensile Strength (psi) =} \frac{\text{Maximum Load (lbf)}}{\text{Mean average cross-sectional area (in}^2)}
\]

To convert psi to Pa multiply by 6.895 X 10³.
To convert psi to MPa multiply by 6.895 X 10⁻³.

5.2.1.1 If Tensile Tester is equipped with area compensator after the test is complete, the Tensile Strength can be read directly from the chart.

5.2.2 Select an appropriate load range on the tensile tester so that the expected force is within the acceptable load range for the cell.

5.2.3 Place the sample in the jaws of the Tensile Tester being careful that it is properly centered and the axis aligned with the jaws.

5.2.4 Test Conditions

5.2.4.1 Gage length: 50 mm

5.2.4.2 Crosshead speed: 0.05 to 0.5 mm/mm per minute of the length of the reduced section (or the distance between the grips for straight sided specimens).
5.2.4.3 Chart speed: 500 mm/min.

5.3 Evaluation

5.3.1 Activate crosshead to break sample and make calculations of tensile strength in Mpa and elongation in %.

5.3.2 Percent elongation may be determined by fitting the ends of the fractured specimen together carefully and measuring the distance between the original gage marks to the nearest 0.25 mm. Elongation is the increase in length of the gage length, expressed as a percentage of the original gage length.

Percent elongation =

\[
\frac{\text{length at break} - \text{original gage length}}{\text{original gage length}} \times 100
\]

5.3.3 Average all five elongation readings. See IPC-TM-650, Method 1.7, for information about discarding invalid results.

6.0 Notes

6.1 The JDC-50 sample cutter has been found suitable for cutting specimens to the appropriate dimensions. This cutter is manufactured by Thwing-Albert Instrument Co., 10960 Dutton Road, Philadelphia, PA 19154.
1.0 Scope  This method determines the hot rupture strength of foil by measuring the elevated temperature rupture pressure and the bulge height at rupture.

2.0 Applicable Documents
IPC-MF-150

3.0 Apparatus
3.1 EMK Model HD550 Hot Rupture Testing Machine, or equivalent, with fixed apertures for 17 micron [1/2 oz.], 34 micron [1 oz.] and 68 micron [2 oz.] foil.

3.2 Mettler balance, Type H16 Cap 80 gms, or equivalent; and hand shears or precision paper cutter.

4.0 Test Specimen Generation
4.1 Nine (9) test specimens, up to 114 x 114 mm [4.5 x 4.5 inches] in size, are required for each sample lot. Larger sample panels can be cut into specimen squares by the use of a template and hand shears.

4.2 Foil samples should be representative of foil material lots as defined in IPC-MF-150.

4.3 For the rupture testing of in-house PTH copper, electro-plate a sample onto a smooth stainless steel panel per existing PWB shop practice. The current density used for sample preparation should be equivalent to that used in PTH production schedules. The deposited thickness should be held within ±5% of 0.018 mm [1/2 oz.], 0.035 mm [1 oz.], or 0.071 mm [2 oz.] foil.

4.4 Thermal strain relief prior to rupture testing is limited to times and temperatures at or below the highest heating cycles used in PWB production.

5.0 Test Procedure
5.1 For Inner-layer foil specimens, record the date, source, lot identification, nominal foil thickness, foil type, foil grade, and the aperture diameter.

5.2 For PTH foil specimens, record the date, source, PTH bath type, the measured thickness and the aperture diameter.

5.3 Aperture Plates  Select and install the desired aperture plate for 0.018 mm [1/2 oz.], 0.035 mm [1 oz.] or 0.071 mm [2 oz.] test specimen.

5.3.1 Aperture diameters are fixed at 22.2 + 3.2 mm [0.875 + 0.125 ″ r] for 1/2 oz. foil; 22.2 + 3.2 mm [1.875” + 0.125” r] for 1 oz. foil; and 73 + 3.2 mm [2.875” + 0.125” r] for 2 oz. foil.

5.4 Flow Control  Rate of flow is fixed for the stress rupture test. The flow rate is fixed by setting the source pressure at 100 psig, sealing the system and adjusting the flow to reach 50 psig in 5 seconds.

5.5 Test Temperature  Set the test equipment for tests, in turn, at room temperature, 350°F [177°C] and 550°F [288°C]. Temperature stabilization for hot tests requires a minimum of 15 minutes at temperature (without foil specimens) before the first test is run.

5.6 Pressure  Set the test pressure regulator at the source pressure limit. Re-set the pressure gauge to zero and set the Peak and Hold modes.

5.7 Specimen Insertion  Place treated foil specimens in the test fixture with the treated side up, others with either side up. Clamp in place with sufficient force to provide a pressure-tight seal.

5.8 Height  Position the height gauge at the center of the aperture. Re-set the height gauge to zero and set the Peak and Hold modes.

5.9 Turn on the test pressure. After rupture occurs, turn the pressure off, and remove the test specimen.

5.10 Record the test temperature, the pressure at rupture, and the bulge height at rupture. With digital gauges, take Peak readings within 10 seconds of rupture (because of an inherent decay in the peak signal).
5.11 At least three test specimens, per lot, are tested at each test temperature.

5.12 To avoid creep and/or thermal effects, keep the total test cycle time (Steps 5.7 through 5.9) under 2 minutes.

6.0 Evaluation

6.1 The stress rupture test is quantitative for rupture pressure and for bulge height at each test temperature.

6.2 Report the rupture pressure and the bulge height at rupture for each test specimen at each test temperature.

6.3 Discard test specimens with obvious defects and/or evidence of plating artifacts (before or after the rupture test).
1.0 Scope

This test method establishes a procedure for determining the tensile strength, elongation and Young’s modulus of organic free films.

2.0 Applicable Documents

ASTM D 618  Standard Practice for Conditioning Plastics and Electrical Insulating Materials for Testing
ASTM D 882  Standard Test Methods for Tensile Properties of Thin Plastic Sheeting

3.0 Test Specimen

The test specimen shall consist of a strip 12.70 mm wide by 76.20 mm in length and at least 10 µm in thickness. The width of the specimen should not deviate by more than 2% over the length of the specimen between the grips. The thickness of the films shall not vary by more than 10% over the entire film. A minimum of ten specimens are required.

4.0 Apparatus or Material

4.1 Thickness Measurement Device  Mitutoyo 519-605 Mini-Checker with a 519-891 probe with vacuum assist connected to a MUX-10 multiplexer or equivalent thickness measurement device accurate and precise to 0.1 µm.

4.2 Width Measurement Device  Micrometer or equivalent width measurement device capable of measuring to 0.25 mm.

4.3 Specimen Cutter  Thwing-Albert JDC Precision Cutter or equivalent. The specimen cutting device must be capable of cutting a film strip 12.70 ± 0.25 mm wide over the length of the specimen. It is imperative that the cutting edges be kept sharp and free from visible scratches or nicks. The use of striking dies is not recommended because of poor and inconsistent specimen edges.

4.4 Tensile Tester  Instron Model 4501 Tensile Tester with a 0.2 kN load cell or equivalent. The testing machine must be equipped with a load cell whose compliance is a maximum of 2% of the specimen extension within the range being measured. Digital (as opposed to analog) self-calibrating load cells are preferred since they eliminate the need for and potential error associated with calibrating analog load cells using external weights. The testing machine must be equipped with a device for recording the tensile load and the amount of separation of the grips; both of these measuring systems should be accurate to ± 2%. The rate of separation of the grips shall be accurate to ± 0.1% and capable of adjustment from approximately 0 to 50 mm/min.

4.5 Gripping Devices

A gripping system that minimizes both slippage and uneven stress distribution must be used. The grips must be self-aligning, i.e. they must be attached in such a manner that they will move freely into alignment as soon as any load is applied so that the long axis of the specimen will coincide with the direction of the applied pull through the center line of the grip assembly.

4.6 Grip Faces

Specimen slippage and necking of the specimen up into the grips are two of the most common problems with this test method. Slippage can be checked by drawing a series of parallel lines across the part of the specimen in the grips. After pulling the specimen, if the lines are not parallel, the specimen may be slipping on one side. On specimens with high elongations, necking of the specimen into the grips is a problem. As the specimen elongates, the reduction of area (necking) results in a loosening of the specimen at the inside edges of the grips. This loosening propagates further back into the grips with continued elongation of the specimen. This can lead to erroneous results for the elongation. Air-actuated grips lined with rubber faces (e.g., neoprene) that have been machined flat were found to be effective against both of these problems and still allowed the specimen to be easily removed from the grips after the test. Another approach is to use line grips, i.e. grips having faces designed to concentrate the entire gripping force along a single line the width of the specimen perpendicular to the direction of the testing stress. This is usually done by combining one standard flat grip face and an opposing grip face that has been cut down. In cases where specimens frequently fail at the edge of the grips, it may be advantageous to round the edges of the grip faces where they meet the test area of the specimen.
4.7 Extension Indicators (optional) Extension indicators (e.g., extensometers) must be designed as to minimize stress on the specimen at the contact points of the specimen and the indicator. Clip type extensometers are not recommended for this reason. Laser extensometers can be used if the method of marking the specimen does not induce any stress or strain into the specimen (e.g., scratching the specimen) or change the specimen in any fashion (e.g., heating the specimen).

4.8 Calibration The thickness gauge should be calibrated every six months using standard gauge blocks. The blades on the film cutter should be resharpened or replaced at least once a year. The load cell on the tensile tester should be calibrated at least once a week following the manufacturer’s recommended procedure. Also, the stops which control the initial grip separation should be checked once a week.

5.0 Procedure

5.1 Operating Conditions The tests should be conducted at 23 ± 2°C and 50 ± 5% relative humidity.

5.2 Preparation of Test Specimens

5.2.1 The test specimens should be conditioned at 23 ± 2°C and 50 ± 5% relative humidity for not less than 24 hours prior to testing. Refer to ASTM D 618.

5.2.2 The free films are placed between two cover sheets of clear film (Mylar® or equivalent) to facilitate handling of the specimens.

5.2.3 Cut at least 10 specimens 76.20 mm long and 12.70 mm wide. No specimen shall vary by more than 2% in width along its entire length. The utmost care must be exercised in cutting specimens to prevent nicks and tears along the edges of the specimen that are likely to cause premature failure. If the properties in the plane of the film are not isotropic (e.g., the films were not prepared by spin coating), then ten films must be cut in both the machine direction (MD) and transverse direction (TD).

5.4 Testing

5.4.1 Measure and record the thickness of the test specimen to an accuracy of 0.1 µm at no fewer than five different places within the gauge length area. Refer to ASTM D 1005 and AST D 2370.

5.4.2 Set the initial gauge length (grip separation) at 25.4 mm and the rate of grip separation at 5.08 mm/min.

5.4.3 Place the specimen in the grips of the testing machine, taking care to align the long axis of the specimen with an imaginary line joining the points of attachment of the grips to the machine. The specimen should be aligned as perfectly as possible with the direction of pull so that no rotary motion that may induce slippage will occur in the grips. Tighten the grips evenly and firmly to the degree necessary to minimize slipping of the specimen during testing. The use of air activated grips facilitates the mounting of the specimen in the grips.

5.4.4 Start the test and record the load versus extension.

5.4.5 Repeat steps 5.4.1 - 5.4.4 for each series of ten specimens.

5.5 Calculations

5.5.1 For each series of ten specimens, the arithmetic mean and standard deviation of each property for the specimens with the five highest tensile strengths shall be calculated to the proper number of significant figures. This is done on the basis that the expected errors (nicks or flaws in the specimen, breaks within the grips, specimen slippage, etc.) would all tend to produce lower results. The standard deviation is calculated as follows and reported to two significant figures:

\[ s_x = \sqrt{\frac{N \sum \left( X_i^2 \right) - \left( \sum X_i \right)^2}{N(N-1)}} \]

where \( X_i \) is the value of a single observation (\( i = 1 \) through \( N \)), \( N \) is the number of observations, and \( s_x \) is the estimated standard deviation.

5.5.2 Tensile Strength Tensile strength is calculated by dividing the load at break by the original minimum cross-sectional area. The result is expressed in megapascals (MPa) and reported to three significant figures.

\[ \text{tensile strength} = \frac{\text{load at break}}{\text{original width} \cdot \text{original thickness}} \]

5.5.3 Percent Elongation Percent elongation is calculated by dividing the elongation at the moment of rupture by the initial gauge length and multiplying by 100. When gauge marks or extensometers are used to define a specific test section,
only this length is used in the calculation, otherwise the distance between the grips is used as the initial gauge length. The result is expressed in percent and reported to two significant figures.

\[
\text{percent elongation} = \frac{\text{elongation at rupture}}{\text{initial gage length}} \times 100
\]

5.5.4 Young’s Modulus Young’s modulus is calculated by drawing a tangent to the initial linear portion of the stress-strain curve, selecting any point on this tangent, and dividing the tensile stress by the corresponding strain. For purposes of this calculation, the tensile stress shall be calculated by dividing the load by the average original cross section of the test specimen. The result is expressed in gigapascals (GPa) and reported to three significant figures.

\[
\text{Young’s modulus} = \frac{\text{load at point on tangent}}{(\text{original width})(\text{original thickness})} \frac{\text{original width}}{(\text{original thickness})} \frac{\text{elongation at point on tangent}}{\text{initial gage length}}
\]

5.5.5 Toe Compensation (from ASTM D 882) In a typical stress-strain curve (see below), there is a toe region, AC, which does not represent a property of the material. It is an artifact caused by a take-up of slack, and alignment or seating of the specimen. In order to obtain correct values of such parameters as modulus, strain, and yield point, this artifact must be compensated for to give the corrected zero point on the strain or extension axis. In the case of a material exhibiting a region of Hookean (linear) behavior as shown below, a continuation of the linear (CD) region of the curve is constructed through the zero-stress axis. The intersection (B) is the corrected zero-strain point from which all extensions or strains must be measured, including the yield point, if applicable. The elastic modulus can be determined by dividing the stress at any point along line CD (or its extension) by the strain at the same point (measured from point B, defined as zero-strain).

6.0 Notes The tensile properties determined using this test method will vary with method of specimen preparation, specimen thickness, specimen width, rate of grip separation, initial gauge length, type of grips used, and method of measuring extension. The tensile strength and elongation are sensitive to the specimen dimensions and any flaws in the specimen. Young’s modulus is an index of the stiffness of the specimen and is sensitive to the rate of grip separation. Note that materials that fail by tearing give anomalous data that cannot be compared with those from normal failure (rupture). A tear failure is a tensile failure characterized by fracture initiating at one edge of the specimen and progressing across the specimen at a rate slow enough to produce an anomalous stress-strain curve. Results obtained using different specimen dimensions or at different rates of grip separation are not comparable; consequently, when trying to make quantitative comparisons between specimens or between laboratories, these factors must be carefully controlled.
1 Scope
This test is to determine the tensile strength and elongation on specimens exposed to mechanical loads.

2 Applicable Documents
None

3 Test Specimen
The test specimen shall consist of a strip of flexible material 152.4 mm long x 12.7 mm wide. A minimum of 10 specimens, five from the machine direction, and five from the transverse direction, shall be prepared.

4 Apparatus

4.1 Equipment
Tinius-Olson Super L Tester or equivalent (with appropriate load cell). The machine used for tension testing shall be in current calibration. The loads used in determining tensile strength shall be within the loading range of the testing machine.

4.2 Gripping Devices
Various types of gripping devices may be used to transmit the measured load applied by the testing machine to the test specimens. To ensure axial tensile stress within the gauge length, the axis of the test specimen should coincide with the centerline of the heads of the testing machine.

4.3 Sample Cutter
Thwing Albert Sample Cutter, Model No. JDC-50, or equivalent.

4.4 Etcher

4.5 Sander

4.6 Micrometer with 0.0025 mm resolution

4.7 Conditioning chamber or work area 23°C ± 2°C, 50% ± 5% RH

5 Procedure

5.1 Preparation of Specimens

5.1.1 Condition specimens for 24 hours at 23°C ± 2°C and 50% ± 5% relative humidity (RH). Stabilization time may be reduced if statistically sound evidence has been generated on the specific product line to support shorter conditioning times to reach equilibrium.

5.1.2 Cut at least 10 specimens, 152.4 mm long by 127 mm wide, using a precision sample cutter, which produces smooth and undistorted edges. Specimens may be sanded on the edges with 400-600 grit emery paper to further smooth the edges and improve the repeatability of the test.

5.2 Test

5.2.1 Measure and record the width and thickness of the specimen at several points along its length. Calculate the minimum cross-sectional area using the measured width. For coated materials, ignore the thickness of the coating, assumed to contribute nothing to the tensile properties of the composite, and use the nominal substrate thickness for the cross-sectional area calculation.

5.2.2 Set the grip separation to 101.6 mm and the rate of grip separation to 50.8 mm per minute.

5.2.3 Place the test specimen in the grips of the testing machine, taking care to align it with the centerline of the grips. There should be no slack in the specimen.

5.2.4 Start the machine and record load versus extension (grip separation).

5.3 Evaluation

5.3.1 Tensile strength shall be calculated by dividing the load at break by the original cross-sectional area of the specimen. Average the five values obtained for the machine direction samples and report the average. Average the five values
obtained for the transverse direction samples and report the average.

5.3.2 Elongation shall be calculated by the following formula:

\[
\frac{D_2 - D_1}{D_1} \times 100 = \% \text{Elongation}
\]

Where:
- \(D_1\) = Initial grip separation 101.6 mm
- \(D_2\) = Grip separation at break

Average the five values obtained for the machine direction samples and report the average. Average the five values obtained for the transverse direction samples and report the average.

6 Notes If a statistically sound evaluation shows that MD and TD differ, the direction giving the lower measurement shall be the only direction tested. If the two are the same, only MD needs to be tested.
1.0 Scope  This test method is to determine the terminal bond strength, after repeated soldering and unsoldering, by mechanical pull in the perpendicular plane.

2.0 Applicable Documents  None

3.0 Test Specimen  Use test coupon "F" from test pattern described in part 5.8 of this publication.

4.0 Apparatus

4.1 60-watt soldering iron capable of producing a tip temperature of 232°C to 260°C (450°F to 500°F).

4.2 Vertical pull force tester capable of operating at a speed of 2 inches per minute and measuring up to 20 lbs. load.

5.0 Procedure

5.1 Preparation

5.1.1 Insert and solder 0.017 inch copper wire in holes #10, 12, 14, and 16.

5.1.2 Insert wires so that the portion extending from the soldered side of the circuit may be fitted into the gripping mechanism of a tensile tester.

5.1.3 The leads must not be crimped on the solder side.

5.2 Solder Cycles

5.2.1 The wires shall not be clinched. Subject wires to five cycles of unsoldering and soldering by hand after the initial machine or hand soldering.

5.2.2 During the five cycles the wires shall be completely removed during each soldering operation.

5.2.3 A 60-watt conventional soldering iron operated at a reduced voltage sufficient to produce a tip temperature of 450°F shall be used for the unsoldering and soldering operation.

5.2.4 The iron shall be applied to the leads, not the foil, and shall be applied only as long as necessary to perform the unsoldering or soldering operation.

5.3 Test

5.3.1 Following the fifth cycle, clamp the specimen sufficiently in the jaws of the bond tester to assure that the specimen is perpendicular to the direction of pull.

5.3.2 Apply a pull at the rate of 2 inches per minute (50.8 mm/min.) to the wire on the pattern side of the board.

5.3.3 The load must be applied perpendicular to the major surface of the terminal area until the required poundage is reached, or failure occurs.

5.4 Evaluation  Examine specimen for loosening of bond and for loosening of the pad from the dielectric substrate.

6.0 Notes  Breaking of a wire, or wire pullout shall not be considered as a failure, but the wire shall be resoldered and pulled again.
1.0 **Scope**

This test method is to determine the land bond strength of unsupported holes, after repeated soldering and unsoldering, by mechanical pull in the perpendicular plane.

2.0 **Applicable Documents**

IPC-D-275 Design Standard for Rigid Boards and Rigid Board Assemblies

3.0 **Test Specimen**

Any unsupported component hole sample or test coupon “B” described IPC-D-275. Three holes per sample or test coupon shall be tested.

4.0 **Apparatus or Material**

4.1 **Soldering Iron**

60-watt soldering iron capable of producing a tip temperature of 232 to 260°C [450 to 500°F].

4.2 **Force Tester**

Vertical pull force tester capable of operating at a speed of 50 mm [2.0 in] per minute and measuring up to 9 kg [20 pounds] load.

4.3 **Tinned or solder coated copper wire.**

5.0 **Procedure**

5.1 **Preparation**

5.1.1 If conductors are connected to the land area, the following procedure is to be followed:

Take a sharp model knife and cut conductor at least 6 mm [0.2 in] away from the land. Place blade of knife on edge of land area where conductor enters. While holding the blade down, pull conductor to the land and use knife blade as fulcrum to break conductor from land without disturbing bond of the land.

5.1.2 Insert wire so that the portion extending from the soldered side of the circuit may be fitted into the gripping mechanism of a tensile tester. The wires shall have a diameter of 50 μm to 150 μm [0.002 to 0.006 in] smaller than the diameter of the hole. The wires shall not be clinched. Select suitable wire of sufficient length to connect to gripping mechanism of bond strength tester.

5.1.3 Insert wire in holes in selected lands and solder to lands by machine or hand, as applicable. The wire shall not be clinched.

5.2 **Soldering cycles**

5.2.1 Subject wires to five cycles of unsoldering and soldering by hand after the initial machine or hand soldering.

5.2.2 During the five cycles the wires shall be completely removed during each unsoldering operation and replaced during each soldering operation.

5.2.3 The soldering iron shall be applied to the wires, not the land area, and shall be applied only as long as is necessary to perform the unsoldering or soldering operation.

5.3 **Pull Test**

5.3.1 Following the fifth cycle, clamp the test specimen sufficiently in the jaws of the bond tester to assure that the test specimen is perpendicular to the direction of pull.

5.3.2 Apply a pull at the rate of 50 mm per minute [2.0 in per minute] to the wire on the pattern side of the test specimen.

5.3.3 The load must be applied perpendicular to the major surface of the land. The load shall be applied until failure occurs or the minimum force as specified by the procurement documentation is reached. The formula to calculate force for circular lands is as follows:

\[
\frac{4L}{\pi(D_2^2 - D_1^2)}
\]

Where:

- \(D_1\) = Hole diameter
- \(D_2\) = Land diameter
- \(L\) = Load (force)

5.4 **Evaluation**

Examine test specimen for loosening of bond and for loosening of the land from the base material. It shall be considered a failure when a land around an unsupported hole is loosened.
6.0 **Notes**

6.1 Breaking of a wire, or wire pull-out, shall not be considered a failure, but the wire shall be resoldered and pulled again.

6.2 The following details are to be specified in the applicable performance specification:

a. Test specimen, if other than specified in 3.0.

b. Force, if other than specified in 5.3.3.
1 Scope  This test method is used to determine the bond strength (breakaway strength) of surface mount lands from substrate materials by a perpendicular pull and force measurement. It is designed to test solderable metals on any type of substrate in a variety of surface mount land sizes. The surface finish shall be the same as the board it represents.

This test may be imposed in the as received condition during maximum use temperatures, after exposure to commonly used solvents, after high humidity, and after extended aging.

It is important to note this perpendicular test provides entirely different results than tests where the test leads are soldered parallel to the plane of the land and bent perpendicular for testing.

2 Applicable Documents

IPC-D-275 Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies

3 Test Samples/Specimens

3.1 Qualification  Standard surface mount lands (full variety) as shown in Figure 1 (IPC-D-275, Coupon N). Unless otherwise specified, a minimum of five of each land size shall be tested for qualification.

3.2 Production  Standard quality conformance circuitry coupon, N, as shown in IPC-D-275. For production, a minimum of three lands of each size used on the board shall be tested.

3.3 Materials and Configurations Tested

3.3.1 Printed boards and substrate materials used for surface mount printed boards

3.3.2 Finishes used on surface mount lands on printed boards, such as tin-lead platings or coatings, gold platings, etc.

3.3.3 All surface mount land sizes

Figure 1  Coupon N, surface mounting bond strength, mm, nominal
4 Apparatus

4.1 Force Testers All force testers must have maximum force retention capability. All force testers must have capacity from 0 kg to 14 kg. Suggested force testers include the following:

4.1.1 Hand Held—Ametek Accurforce Cadet Digital Force Gauge, or equivalent

4.1.2 Hand Held—Ametek L-20 Force Gauge (Dial Indicator), or equivalent

4.1.3 Automatic—Unite-O-Matic with Houston Instruments 2000 Recorder, Instron, Tinius-Olson with Recorders, or equivalent

4.2 A standard pin made of steel core (1018 wire), which has been copper clad with a thickness of 0.038 mm minimum copper covered by a solder coating consisting of 63% (by weight) of tin, with the remaining lead, and a thickness of between 7 µm and 10 µm.

Standard test pins are pre-tinned.

Measurements are:

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Length</td>
<td>30 mm</td>
</tr>
<tr>
<td>Head Diameter</td>
<td>1.6 mm</td>
</tr>
<tr>
<td>Shaft Diameter</td>
<td>0.5 mm</td>
</tr>
</tbody>
</table>

4.3 Soldering Iron 60-watt soldering iron capable of producing a tip temperature of 232°C to 260°C

4.4 Optical inspection aid, cable of 10x magnification minimum, or equivalent

5 Test

5.1 Preparation

5.1.1 Measure the dimensions of the surface mount lands using magnifications not less than 10x (10x to 30x preferred). Calculate and record the surface area of the land before soldering the headed pin.

For production testing, use three of each land size used on the associated board.

For qualification testing, use five of each land size shown in Coupon N of IPC-D-275.

5.2 Procedure

5.2.1 Upon completion of the soldering, place the specimens either in the base specimen receptacle of the automatic tensile tester or the hand held tester (see Figure 3). Testing is at ambient room temperature, 18°C to 30°C, unless a specified use temperature is designated.

5.2.2 Clamp the loose end of the pin in the jaws of the tester.

5.2.3 Pull the pin perpendicular at an approximate rate of 50 mm per minute until failure occurs or the force exceeds the specified value required for this test (perpendicular is considered within 5% of 90°).
5.3 Evaluation

5.3.1 Record the force in units as measured by the force tester required to produce the bond failure or the measured force that exceeds the specified value. Force units are those measured by the force test equipment.

5.3.2 Examine the conductor square area with 10X to 30X magnification to determine failure mode. Each conductor land shall be classified into one of the following categories.

A) No failure of the bond of the surface mount land from the substrate was observed and the specimen withstood the specified required force per surface area as stated in the appropriate specification.

B) Separation of the surface mount land from the substrate

C) The land remained bonded to the substrate and the standard test pin broke.

D) The solder joint failed by the standard test pin pulling off the land.

E) The solder joint pulled off the land (poor wetting).

5.3.3 Breaking off of a test pin or a test pin pull out shall not be considered as a failure, but a new standard pin shall be soldered onto a new land and pull tested. If failures continue to occur at non-land/substrate areas, a larger, stronger pin may be used to determine exact values of the land/substrate interface bond strength.

5.3.4 Specimens that fail to meet the requirements should be photographed, if desired, to be included in a test report.

6 Notes

6.1 The Square Area Concept  One of the most significant variables encountered is the difficulty in comparing bond strength test results with the large variety of land sizes.

By calculating the surface area on each land, one can group sizes to develop accurate evaluations for a wide variety of land sizes.

6.2 Variables to be considered are:

- Variable land sizes on a given board (surface areas)
- Base material or substrate
- Foil formations (dendrites)
- Finished metals (fused T-L and gold, nickel, etc.)
- Operator variables
- Soldering techniques
- Mode of failure (land removal vs. test nail break, etc.)

6.3 Suggested source for standard headed pin: The Quad Group
1815 Lewis
Spokane, Washington 99204
(509) 458-4558
P/N 901050U

6.4 The test data that was generated as part of the development of this test method may be found in “Preliminary IPC Round Robin Study on Bond Strength (Breakaway) Test of Surface Mount Lands.” Copies of this report are available through the IPC office. Further studies are being planned by the IPC Test Methods Subcommittee. The subcommittee also requests that any test data or any suggestions in improving this method be submitted to the IPC office.
1 Scope This test method covers three procedures used to determine the bow and twist percentage of individual rigid printed boards, rigid portions of rigid-flex printed boards, and/or multiple printed panels. Measurements on non-rectangular samples pose a unique testing problem and may necessitate careful evaluation of the requirements imposed by the users of this test method. This test method does not describe the special considerations necessary when testing the bow and twist of printed board assemblies (i.e., component placement & weight, edge supports & connectors, etc.).

The first two procedures describe production (Go/No-Go) methods that generally characterize the bow and twist as being no more than a specific value. The other procedure is a referee method used to precisely determine the twist.

1.1 Definitions Bow and twist are defined in IPC-T-50. The definitions are repeated in this test method for convenience.

1.1.1 Bow (Sheet, Panel, or Printed Board) The deviation from flatness of a board characterized by a roughly cylindrical or spherical curvature such that, if the product is rectangular, its four corners are in the same plane (see Figure 1).

1.1.2 Twist The deformation of a rectangular sheet, panel, or printed board that occurs parallel to a diagonal across its surface, such that one of the corners of the sheet is not in the plane that contains the other three corners (see Figure 2).

2 Applicable Documents

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-TM-650 Test Methods

3 Test Specimens The test specimens shall be in the form of either printed boards or multiple printed panels (single-sided, double-sided, multilayer, or rigid-flex boards).

3.1 For non-rectangular test specimens, the most convenient way to measure bow and twist is approximating a rectangle over the test specimen. To accomplish this, an imaginary rectangle that totally encloses the sample must be superimposed over the test specimen. The dimensions of this superimposed rectangle should be the smallest that will fully enclose the specimen. Although this technique will give an approximation of bow and twist, the actual noted values will be less than the actual bow and twist of the sample.
4 Equipment/Apparatus

4.1 Precision surface plate

4.2 Thickness measurement shims (feeler or pin gauges)

4.3 Leveling jacks

4.4 Standard metrology height dial indicator gauge

4.5 Gauge blocks

4.6 Linear measuring devices of suitable accuracy

4.7 Micrometer of suitable accuracy for thickness measurement

5 Procedure

Unless otherwise specified, testing shall be performed at standard laboratory conditions (see IPC-TM-650, Section 1.3).

5.1 Production Testing (Bow)

5.1.1 Place the sample on the surface plate. While applying sufficient pressure to flatten the test sample, measure the length and width of the sample and record it as length (L) & width (W) (see Figure 3).

5.1.2 Calculate the size of the feeler/pin gauge (Go/No-Go) to be used for maximum bow percentage using the following formula:

\[
R_L = \frac{L}{100} \quad R_W = \frac{W}{100}
\]

Where:

- \(R_L\) = Go/No-Go feeler/pin gauge size for sample length
- \(R_W\) = Go/No-Go feeler/pin gauge size for sample width
- \(L\) = Length measurement as determined above
- \(W\) = Width measurement as determined above
- \(B\) = Maximum allowable bow percentage

5.1.3 Place the sample to be measured on the surface plate with the convex of the sample facing upwards. For each edge, apply sufficient pressure on both corners of the same sample edge to ensure contact with the surface (see Figure 4).

5.1.4 Attempt to slide the feeler/pin gauge of thickness \(R_L\) under the length side(s) of the sample and \(R_W\) under the width side(s) of the sample. If the Go/No-Go feeler/pin gauge will slide between the sample and the surface plate, the bow in that direction exceeds the allowable percentage used in the calculation above. Repeat this procedure until all sides of the sample have been measured.

5.1.5 If a determination of actual percentage of bow is desired, repeat 5.1.1 through 5.1.4 using a feeler/pin gauge that will easily fit between the side of the sample and the surface plate. Continue to increase the feeler/pin gauge size until the largest feeler/pin gauge that will fit between the sample and the surface plate for both the length (x2) and width (x2) is obtained. Measure this feeler/pin gauge with the micrometer and record as \(R_L\) or \(R_W\).

Calculate the percentage for bow as follows:

\[
B_L = \frac{R_L}{L} \times 100 \quad B_W = \frac{R_W}{W} \times 100
\]

Where:

- \(B_L\) = Percentage bow in the length direction
- \(B_W\) = Percentage bow in the width direction
- \(R_L\) = Measured maximum feeler/pin gauge size across sample length
- \(R_W\) = Measured maximum feeler/pin gauge size across sample width
- \(L\) = Length measurement as determined above
- \(W\) = Width measurement as determined above
5.2 Production Testing (Twist)

5.2.1 Place the sample on the surface plate. While applying sufficient pressure to flatten the test sample, take the diagonal measurement across the sample and record it as D (see Figure 3).

5.2.2 Calculate the size of the feeler/pin gauge (Go/No-Go) to be used for maximum twist percentage using the following formula:

\[ R = \frac{2(D)(T)}{100} \]

Where:
- \( R \) = Go/No-Go feeler/pin gauge size
- \( D \) = Diagonal measurement across the sample as determined above
- \( T \) = Maximum allowable twist percentage

Note: This formula includes a factor of two because, by constraining one corner of the sample on a surface plate, the vertical deflection of twist is approximately doubled.

5.2.3 Place the sample to be measured on the surface plate with any three corners of the sample touching the surface. Apply sufficient pressure (if necessary) to only one corner of the sample to ensure three of the four corners are in contact with the surface plate. It may be necessary to turn the sample over to accomplish this (see Figure 5).

5.2.4 If it is not possible to get three corners of the sample to touch the surface plate by restraining only one corner, this production test is not applicable and the referee test described in 5.3 shall be used.

5.2.5 Attempt to slide the feeler/pin gauge of thickness \( R \) under the corner not touching the surface plate. If the Go/No-Go feeler/pin gauge will slide under the corner feeler/pin gauge will slide under the corner not touching the surface plate without lifting any of the other three corners of the sample from the surface plate, the twist in that direction exceeds the allowable percentage used in the calculation above. Repeat this procedure until all corners of the sample that can be measured using this technique have been measured.

5.2.6 If a determination of actual percentage of twist is desired, repeat 5.2.1 through 5.2.5 using a feeler/pin gauge that will easily fit under the corner that is not touching the surface plate. Continue to increase the feeler/pin gauge size until the largest feeler/pin gauge size that does not lift any of the three touching corners from the surface plate is obtained. Measure this feeler/pin gauge with the micrometer and record as \( R \).

5.2.7 Calculate the percentage of twist as follows:

\[ \text{Percentage Twist} = \frac{R}{2(D)} \times 100 \]

Where:
- \( R \) = Go/No-Go feeler/pin gauge size
- \( D \) = Diagonal measurement across the sample as determined above

Note: This formula includes a factor of two because, by constraining one corner of the sample, the vertical deflection of twist is approximately doubled.

5.3 Referee Method (Twist)

5.3.1 Place the sample to be measured on the datum surface with the two lower opposite corners touching the datum surface or on a raised parallel surface of equal height from the datum surface (see Figure 6).
5.3.2 Support the other two corners with leveling jacks or some other appropriate devices, ensuring the two raised corners are of equal height from the datum surface. This may be checked by using the dial indicator (see Figure 7).

5.3.3 Using the dial indicator, measure the highest raised portion on the board and record the reading as R1 (see Figure 8).

5.3.4 Without disturbing the sample, take a reading with the dial indicator on one of the corners contacting the surface (R2) and record the reading (see Figure 8).

5.3.5 Take the diagonal measurement of the sample and record the reading.

5.3.6 Calculation Deduct the measured R2 from the measurement R1. This difference is denoted as twist. Divide the measured deviation by the recorded length and multiply by 100. The result of this calculation is the percentage of twist.

\[
\text{Percentage Twist} = \frac{R1 - R2}{L} \times 100
\]

6 Notes None
Figure 7 Corners Supports

Figure 8 Highest Point Measurement
1.0 Scope  This method covers the measurement of bow and twist by maximum vertical displacement of an unrestrained panel of either cut to size panels or finished rigid printed boards including single- and double-sided, multilayer, and the rigid segments of rigid flex printed circuits. This test method is only applicable to laminates greater than or equal to 0.5 mm [0.020 in] in thickness. This test method can also be used after etching or after thermal stress with requirements as agreed between user and vendor.

2.0 Applicable Documents

None

3.0 Test Specimen  The test specimen for incoming inspection shall be 300 x 300 mm ± 2 mm [12 x 12 in ± 0.08 in] in size. For smaller panel sizes and finished printed wiring boards, use actual size. A minimum of three specimens is required per sample, when evaluating pressed laminate sheets.

4.0 Apparatus

4.1 Sample Shear

4.2 Granite Surface Plate or Equivalent

4.3 Feeler Gauges or Equivalent

4.4 Micrometer

5.0 Test Procedure

5.1 Preparation of the Test Specimen

5.1.1 For laminate sheet, the test specimens are to be cut in such a fashion as to minimize mechanical flexing.

5.1.2 For cut to size panels or printed wiring boards, use actual size.

5.1.3 Mark the specimen for traceability. No mechanical or chemical pre-cleaning is permitted on the specimens.

5.2 Measurement of Bow and Twist

5.2.1 Place the test panels on the surface plate such that the maximum vertical displacement is observed. The panel should be turned over in establishing the maximum vertical displacement. The maximum vertical displacement may be a corner or a side of the test specimen as illustrated in Figures 1 and 2.

5.2.2 Measure the maximum vertical displacement by inserting the feeler gauges between the surface plate and the bottom surface of the laminate.

5.2.3 Verify the thickness measurement by measuring the total thickness of the feeler gauges with the micrometer.

5.2.4 Record the maximum vertical displacement in 0.25 mm [0.01 in]. One value is recorded per test specimen. This is the bow and twist of the test specimen.
5.3 Calculation of Results

5.3.1 Average Bow and Twist Results
Bow and Twist =
\[
\text{Sum of the Measured Maximum} \\
\text{Vertical Displacements in mm [in]} \\
\text{Number of Test Specimens}
\]

5.3.2 Maximum Bow and Twist Results
The maximum vertical displacement in mm [in] obtained for each lot of material.

6.0 Notes

6.1 This is the referee method; other methods of measurement are allowable, if agreed upon between user and vendor.
1.0 Scope  This test method establishes a procedure for determining the flatness of silicon wafers coated with deposited organic films.

2.0 Applicable Documents

ASTM D 618  Standard Practice for Conditioning Plastics and Electrical Insulating Materials for Testing

3.0 Test Specimen  The test specimens are 125 mm diameter silicon wafers 625 ± 15 µm in thickness. The surface of the wafers must be clean, and at least one side of the wafers must be polished. A minimum of 9 wafers are required.

4.0 Apparatus or Material

4.1 Radius Of Curvature Measurement Device  Flexus Thin Film Stress Measuring Apparatus (TFSMA) Model 2-300 or equivalent.

4.2 Wafer Thickness Measurement Device  Micrometer capable of measuring accurately to 5 µm. A thickness gauge including weights can also be purchased from Flexus that can be used with the TFSMA to measure thickness.

4.3 Film Thickness Measurement Device  Nanospec Model 210, Tencor AlphaStep, or equivalent film thickness measurement device capable of measuring accurately to 0.1 µm.

5.0 Procedure

5.1 Radius Of Curvature Of Uncoated Wafers

5.1.1 Label each wafer with a unique identification.

5.1.2 Measure the thickness of the uncoated silicon wafers.

5.1.3 Measure the radius of curvature of the uncoated wafers following the manufacturer’s recommended procedure.

5.2 Coat Wafers

5.2.1 Use a minimum of three film thicknesses for each polymer or processing condition investigated. The film thicknesses should span as large a range as possible, e.g., 5, 10 and 15 µm. Coat at least three wafers for each film thickness for a minimum of nine wafers.

5.2.2 Coat the polymer solution onto the back (unpolished side) of the silicon wafers using manufacturer’s recommended deposition technique (e.g., spin coating). Process the coating according to the manufacturer’s recommended procedures. The final film thickness must not vary by more than 2% across the substrate surface.

5.3 Radius Of Curvature Of Coated Wafers

5.3.1 The coated wafers should be conditioned at 23 ± 2°C and 50 ± 5% relative humidity for exactly 24 hours prior to testing. Many polymers exhibit stress relaxation or a decrease in stress associated with moisture absorption, therefore it is essential that the coated wafers are equilibrated under identical conditions. Refer to ASTM D 618.

5.3.2 Measure the radius of curvature of the coated wafers following the equipment manufacturer’s recommended procedure. Correct placement of the wafers in the device is essential to compensate for nonuniform wafers, therefore the wafer must be placed in the same position for each measurement. At this point the coating thickness is unknown; however, some value may be required by the curvature measurement device. Use whatever number is convenient for now, the data will be edited later.

5.3.3 Repeat step 5.3.1 four (4) times for each wafer. The reason for the repeated measurements is to generate an average to compensate for errors in placing the wafer in the curvature measurement device at the exact position in which it was originally measured during step 5.1.3.

5.4 Film Thickness Measurements  Measure the film thickness on each coated wafer to an accuracy of 0.1 µm or better using the film thickness measurement device. The thickness should be measured at several different locations to compensate for nonuniform coatings.

5.7 Calculations
5.7.1 Calculate the average effective radius of curvature and the standard deviation for each wafer from the 4 measurements made on each wafer in step 5.3.2 using the following equation:

\[
R = \frac{(R_1 \times R_2)}{(R_1 - R_2)}
\]

where \(R_1\) and \(R_2\) are the radius of curvature of the uncoated and coated wafers respectively. The standard deviation is calculated as follows and reported to two significant figures:

\[
S_x = \sqrt{\frac{N \sum_{i=1}^{N} X_i^2 - (\sum_{i=1}^{N} X_i)^2}{N(N-1)}}
\]

where \(X_i\) is the value of a single observation (\(i = 1\) through \(N\)), \(N\) is the number of observations and \(s_x\) is the estimated standard deviation.

5.7.3 Calculate the average effective radius of curvature for each film thickness using the averages from step 5.7.1 of all three wafers at the same film thickness. Do not include in the calculation the data from any wafer for which the standard deviation from 5.7.1 is greater than 10%.

5.7.4 Convert the average effective radius of curvature for each film thickness from step 5.7.3 into the wafer deformation, \(h\), using the following equation

\[
h = R_A - \sqrt{R_A^2 - \frac{L^2}{4}}
\]

where \(L\) is the diameter of the wafer and \(R_A\) is the average effective radius of curvature obtained in 5.7.3.

5.7.5 Curvature Slope The wafer deformation values for each film thickness from step 5.7.4 are plotted as wafer deformation (y-axis) versus film thickness (x-axis). An equation of the form \(y = mx\) (i.e. a straight line with intercept at \(x = 0\), \(y = 0\)) is fit to the data (unweighted) and the slope of the line can be used to compare different materials or processes when coated on identical substrates. A typical plot is illustrated in Figure 1.

6.0 Notes

6.1 The Flexus determines the radius of curvature by shining a He-Ne laser beam through a beam splitter. The two beams are reflected off the surface of the wafer into detectors. The radius of curvature, \(R\), is calculated from the angle of reflection and the distance between the two beams. If measurements are made on the coated side of the wafer, the laser beam is refracted twice, once upon entering the polymer layer and again upon exiting the polymer layer. As the polymer layer increases in thickness, the refracted laser beam can no longer be correctly detected by the detector, resulting in erroneous values for the radius of curvature. In practice, the upper limit on thickness for polyimides was found to be approximately 10-12 \(\mu\)m. To avoid this complication, the polymer films are deposited on the back of the wafers and the measurements are made on the front (polished side) of the wafer. This extends the useful thickness range to 50 \(\mu\)m.

6.2 The radius of curvature will depend on the thickness of the wafer. Wafers of comparable thickness \((625 \pm 15 \mu m)\) must be used when making comparisons of different materials.
1 Scope  This test method is used to determine the resistance of laminate materials (both unclad and etched surfaces) to the thermal abuse of a solder dip. Resistance to softening, loss of surface resin, scorching, delamination, blistering and measling are considered in the evaluation.

2 Applicable Documents

2.4.1  Adhesion, Tape Testing
2.4.12  Solderability, Edge Dip Method
MIL-F-14256  Flux

3 Test Specimen  Each specimen must be 3.18 cm x 3.18 cm thickness. A separate specimen is required for the unclad, etched, fluxed, and unfluxed tests. Three samples are required from each sheet.

4 Equipment/Apparatus

4.1  An electrically heated, thermostatically controlled pot of sufficient size to accommodate the specimen and containing no less than 2.25 kg of Sn60 or Sn63

4.2  A device, as shown in Figure 1, or some other similar device may be used, if:
  • The rate of immersion, dwell time, and withdrawal are within the test limits described in the procedure
  • The specimen and solder surface remain perpendicular within 5°
  • Wobble, vibrations, and other extraneous movements are eliminated

4.3  Warnow 2-710 black acid resisting ink, or equivalent

4.4  NAZ-DAR ER-111 black epoxy ink, or equivalent

4.5  A convection drying oven capable of attaining at least 149°C

5 Procedure

5.1 Etched and Unetched Specimen

5.1.1  Expose:
  • One specimen having a surface upon which no metal cladding was ever applied
  • One specimen on which the metal cladding has been removed by standard etching processes
  • One specimen with metal cladding remaining to the Solderability Edge Dip Method in IPC-TM-650, Method 2.4.12

5.1.2  Examine the specimens for evidence of discoloration or surface contaminants, loss of surface resin, softness, delamination, interlaminar blistering, or measles. The specimen having metal cladding must also be examined for blistering or delamination of the metal foil from the laminate material.

5.2 Plastic Surface Tape Test

5.2.1  Screen print one of the test inks to the surfaces of an unclad specimen and an etched specimen.

5.2.2  Treat test inks as follows:
  1. Warnow 2-710: Cure for a minimum of 30 minutes in air or oven. The dry film must be hard and dull in finish.
  2. NAZ-DAR ER-111: Cure for a minimum of 8 minutes at 135°C. The cured ink must have a hard glossy finish.

5.2.3  After the specimens have cured properly, perform the plating adhesion test on the inked surfaces, as defined in IPC-TM-650, Method 2.4.1. Use type I class A tape.

5.2.4  Carefully examine specimens for the items discussed in 5.1.2.

5.2.5  Examine for evidence of mold release agents, indicated by particles of ink adhering to the tape, or by the absence of ink from the laminate surface, or both.

5.3 Fluxed and Unfluxed Specimens
5.3.1 Clean the metal clad specimen by light abrasion or other suitable method, then flux the metal surface with a rosin flux conforming to MIL-F-14256.

5.3.2 Clean the unclad specimens by standard production techniques, then flux the laminate material with a rosin flux conforming to MIL-F-14256.

5.3.3 Carefully examine all specimens, then perform the tests described in 5.1.1 through 5.2.5.
1.0 Scope  This test is designed to determine the Glass Transition Temperature \( (T_g) \) and the Thermal Expansion in the Z-Axis of dielectric materials used in printed boards by the use of thermal mechanical analysis (TMA).

Thermal Expansion (TE) is expressed in Coefficient of Thermal Expansion (CTE) or Percent of Thermal Expansion (PTE).

2.0 Applicable Documents  None

3.0 Test Specimens

3.1 Size  Specimens shall be approximately 6.35 mm x 6.35 mm [0.25 in x 0.25 in]. The thickness shall be a minimum of 0.51 mm [0.020 in]; for thicknesses less than 0.51 mm [0.020 in], or to increase the accuracy of the test, see 6.4.

3.2 Quantity and Sampling  Unless otherwise specified, two specimens shall be tested, to be taken from random locations of the material in question.

4.0 Apparatus or Material

4.1 Thermomechanical analyzer (TMA) capable of determination of dimensional change to within 0.0025 mm [0.0001 in] over the specified temperature range.

4.2 Diamond blade or wheel, sanding equipment, or equivalent, to provide a specimen of the size and edge quality specified.

4.3 Desiccator capable of an atmosphere less than 30% R.H. at 23°C [73.4°F].

4.4 Etching system capable of complete removal of metallic cladding.

4.5 Air circulating oven capable of maintaining 105 ± 2°C [221 ± 3.6°F].

4.6 Micrometer capable of thickness measurements to within 0.00025 mm [0.0001 in].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Metallic clad laminate shall be tested without the cladding. Specimens taken from multilayer boards shall have no internal metal layers, if possible. Exterior metallic cladding shall be removed by etching using standard industry practices.

5.1.2 Specimens shall be cut to the specified size using appropriate procedures and equipment to minimize mechanical stress or thermal shock.

5.1.3 The edges shall be smooth and burr-free by means of sanding or equivalent (to allow the specimen to rest completely flat on the mounting stage). Use care to minimize stress or heat on the specimen.

5.1.4 Specimens shall be preconditioned by baking for 2 ± 0.25 hours, at 105 ± 2°C [221 ± 3.6°F], then cooled to room temperature in a desiccator.

5.1.5 If applicable, determine the thickness of the specimen (for determination of Percent of Thermal Expansion) and record as \( T_o \).

5.2 Measurement

5.2.1 Mount the specimen on the stage of the TMA and apply a load between 0.1 g and 10.0 g (see note 6.5 for explanation of the load selection criteria).

5.2.2 Initial Temperature for Startup

a. For \( T_g \) determination, start the scan at a temperature no higher than 35°C [95°F]. An initial temperature of 23°C [73°F] is recommended.

b. For TE determination start the scan at a temperature sufficiently lower than the specified temperature range such that the specified heat rate is stabilized (see 6.6).

5.2.3 Unless otherwise specified, maintain the scan rate at 10°C [18°F] per minute.

5.2.4 Temperature Excursion

a. For \( T_g \) determination, continue the temperature ramp to at least 30°C [54°F] above the anticipated transition region.

b. For TE determination, continue the temperature ramp to...
250°C [482°F] or other temperature as specified (such as, representative of a soldering operation).

For example, determination of Tg on a material with an anticipated Tg of 270°C [518°F] would require that the test temperature should reach in excess of 300°C [572°F]. TE measurements should be determined only from that part of the plot reaching 250°C [482°F] (or other temperature of interest).

5.2.5 If residual stresses cause a sudden irreversible deflection at the glass transition, a second scan shall be run, either on the same specimen or if desired, a new specimen.

5.3 Evaluation

5.3.1 The data for the scan should resemble the plot as shown in Figure 1.

5.3.2 From the TMA plot, record the thickness of the specimen as four points: Temperature “A” shall be chosen just above room temperature, e.g., 25°C [77°F]. Temperatures “B” and “C” shall be chosen such that they are on the linear portion of the graph, but just below and above the transition region, respectively. Temperature “D” shall be selected to represent a temperature of interest, such as a soldering operation. Unless otherwise specified, Temperature “D” shall be 250°C [482°F].

5.4 Calculations

5.4.1 Glass Transition Temperature Determine the point at which lines drawn through points A and B and points C and D will intersect. The temperature at which the tangent lines intersect is the Tg.

5.4.2 Coefficient of Thermal Expansion in the Z-Axis
The CTE shall be calculated over the specified regions and recorded in units of ppm/°C.

a. CTE Below the Glass Transition
\[ \alpha(A - B) = \frac{(t_B - t_A) \times 10^6}{t_A (T_B - T_A)} \]

b. CTE Above the Glass Transition.
\[ \alpha(C - D) = \frac{(t_D - t_C) \times 10^6}{t_C (T_D - T_C)} \]

c. CTE from Near Room Temperature to 250°C (Or Other Temperature of Interest)
\[ \alpha(A - D) = \frac{(t_D - t_A) \times 10^6}{t_A (T_D - T_A)} \]

Where:
- TA = Temperature at point A on plot
- TB = Temperature at point B on plot
- TC = Temperature at point C on plot
- TD = Temperature at point D on plot
- tA = Thickness at TA
- tB = Thickness at TB
- tC = Thickness at TC
- tD = Thickness at TD

5.4.3 Percent of Thermal Expansion in the z-axis.

5.4.3.1 Select the temperature range over which the expansion in percentage shall be determined. The temperature range from point A to point D is considered most meaningful.
5.4.3.2 The PTE is calculated as follows:

\[
\text{Percent TE} = \frac{t_D - t_A}{t_O} \times 100
\]

Where

- \( t_o \) = Initial thickness (see 5.1.5)
- \( t_D \) = Thickness at Temperature D
- \( t_A \) = Thickness at Temperature A

5.5 Report

5.5.1 Report the glass transition temperature of each specimen.

5.5.2 Report the TE as CTE in ppm/°C or as PTE in percentage, and the temperature ranges over which the TE has been determined. If specified, report the CTE over the temperature ranges above and below the \( T_g \) (A-B and C-D).

5.5.3 Report the scan rate and final TE temperature if other than that specified.

6.0 Notes

6.1 Calibration of the TMA must be carried out according to the manufacturer’s instructions.

6.2 The \( T_g \) for a given material may be significantly different when measured by DSC versus TMA. The test equipment used should be noted after the reported glass transition value, i.e., 136.4° (DSC) or 132.6° (TMA).

6.3 Most thermal analysis equipment have the software capability to determine \( T_g \) and CTE values; it is recommended that this approach be used for consistency, provided test parameters (e.g., temperatures, edge smoothing factors, etc.) do not conflict with the procedures specified.

6.4 To improve the accuracy of the test, the thickness should be at least 0.76 mm [0.030 in] and preferably 1.6 mm [0.062 in]. If the material thickness to be measured is less than 0.020 inch, a specimen stack-up to at least 0.51 mm [0.020 in] may be used although the test error probability is greatly increased. A sample of suitable thickness may be prepared from the prepreg used in the manufacture of the base material by laminating and curing as recommended by the supplier. Specimen thickness should not exceed 2.36 mm [0.093 in] to avoid variability from thermal gradients occurring within the specimen.

6.5 Load selection criteria. Initial load is recommended to be 5g. The load should be adjusted for differences in material types or specimen configuration in order to assure intimate contact between the probe, specimen, and stage. Avoid excess load which may result in penetration or distortion of the specimen.

6.6 Initial temperature for starting the scan is determined by an evaluation of the derivative of the time/temperature curve for the equipment. Test data is not valid until the time/temperature curve is stabilized. Refer to operating instruction of the equipment for additional information.

6.7 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.
1.0 Scope  This method describes the method for determining the time to delamination of laminates and printed boards through the use of a thermomechanical analyzer (TMA).

2.0 Applicable Documents

IPC-TM-650  Method 2.4.24, Glass Transition Temperature and Z-Axis Thermal Expansion by TMA.

3.0 Test Specimens

3.1 Size  Specimens shall be approximately 6.35 mm x 6.35 mm [0.25 in x 0.25 in] by the thickness of the sample.

3.2 Quantity and Sampling  Unless otherwise specified, two specimens shall be tested, to be taken from random locations of the material in question.

4.0 Apparatus or Material

4.1 Drying Chamber  Air circulating oven capable of maintaining 105 ±2°C [221 ±3.6°F].

4.2 Cutting Equipment  Diamond blade or wheel, sanding equipment, or equivalent, to provide a specimen of the size and edge quality specified.

4.3 Desiccator  Dessication chamber capable of maintaining an atmosphere less than 30% RH at 23°C [73.4°F].

4.4 Tester  Thermal Mechanical Analyzer (TMA) capable of determination of dimensional change to within ±0.0025 mm [0.0001 in] over the specified temperature range.

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Metallic clad laminates shall be tested as is. Multilayer printed boards may be sampled with internal conductors present. (For determination of a multilayer board’s bond integrity, presence of internal conductors is preferred.)

5.1.2 Specimens shall be cut to the specified size using appropriate procedures and equipment to minimize mechanical stress or thermal shock.

5.1.3 The edges shall be smooth and burr-free by means on sanding or equivalent (to allow the specimen to rest completely flat on the mounting stage). Use care to minimize stress or heat on the specimen.

5.1.4 The specimen shall be preconditioned by baking for 2 hours at 105 ±2°C [221 ±3.6°F], then cooled to room temperature in a desiccator.

5.2 Measurement

5.2.1 Remove the specimen from the desiccator and place the specimen on the stage of the TMA taking care that the sample is centered and resting flat on the stage.

5.2.2 Lower the TMA’s probe onto the specimen and apply a force of 0.005 Newtons [5g]; then lower the furnace into place around the stage.

5.2.3 Start the temperature ramp (or scan) from an initial temperature no higher than 35°C [95°F].

5.2.4 Maintain the scan at the specified rate. Unless otherwise specified, the scan rate shall be 10°C/minute (see 6.4).

5.2.5 After the scan reaches the specified isothermal temperature, hold at that temperature for 10 minutes or to failure. Unless otherwise specified, the isothermal temperature shall be 260°C [500°F].

If the instrument allows real time display of the data, terminate the experiment after evidence of delamination is displayed.

5.3 Evaluation  The time to delamination is determined as the time from the onset of the isotherm to failure. Failure is any event or deviation of the data plot where the thickness is shown to have irreversibly changed. The scan in Figure 1 is typical of an epoxy material at 260°C [500°F] isothermal temperature. On occasion, some materials will delaminate before

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the isotherm is reached. In this case, the temperature at the
time of failure shall be recorded.

5.4 Report

5.4.1 Report the Time to Delamination as determined in 5.3. Report the time at which any other plot event has taken place which was not determined to be irreversible.

5.4.2 Report the configuration of the sample (e.g., whether external or internal foil is present).

5.4.3 Report the ramp rate and isothermal temperature if other than that specified.

6.0 Notes

6.1 For epoxy laminates and similar materials, the recommended isothermal temperature is 260°C [500°F]. For polyimides and other high temperature materials, the isothermal temperature may be increased to 288°C [550°F]. For other material types, consult with the material manufacturer.

6.2 Calibration of the instrument should be carried out according to the manufacturer’s instructions.

6.3 The $T_g$ of the material may be obtained from this test, which is similar to Method 2.4.24. It should be noted that the $T_g$ so obtained is a “first pass” value.

6.4 A faster ramp rate will decrease the time to run, provide some greater distinction between materials, and provide a closer equivalence to the Thermal Stress test, 2.4.13.1. A rate of 100°C/minute [212°F/minute] is recommended for such determinations.
1.0 **Scope**  This test method establishes a procedure for determining the glass transition temperature of organic films using dynamic mechanical analysis (DMA).

2.0 **Applicable Documents**

ASTM D 618  Standard Practice for Conditioning Plastics and Electrical Insulating Materials for Testing

3.0 **Test Specimen**  The test specimen shall consist of a strip 22.5 mm long and 6.25 mm wide with a minimum thickness of 5 µm. The analysis is based on the assumption of a constant specimen geometry, therefore the test specimens must be stiff enough not to plastically deform during the experiment.

4.0 **Apparatus or Material**  Rheometrics Solids Analyzer Model RSA-II with a film/fiber fixture or equivalent.

5.0 **Procedure**

5.1 The test specimens should be conditioned at 23 ± 2°C and 50 ± 5% relative humidity for not less than 24 hours prior to testing. Refer to ASTM D 618.

5.2 Follow the manufacturer’s recommendations for equipment startup and calibration.

5.3 Mount the specimen in the film/fiber fixture. Make certain that the specimen is mounted perpendicular to the clamps. Hand tighten the clamps as much as possible to prevent specimen slippage during a run.

5.4 Operate at a frequency of 1 Hz (6.28 radians/sec). Heat the specimen in dry nitrogen at a rate of no faster than 2°C/min., or in steps of 5°C increments, in dry air.

5.5 When the transition has been observed, heat at least 50°C beyond the apparent completion of the thermal activity before returning to initial conditions.

5.6 The glass transition temperature is defined as the temperature corresponding to the maximum in the tan δ vs. temperature curves at a frequency of 1 Hz. Tan δ is calculated from

\[ \tan \delta = \frac{E''}{E'} \]

where \( E'' \) is the loss modulus and \( E' \) is the storage modulus. A typical plot is shown in Figure 1.

5.7 Report both the glass transition (maximum in tan δ), e.g., 200°C (DMA-1 Hz), and the temperature range over which the storage modulus (E') changes (i.e., the transition range), e.g., transition range: 160-205°C.

6.0 **Notes**

6.1 Calibration of the instrument must be carried out according to the manufacturer’s recommendations with at least one standard being indium.

6.2 The glass transition temperature for a given material will be significantly different depending on the method of analysis (i.e., DMA, DSC, or TMA). The glass transition determined by DMA is frequency dependent and increases with increasing frequency. The glass transition determined by DSC or TMA will depend on the heating rate. The test method used along with the frequency (DMA) or heating rate (DSC or TMA) should be noted beside the glass transition value, e.g., 135°C (DMA-1 Hz) or 141°C (DSC-5°C/min).

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**Figure 1**

A typical plot showing glass transition temperature (200°C) and storage modulus (E') vs. temperature in dry nitrogen.
6.3 In general, DMA is more sensitive that DSC or TMA. This is especially important for high temperature polymers with weak transitions.

6.4 If the polymer decomposes before the glass transition is reached, report the decomposition temperature and indicate that it is a decomposition temperature and not a glass transition temperature.
1.0 Scope  This test method establishes a procedure for determining the glass transition temperature of organic films using thermal mechanical analysis (TMA).

2.0 Applicable Documents

ASTM D 618  Standard Practice for Conditioning Plastics and Electrical Insulating Materials for Testing

3.0 Test Specimen  The test specimen shall consist of a strip 15-20 mm long and 2 mm wide with a minimum thickness of 10 μm.

4.0 Apparatus or Material  Perkin-Elmer TMA-7 with a film fixture in extension mode or equivalent equipment capable of handling films less than 25 μm thick.

5.0 Procedure

5.1 The test specimens should be conditioned at 23 ± 2°C and 50 ± 5% relative humidity for not less than 24 hours prior to testing. Refer to ASTM D 618.

5.2 Follow the manufacturer’s recommendations for equipment startup and calibration.

5.3 Mount the test specimen in the film holder. The sample length (between the grips) should be between 11-13 mm.

5.4 Set the force at 30 mN.

5.5 Perform a prescan by heating at a rate of 20°C/min under inert atmosphere from ambient to 50°C beyond the apparent completion of the thermal activity to erase previous thermal history.

5.6 Hold the temperature for 10 min.

5.7 Cool to 50°C below the transition temperature observed in the prescan.

5.8 Reheat the specimen at a rate of 5°C/min until all desired transitions have been completed.

5.9 The glass transition is determined by a construction procedure on the transition region of the extension versus temperature curve (Figure 1).

5.10 Construct a tangent line to the curve above and below the transition.

5.11 The temperature at which the tangents intersect is the glass transition temperature.

5.12 Report both the glass transition (intersection of tangents), e.g., 200°C (TMA-5°C/min), and the temperatures at the beginning of tangent A (TA) and tangent B (TB) (i.e., the transition range), e.g., transition range: 160-205°C.

6.0 Notes

Figure 1

5.12 Report both the glass transition (intersection of tangents), e.g., 200°C (TMA-5°C/min), and the temperatures at the beginning of tangent A (TA) and tangent B (TB) (i.e., the transition range), e.g., transition range: 160-205°C.
6.1 Calibration of the instrument must be carried out according to the manufacturer’s recommendations. Two calibrations are required, one to establish the baseline and the other to calibrate the TMA relative to a standard.

6.2 A quartz specimen of 11-13 mm in length (between the grips) is run at 5°C/min under inert gas purge (He) from −20 to 400°C to establish a baseline. The baseline is used to eliminate the effects of grip expansion on extension measurements. The coefficient of linear thermal expansion of quartz is 0.57 x 10^-6/°C (16-500°C).\(^1\)

6.3 After the baseline is established, the TMA must be calibrated with at least one standard being 99.9999% pure aluminum which has a linear CTE of 24.9 x 10^-6/°C from 0-250°C. An aluminum specimen is run between -10 and 200°C and the coefficient of linear thermal expansion is calculated. If the measured value differs from the literature value, the specimen size is adjusted to correspond to the measured value, and the specimen is rerun. Once the measured and literature values are in agreement, this constant factor is used on subsequent specimen sizes.

6.4 The glass transition temperature for a given material will be significantly different depending on the method of analysis (i.e., DMA, DSC, or TMA). The glass transition determined by DMA is frequency dependent and increases with increasing frequency. The glass transition determined by DSC or TMA will depend on the heating rate. The test method used along with the frequency (DMA) or heating rate (DSC or TMA) should be noted beside the glass transition value, e.g., 135°C (DMA-10 Hz) or 141°C (DSC-5°C/min).

6.5 In general, DMA is more sensitive than DSC or TMA. This is especially important for high temperature polymers with weak transitions.

---

1 Scope  This test is designed to determine the glass transition temperature ($T_g$) and room temperature storage modulus ($E'$) of dielectric materials used in High Density Interconnect (HDI) and Microvias by the use of dynamic mechanical analysis (DMA).

When testing a stand alone HDI dielectric layer, DMA will provide modulus as a function of temperature and glass transition for this layer. When DMA is used on built-up constructions, the data will be a complex curve representing the composite moduli and glass transitions.

Two methods are presented:

- Method A for thick specimens
- Method B for thin specimens (recommended for HDIS and Microvia dielectric layers).

For anisotropic materials (reinforced dielectrics), the x and y directions will have different modulus vs. temperature behavior. Anisotropic materials shall be tested in both the x and y directions.

2 Applicable Documents

2.1 ASTM Documents

- E 1640  Test Method for Assignment of the Glass Transition Temperature by Dynamic Mechanical Analysis
- D 4065  Standard Practice for Determining and Reporting Dynamic Mechanical Properties for Plastics
- D 4092  Standard Terminology Relating to Dynamic Mechanical Measurements on Plastics

3 Test Specimen

3.1 Size

Method A  Flexural bending geometry – thick specimens (>0.5 mm): Specimens shall be approximately 8 mm to 12 mm wide, 20 mm to 40 mm long, and 1 mm to 2 mm thick. The thickness shall be a minimum of 0.5 mm; for thicknesses <0.50 mm, use Method B. An aspect ratio of length/thickness = 10/1 or greater should be maintained. Exact specimen dimensions should be determined by the apparatus used.

Method B  Thin film tension geometry – thin specimens (<0.50 mm): Specimens shall be approximately 15 mm to 20 mm long and 2 mm wide. The minimum thickness is determined by the strength of the material; it should not break during testing. Exact specimen dimensions may be determined by the apparatus used.

3.2 All specimens should be fully cured according to manufacturer’s recommendations. Thick specimens may be made by use of multiple lamination/cure cycles if required.

3.3 Unless otherwise specified, one specimen shall be tested, to be taken from a random location in the material in question.

4 Apparatus or Material

4.1 A DMA capable of determination of modulus to +1% precision and tan $\delta$ resolution of 0.01 over the specified temperature range. The DMA will preferably have computer data acquisition and analysis. The DMA must have an environmental chamber capable of having inert flush gas and capable of heating the specimen to at least 310°C.

4.2 Diamond blade or saw, sanding equipment, or equivalent to provide specimens of the size and edge quality required for Method A

4.3 Scissors, razor blades, or equivalent to provide specimens of size and edge quality for Method B

4.4 Air circulating oven capable of maintaining 105°C ± 2°C

4.5 Dessicator capable of an atmosphere <30% RH at 23°C

4.6 Etching system capable of complete removal of metallic cladding

5 Procedure

5.1.1 Metallic clad specimens shall be tested without the cladding. Etch and dry using appropriate procedures and equipment.
5.1.2 Specimens shall be cut to the specified size using appropriate procedures and equipment to minimize thermal shock and mechanical stress. Method A specimens shall have their edges smooth and burr-free by means of sanding or equivalent (to allow the specimen to rest flat on the mounting stage). Method B specimens shall be rectangular, with their long edges parallel (to ensure good mounting in the film fixture). Method B specimens shall have smooth edges without nicks or tears.

5.1.3 Specimens shall be preconditioned by baking for one hour ± 15 minutes at 105°C, then cooled to room temperature in a dessicator.

5.2 Measurement

5.2.1 Apparatus Set-up

5.2.1.1 Install the Required DMA Clamp

Method A Install and calibrate the DMA with a bending geometry fixture/clamp.

Method B Install and calibrate the DMA with a thin film fixture/clamp.

5.2.1.2 Start the Experiment

Method A Measure the length, width, and thickness of the specimen to within at least +0.01 mm or preferably +0.005 mm. Clamp the specimen in the DMA fixture. Set the sample strain amplitude to operate within the linear viscoelastic range of the material. Strains <1% are recommended and are typically 0.1%. Program the sample temperature range. Enclose the specimen and fixture in the environmental chamber (furnace).

Method B Measure the length, width, and thickness of the specimen to within at least +0.01 mm or preferably +0.005 mm. Sample lengths of 10 mm to 20 mm are typical. Mount the specimen in the clamps of the film fixture according to the manufacturer’s instructions. Apply tension force between 10 g and 50 g. A typical base force would be 20 g (see 6.5 for an explanation of the load criteria). Enclose the specimen and probe in the environmental chamber.

5.2.1.3 Provide an inert gas purge (helium or nitrogen) to the environmental chamber. Temperature calibration of the DMA must be performed under the same gas conditions.

5.2.2 Running the DMA Temperature Scan

5.2.2.1 Initial Temperature \( (T_{\text{initial}}) \)

a. For specimens with \( T_g \) below or near room temperature, start the scan at least 20°C below the anticipated transition. This may require a DMA with subambient cooling control of the environmental chamber.

b. For specimens with \( T_g \) greater than room temperature, start the scan at 30°C.

5.2.2.2 Sample Heating and Deformation Rate The specimen shall be run at 2°C/min and an oscillation frequency of 1 Hz.

5.2.2.3 Temperature Excursion Heat the specimen to at least 20°C greater than the \( T_g \). This test is general in nature and data may be taken above \( T_g \) if required. There is no required upper temperature.

5.3 Evaluation

5.3.1 The DMA storage modulus should resemble the plot shown in Figure 1.

5.3.2 An idealized DMA curve has a linear section below the transition (glassy region below the temperature of \( T_g \)) and a stepwise drop through the glass transition region. These linear sections are used in calculating \( T_g \) by onset of the modulus drop (see Figure 1).
5.3.3 Examine all specimens after the test to look for signs of excessive loads, distortions, tears, and other defects. If any defects or sample irregularities are found, discard the sample and the data, rerun another specimen, or pick a different method for determining T_g and storage modulus.

5.4 Calculations

5.4.1 Glass Transition Temperature (T_g) Construct a tangent line to the curve below the transition temperature in the modulus curve. Construct a tangent to the storage modulus curve at or near the inflection point approximately midway through the step change in the transition. The temperature where these tangents intersect is the reported T_g for the material. For consistency it is recommended that the DMA computer analysis software be used for this calculation. See Figure 1 for an example of this tangent intersection method.

5.4.2 Storage Modulus (E') The sample storage modulus (E') shall be calculated at room temperature (22°C) and reported in units of Pa (N/m²). For consistency it is recommended that the DMA computer analysis software be used for this geometry specific calculation.

5.4.3 Alternative thermal transitions may be reported as the transition peak temperature in the sample loss modulus (T_l) or tan δ plots (T_t) (see Figure 2 and Figure 3).

Figure 2 DMA Tan Delta Plot
Note: T_l is the transition peak temperature.

Figure 3 DMA Loss Modulus Plot
Note: T_l is the transition peak temperature.

5.5 Report

5.5.1 Report the glass transition temperature 22°C (room temperature) for each specimen, rounding to the nearest whole number.

5.5.2 Report the modulus in units of Pa (N/m²) at 22°C.

5.5.3 For anisotropic (reinforced) samples report the both the x and y direction modulus.

5.6 Plot

5.6.1 Plot the storage modulus vs. temperature (°C) for the specimen. If using computer-based analysis, include the T_g
and measurement start and end points and computer generated lines (see Figure 1).

5.6.2 Optionally plot the storage modulus, loss modulus, and tan δ vs. temperature (°C) for the specimen (see Figure 4).

6 Notes

6.1 Calibration of the DMA must be carried out according to the manufacturer’s instructions for the relevant sample geometry and thermocouple temperature.

6.2 There are several methods for determining the T_g of organic materials:
- Differential scanning calorimetry (DSC)
- TMA
- DMA

T_g in organic materials is a broad transition, which arises when molecular mobility greatly increases in the specimen as a result of heating. No one method is superior to another; they each measure different physical changes that occur in a specimen near and around T_g.

![Figure 4 DMA Plot for Storage Modulus, Loss Modulus, and Tan Delta on One Plot](image)
DSC measures the heat capacity of a specimen, TMA measures the expansion of a specimen, and DMA measures the stiffness of the specimen. The \( T_g \) determined from TMA, DSC, and DMA may vary significantly (up to 20°C) because they are measuring different physical properties, which change differently as the specimen goes through \( T_g \). As a result, the test equipment used should be noted after the reported \( T_g \) value (i.e., 136°C; DSC, TMA, or DMA).

6.3 Most thermal analysis equipment have the software capability to determine sample \( T_g \) and modulus values; it is recommended that this approach be used for consistency.

6.4 Load Selection Criteria The initial load should be 5 g of tension (approximately 50 mN). The load (or force) may be adjusted for differences in material types or specimen configuration in order to assure the specimen is being held without slack. Avoid an excessive load (or force), which may result in elongation of the specimen due to the applied tension. Specimens above \( T_g \) may become so soft as to be stretched.

Examine all specimens after the test to look for signs of excessive loads, distortions, tears, and other defects.

6.5 Thermal Stresses and Other Anomalies DMA results may be affected by any stresses that might have been frozen into the sample during processing. Samples showing anomalous behavior should be run a second time or preconditioned to remove such stresses. Holding the sample temperature at 20°C above the glass transition and holding for five minutes, followed by slow cooling, will normally remove the stresses in the sample.

6.6 Understanding DMA Refer to ASTM D-4092 for a better understanding of concepts and definitions of terms for dynamic mechanical measurements.

6.7 Instrument Suppliers DMA instruments capable of meeting the requirements of this test method are known to be available from:

TA Instruments
Perkin Elmer Corp.
Seiko Instruments, Inc.
Rheometrics Scientific
Netzsch Instruments, Inc.
1 Scope  This test is designed to determine the glass transition temperature ($T_g$) and coefficient of thermal expansion (CTE) of dielectric materials used in high density interconnect (HDI) and microvias by the use of thermal mechanical analysis (TMA). For isotropic (unreinforced) materials, either method (A = thick specimen; B = thin specimen) may be used. For anisotropic materials (reinforced), both methods shall be used, since the z axis expansion (Method A) is not the same as the x-y axis expansion (Method B).

2 Applicable Documents  None

3 Test Specimens

3.1 Size

Method A  Volumetric or Z-axis expansion – thick specimens (>0.50 mm): Specimens shall be approximately 6.5 mm x 6.5 mm. The thickness shall be a minimum of 0.5 mm; for thicknesses <0.5 mm, use Method B. Exact specimen dimensions may be determined by the apparatus used.

Method B  In-plane (x-y) expansion – thin specimens (<0.5 mm): Specimens shall be approximately 15 mm to 20 mm long and 2 mm wide, with a minimum thickness of 10 µm and a maximum thickness of 0.75 mm. Exact specimen dimensions may be determined by the apparatus used.

3.2 All specimens should be fully cured according to manufacturer’s recommendations. Thick specimens may be made by use of multiple lamination/cure cycles if required.

3.3 For Method B, two samples are to be measured, taken at 90° to each other and labeled in the x and y directions. Anisotropic materials are anticipated to have the same CTE for x and y, and reinforced materials are likely to have differing x and y CTE.

4 Equipment/Apparatus

4.1 A TMA capable of determination of dimensional change to within 0.0025 mm over the specified temperature range. Preferably the TMA will have computer data acquisition and analysis. The TMA must have an environmental chamber capable of having nitrogen flush gas and heating of the specimen to 310°C.

4.2 Diamond blade or saw, sanding equipment, or equivalent to provide specimens of the size and edge quality required for Method A

4.3 Scissors or razor blades or equivalent to provide specimens of size and edge quality for Method B

4.4 Air circulating oven capable of maintaining 105°C ± 2°C

4.5 Dessicator capable of an atmosphere less than 30% RH at 23°C

4.6 Etching system capable of complete removal of metallic cladding

5 Procedure

5.1.1 Metallic clad specimens shall be tested without the cladding. Etch and dry using appropriate procedures and equipment.

5.1.2 Specimens shall be cut to the specified size using appropriate procedures and equipment to minimize thermal shock and mechanical stress. Method A specimens shall have their edges smooth and burr-free by means of sanding or equivalent (to allow the specimen to rest flat on the mounting stage). Method B specimens shall be rectangular, with their long edges parallel (to ensure good mounting in the film fixture). Method B specimens shall have smooth edges without nicks or tears.

5.1.3 Specimens shall be preconditioned by baking for one hour ± 15 minutes at 105°C, then cooled to room temperature in a dessicator.

5.2 Measurement

5.2.1 Apparatus Set-up

5.2.1.1 Install the Correct TMA Probe

Method A  Set up the TMA with a non-penetrating quartz expansion probe.

Method B  Set up the TMA with a thin film fixture/clamp.
5.2.1.2 Apply the Load

**Method A**  Mount the specimen on the stage of the TMA and apply load at 5 g (see 6.5 for an explanation of load criteria). Enclose the specimen and probe in the environmental chamber.

**Method B**  Mount the specimen in the clamps of the film fixture according to the manufacturer’s instructions and apply 2 g tension force (see 6.5 for an explanation of the load criteria). Enclose the specimen and probe in the environmental chamber.

5.2.1.3 Provide an inert gas purge (helium or nitrogen) at a rate of 30 ml/min to 150 ml/min to the environmental chamber. Temperature calibration of the TMA must be performed under the same gas conditions.

5.2.1.4 Measure the initial specimen thickness (Method A) or length (Method B) prior to each heat cycle (L₀).

5.2.2 Many specimens have built in thermal stresses from the curing step, which relaxes during the specimen heating during a TMA test. This relaxation results in TMA scans, which make determination of T<sub>g</sub> and CTE impossible (see Figure 1). Two heat cycles are required to obtain valid T<sub>g</sub> and CTE values.

5.2.3 Running the TMA Temperature Scan

5.2.3.1 Initial Temperature (T<sub>initial</sub>)
   a. For specimens with T<sub>g</sub> below or near room temperature, start the scan at least 20°C below the anticipated transition. This may require a TMA with refrigeration control of the environmental chamber.
   b. For specimens with T<sub>g</sub> greater than room temperature, start the scan at 30°C.

5.2.3.2 Temperature Rate  Depending on sample preparation, two heating cycles may be required to obtain accurate T<sub>g</sub> and CTE above T<sub>g</sub>. If the sample shows unexpected shrinkage above T<sub>g</sub> (see Figure 1), the two heat test method is required. If the sample does not show anomalous behavior, only one heat cycle (the second heat cycle at 5°C/min) is required.
   a. First heat: The first heat cycle of the specimen shall be run at 10°C/min.
   b. Second heat (reportable data heat cycle): The second heat cycle of the specimen shall be run at 5°C/min.

5.2.3.3 Temperature Excursion
   a. First heat: Continue heating the specimen to a temperature 20°C greater than the anticipated T<sub>g</sub> or until the anomalous thermal relaxation has stopped. See Figure 1 for an example of anomalous first heat behavior. Hold the specimen at this temperature for a minimum of five minutes. Avoid holding the sample at this temperature for too long; sample degradation might occur. Cool the specimen to the initial temperature under temperature control at 5°C/min to 10°C/min. This should prevent reestablishment of thermal stresses.
   b. Second heat (reportable data heat cycle): The second heat cycle of the specimen shall continue to 310°C (to ensure good data at 300°C).

5.3 Evaluation

5.3.1 The TMA expansion curve should resemble the plot shown in Figure 2.
5.3.2 An idealized TMA curve has a linear section below the transition (expansion below \( T_g \)) and a linear section above the transition (expansion above \( T_g \)). These linear sections are used in calculating the \( T_g \) and CTE of the material.

With real samples, these “linear” sections are often curved so the standard CTE calculation (see 5.4.2) is the average CTE between the defined points (A-B and C-D in Figure 2). The instantaneous CTE provides CTE as a function of temperature and avoids this averaging effect (see Figure 3).

5.3.3 From the TMA plot, pick four temperatures and obtain the specimen thicknesses at these temperatures:

- \( T_A \) – at least 10°C above \( T_{\text{initial}} \) (to ensure thermal equilibrium) and no higher than 25°C above \( T_{\text{initial}} \)
- \( T_B \) – on the linear portion of the graph below the \( T_g \)
- \( T_C \) – on the linear portion of the graph above \( T_g \)
- \( T_D \) – 300°C

Preferred temperatures for HDI materials:

- \( T_{\text{initial}} = 30°C \)
- \( T_A = 40°C \)
- \( T_B \) = material dependent - below the \( T_g \)
- \( T_C \) = material dependent - above \( T_g \)
- \( T_D = 300°C \)

5.4 Calculations

5.4.1 Glass Transition Temperature – \( T_g \) Construct a tangent line to the curve above and below the transition in the curve. The temperature where these tangents intersect is the TMA determined \( T_g \) for the material. If the tangent method fails to provide an adequate \( T_g \), the instantaneous CTE can be calculated (see 5.4.3) and the midpoint of the step change in CTE may be taken as \( T_g \) (see Figure 3). For consistency, it is recommended that the TMA computer analysis software be used for this calculation (see Figure 2).

5.4.2 Mean Coefficient of Thermal Expansion – CTE

The mean CTE shall be calculated over the specified regions and recorded in units of ppm/°C. For consistency it is recommended that the TMA computer analysis software be used for this calculation.
a. CTE below glass transition:

$$\alpha_{B-A} = \frac{(L_B - L_A) \times 10^6}{L_0(T_B - T_A)}$$

For most materials, this will be in the range of 7 ppm to 50 ppm (reinforced) or 30 ppm to 150 ppm (unreinforced).

b. CTE above glass transition:

$$\alpha_{D-C} = \frac{(L_D - L_C) \times 10^6}{L_0(T_D - T_C)}$$

For most materials, this will be in the range of 50 ppm to 100 ppm (reinforced) or 150 ppm to 500 ppm (unreinforced). Any reinforced materials, where the reinforcement has a negative CTE, will shrink rather than expand when heated above T_g of the resin.

Where:

- $T_A$ = Temperature at point A in Figure 2
- $T_B$ = Temperature at point B in Figure 2
- $T_C$ = Temperature at point C in Figure 2
- $T_D$ = Temperature at point D in Figure 2
- $L_0$ = Initial length or thickness
- $L_A$ = Length or thickness at point A in Figure 2
- $L_B$ = Length or thickness at point B in Figure 2
- $L_C$ = Length or thickness at point C in Figure 2
- $L_D$ = Length or thickness at point D in Figure 2

**5.4.3 Instantaneous Coefficient of Thermal Expansion Curve (Optional)**

The instantaneous CTE expansion curve is the slope of the TMA expansion curve plotted as a function of temperature. Figure 3 shows a combined expansion curve and its resulting instantaneous CTE curve.

Instantaneous CTE ($\alpha_{T}$) is calculated at each temperature ($T_i$) from the slope of the TMA expansion curve ($dL/dT$) at that temperature:

$$\alpha_{T} = \frac{1}{L_0} \left( \frac{dL}{dT} \right)$$

d$L$/dT is determined at each temperature ($T_i$) from the L vs. T curve by:

$$\left( \frac{dL}{dT} \right) = \frac{(L_{i+1} - L_i)}{(T_{i+1} - T_i)}$$

This calculation can be done in a spreadsheet that contains the L vs. T data. Some TMA computer analysis software performs this calculation for you. For an example of plot $\alpha_{T}$ vs temperature, see Figure 3.

**5.4.4 Percent Thermal Expansion (PTE) (Optional)**

The total percent of thermal expansion is calculated as follows:

$$\text{Percent TE} = \frac{(T_D - T_A) \times 100}{L_0}$$

For consistency, it is recommended that the TMA computer analysis software be used for this calculation.

**5.5 Report**

**5.5.1** Report the glass transition temperature of each specimen, rounding to the nearest whole number.

**5.5.2** Report the CTE in ppm/°C above and below $T_g$ and the temperature ranges over which the thermal expansion was determined. For Method B, report $x$ and $y$ CTE values.

**5.5.3** Optionally report the PTE in percent and the temperature ranges over which the thermal expansion was determined.

**5.6 Plot**

**5.6.1** Plot the expansion (µm) vs. temperature (°C) for the specimen. If using computer based analysis, include the $T_g$ and CTE measurement start points and computer generated lines (see Figure 2).

**5.6.2** Optionally plot the instantaneous CTE (µm/°C) vs. temperature (°C) for the specimen (see Figure 3).

**5.6.3** Optionally plot the percent expansion vs. temperature (°C) for the specimen. If using computer-based analysis, include the PTE measurement start points on the plot.

**6.0 Notes**

**6.1** Calibration of the TMA must be carried out according to the manufacturer’s instructions for both probe expansion and specimen temperature.
6.2 There are several methods for determining the $T_g$ of an organic material:

- Differential scanning calorimetry (DSC)
- TMA
- DMA

$T_g$ in organic materials is a broad transition, which arises when molecular mobility greatly increases in the specimen as a result of heating. No one method is superior to another; they each measure different physical changes that occur in a specimen near and around $T_g$.

DSC measures the heat capacity of a specimen. TMA measures the expansion of a specimen and DMA (dynamic mechanical analysis) measures the stiffness of the specimen. The $T_g$ determined from TMA, DSC, and DMA may vary significantly (up to 10°C) because they are measuring different physical properties, which change differently as the specimen goes through $T_g$. As a result, the test equipment used should be noted after the reported $T_g$ value (i.e., 136°C; DSC, TMA, or DMA).

6.3 Most thermal analysis equipment have the software capability to determine $T_g$ and CTE values; it is recommended that this approach be used for consistency.

6.4 To improve the accuracy of this test:

**Method A** Increase the thickness to 0.76 mm or higher. Do not stack single layers of thinner materials to achieve the minimum thickness; this greatly increases test error.

**Method B** Be sure the specimen is mounted in the clamps correctly and that any clamp expansion is corrected properly by calibration of the probe. Method B clamps and specimens may have more difficulty reaching thermal equilibrium.

6.5 Load Selection Criteria

**Method A** The initial load is 2 g. The load may be adjusted for differences in material types or specimen configuration in order to assure intimate contact between the probe, specimen, and stage. Avoid an excess load (15 g), which may result in penetration or distortion of the specimen.

**Method B** The initial load is 5 g of tension (approximately 50 mN). The load (or force) may be adjusted for differences in material types or specimen configuration in order to assure that the specimen is being held without slack. Avoid an excessive load (or force), which may result in elongation of the specimen due to the applied tension. Specimens above $T_g$ may become so soft as to be stretched.

Examine all specimens after the test to look for signs of excessive loads, distortions, tears, and other defects.
1 Scope  This test method shall establish and define the methods for predicting the bond strength, on a go-no-go basis, of additive rigid epoxy glass boards of the swell-etchable type.

2 Applicable Documents
ASTM-D1000 Standard Test Method for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications

3 Test Specimen  A minimum of two boards per test, each board having the dimensions of 76 mm x 152 mm

4 Apparatus

4.1  Liter beakers with slotted lids

4.2  A wooden wallpaper seam roller (see Figure 1 and Figure 2). The type in Figure 1 can be purchased in most hardware shops, while the second roller is described in ASTM-D100.

4.3  An Instron or some other suitable peel tester, capable of peeling at a 90° angle with a uniform, constant peel rate

4.4  3M Brand Filament tape, No. 898, or equal. A 6.4 mm width size is convenient.

4.5  Chemicals  An additive chemical pre-treatment sequence from any of the major electronic chemical suppliers may be used. While the IPC does not endorse any specific chemical supplier, the chemical sequence should consist of several items.

- Conditioner
- Etchant
- Neutralizer

5 Procedure

5.1  Test

5.1.1  Prepare the processing chemistry in one liter beakers in accordance with the chemical suppliers’ recommendations.

5.1.2  In order to ensure that vapors from the processing solution do not attack the resin, some precaution should be taken to maintain minimum exposure of the untreated board area to vapors (e.g., use of a slotted lid over beaker). Also, no more than 10 sample boards/liter of any of the process chemicals shall be processed.

5.1.3  Partially submerge a board (76 mm x 152 mm) in liter beakers following the process below. That portion of the board, not in the liquid, provides an “as is” surface as a control and base comparison.
5.1.4 Process Sequence  For a breakdown of time and temperature requirements of this test, see Table 1.

Table 1  Process Sequence

<table>
<thead>
<tr>
<th>Process</th>
<th>Temp (°C)</th>
<th>Time (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditioner</td>
<td>32</td>
<td>4</td>
</tr>
<tr>
<td>Rinse</td>
<td>16-27</td>
<td>2-3</td>
</tr>
<tr>
<td>Etch</td>
<td>66</td>
<td>6.5</td>
</tr>
<tr>
<td>Air Dry</td>
<td>—</td>
<td>0.75</td>
</tr>
<tr>
<td>Triple Rinse</td>
<td>16-27</td>
<td>3-5</td>
</tr>
<tr>
<td>Neutralizer</td>
<td>52</td>
<td>2.5</td>
</tr>
<tr>
<td>Rinse</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>Air Dry</td>
<td>25</td>
<td>Overnight</td>
</tr>
</tbody>
</table>

5.1.5 Apply tape to both the treated and non-treated surfaces of the board using a wooden roller and fixed uniform pressure (approximately 4.5 kg.). Peel tape on Instron or other peel tester at 900 angle and a 5 cm/min. peel rate. Report the peel force as kg/cm on both treated and non-treated portions board.

5.1.6 Use two boards per test. Put tape on each side of the board and obtain tape results for one tape strip per side per board.

5.2 Evaluation

5.2.1 Report the tape peel strength in kg/cm width.

5.2.2 Report the locus of failure of peeled tape (see Note 1.).

Note 1: The requirement of specifying the locus of mode of failure of the tape is very important and a critical aspect of the test. In order to be consistent with descriptions of failure modes, a common set of criteria is used, as defined in Table 2. Figure 3 shows, in schematic, the various failure modes one could obtain during performing this test. The three layers, from bottom to top, are (1) the epoxy/glass substrate, (2) the adhesive component of the tape, and (3) the tape backing (see top left drawing in Figure 3).

5.2.3 Report the average of the two tape peel strengths (in kg/cm width) for the same side of both boards.

Table 2  Modes of Failure Shown in Figure 3

<table>
<thead>
<tr>
<th>Notation</th>
<th>Meaning of Failure Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA/TB</td>
<td>Interfacial failure, between adhesive and tape backing</td>
</tr>
<tr>
<td>C</td>
<td>Cohesive failure within tape adhesive</td>
</tr>
<tr>
<td>M</td>
<td>Mixed failure mode, a combination of the other types</td>
</tr>
<tr>
<td>IB/A</td>
<td>Interfacial failure, between the board and the adhesive of the tape.</td>
</tr>
</tbody>
</table>

Figure 3  Modes of Failure
1.0 **Scope**  This method is designed to evaluate the resistance of solder mask or conformally coated surfaces to rubbing abrasion.

2.0 **Applicable Documents**  None

3.0 **Test Specimen**  An IPC Multipurpose Test Board, Number IPC-B-25 or any preproduction or production board 10.8 cm x 10.8 cm [4 1/4 in. x 4 1/4 in.] in size and coated with solder mask or conformal coating.

4.0 **Apparatus**

4.1 Taber Abraser Model 5130

4.2 1000 gram load for each wheel

4.3 CS-10 Calibrase wheels

5.0 **Procedure**

5.1 **Preparation**

5.1.1 Drill or punch hole in middle of specimen for mounting specimen on Taber Abraser.

5.1.2 Mount calibrase wheels and pressure load (1000 grams) on equipment.

5.1.3 Clean calibrase wheels (CS-10) according to recommended procedures in Taber Abraser Manual.

5.2 **Test**  Place sample on abraser and test specimen to the required number of cycles of abrasion.

5.3 **Evaluation**  Examine the coated board for breakthrough to the conductive pattern or base material.

6.0 **Notes**  Taber Abraser Model 5130, available from Teledyne Taber, 455 Bryant St., N. Tonawanda, NY 14120 or Pacific Scientific, Gardner Neotech Division, 2431 Linden Lane, Silver Springs, MD 20910 or equivalent.
1.0 Scope  This method is designed to evaluate the hardness of solder masked surfaces and its resistance to abrasion.

2.0 Applicable Documents
ASTM D3363-74  Film Hardness by Pencil Test

3.0 Test Specimen  IPC Multipurpose Test Board, IPC-B-25, or any preproduction or production board coated with solder masking.

4.0 Apparatus  Standard set of hardness pencils (Eagle Turquoise brand suggested, available from local drafting supply houses).

4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H  Soft  →  →  →  →  →  →  →  →  →  →  →  Hard

5.0 Procedure  Place the test board on a firm horizontal surface. Starting with the hardest pencil, hold pencil firmly against the solder mask at a 45 degree angle. Push pencil away from the operator with uniform downward and forward pressure in a 6.4 mm [1/4 inch] stroke. Proceed with the next softer pencil in succession until a pencil is used which will not cut into or gouge the solder mask.

6.0 Evaluation  Record the value of the hardest pencil which will neither cut into nor gouge the solder mask.
1.0 Scope This test method defines the procedure for determining the adhesion of solder masks used over non-melting metals such as copper, gold, nickel, and tin printed wiring boards, both prior to and after soldering.

2.0 Applicable Documents

Commercial Item Description AA-113 Tape, Pressure-Sensitive Film, Office Use

3.0 Test Specimen The test specimen used for preproduction qualification consists of the IPC-B-25 Test Board, Coupons Q and P, clad on both sides with 1 ounce copper, which has the plated metal surfaces that are applicable, and coated with solder mask. For production board testing, use printed wiring boards currently being processed.

4.0 Apparatus

4.1 Cross Hatch Cutter A cutting tool consisting of six parallel blades which will cut through the solder mask film. Spacings between blades are 2 mm.

4.2 Alternative Cutting Device An X-Acto knife with blade No. 6, or equivalent.

4.3 Tape A roll of pressure sensitive tape 3M Brand 600 1/2 inch wide or a tape as described in (CID AA-113), Type 1, Class B, except that the tape may be clear.

5.0 Procedure

5.1 Preparation

5.1.1 Test specimens are to be prepared by processing 1 ounce double clad epoxy glass laminate through the standard plating processes for the metal coatings which are applicable.

5.1.2 For preproduction qualification, test specimens are to be cleaned using cleaning methods as recommended by the solder mask manufacturer and standard production methods for comparison purposes prior to solder mask coating.

5.1.3 Test specimens are to be coated and cured by the standard production method.

5.1.4 Testing should be conducted on specimens both before and after wave soldering.

5.2 Testing

5.2.1 Using the prescribed cutting tool, cross hatch (at 90° angles) an area on the solder mask coated base laminate surface and on the metal conductor surface. Make all cuts 1 inch long. Use sufficient pressure to cut through the film.

Note: Cutting tools must be sharp without defects. When using the alternative cutting tool, the cross hatch pattern created shall simulate that created by the cross hatch cutter.

5.2.2 Lightly brush the cross hatched area with a soft brush to remove any particles of film.

5.2.3 Press a strip of pressure sensitive tape 1/2 inch wide by 2 inches long firmly across the surface of the cross hatched area using a hand roller or eraser.

5.2.4 Rapidly remove the tape by manual force applied approximately perpendicular to the pattern. An unused strip of tape must be used each time.

5.3 Evaluation Visually examine tape for evidence of film particles. Examine board for separation, fracturing, or delamination of the coating from the surfaces of the bare material and conductors.

6.0 Notes

6.1 Erichsen cross hatch cutter, model number GE 2952, available from Pacific Scientific, Gardner Neotech Division, 2431 Linden Lane, Silver Springs, MD 20910, or equivalent.
1.0 Scope  This test method defines the procedure for determining the adhesion of solder resists (masks) used over melting metals, (such as solder plated and reflowed solder printed boards both prior to and after soldering), non-melting metals, and printed board substrates.

2.0 Applicable Documents

J-STD-003  Solderability Test Methods for Printed Boards.
IPC-2221  Design Standard for Rigid Printed Boards.

3.0 Test Specimens  The test specimen used shall be the test coupon shown in Figure 1, which has the plated metal surface that is applicable, and coated with solder resist.

4.0 Apparatus or Material

4.1 Tape  A roll of pressure sensitive tape 3M Brand 600 1/2 inch wide. The shelf life of the tape is one year.

5.0 Procedure

5.1 Preparation

5.1.1 For qualification testing, test specimens are to be prepared by processing 34 micron, double clad epoxy glass laminate through the standard plating process for the metal coatings that are applicable. For production testing, the coupons shall be representative of the board.

5.1.2 For preproduction qualification, test specimens are to be cleaned using cleaning methods as recommended by the solder resist manufacturer and standard production methods for comparison purposes prior to solder resist application.

5.1.3 Test specimens are to be coated and cured by the standard production method.

5.1.4 Testing is to be conducted on specimens before and after soldering in accordance with J-STD-003, Methods A, B, C, or D with no accelerated aging.

5.2 Test

5.2.1 Press a strip of pressure sensitive tape, 50 mm minimum in length, firmly across the surface of the test area removing all air entrapment. The time between application and removal of tape shall be less than one minute. Remove the tape by a rapid pull force applied approximately perpendicular (right angle) to the test area. An unused strip of tape must be used for each test.

5.3 Evaluation

Figure 1  Test Coupon G of IPC-2221
5.3.1 Visually examine the tape and test area for evidence of any portion of the material tested having been removed from the specimen.

5.3.2 The report should note any evidence of material removed by this test.

6.0 Notes

6.1 Figure 1 illustrates the coupon that is used for testing. The black squares indicate metal. The white squares indicate the base material. Solder mask is applied over the entire conductor pattern.

6.2 If foreign material (oil, grease, etc.) is present on the test surface the results may be affected.

6.3 Certification of 3M Brand 600 1/2 inch tape to CID-A-A-113 is not required. The 3M Brand 600 1/2 inch tape is available through most office supply stores.
1.0 This test method is to determine the adhesion quality of solder masks used on flexible circuits.

2.0 Applicable Documents
None

3.0 Test Specimen
IPC-B-29 flexible test pattern or production test samples with solder mask coating. Each flexible section shall be separated and tested independently.

4.0 Apparatus
3 mm [1/8 inch] diameter mandrel.

5.0 Procedures

5.1 Test

5.1.1 Flex the specimen around the mandrel as described below. Each cycle must be at the same point on the flexible circuit.

5.1.2 Subject specimen to 10 cycles (20 folds) of folding 180° in each direction around the 3 mm [1/8 inch] mandrel.

5.2 Evaluation
If specimens have survived the 3 mm [1/8 inch] diameter mandrel bends without any evidence of solder mask separation or cracks, they shall pass the adhesion to flexible circuits test.
1 Scope  This test method is to determine the impact resistance of polymer film circuitry when exposed to a series of falling ball impingements. The method is used to evaluate the resistance to chipping, flaking, convolution or other forms of separation of the polymer film from either the conductor or base laminate material surfaces.

2 Applicable documents  None

3 Test specimen  IPC-B-25 Multi-Purpose Test Board

4 Equipment/Apparatus

4.1 A suitable electromagnetic apparatus to precisely control the height and the point of impact of the falling ball (see Figure 1)

4.2 The test ball shall be 25 mm diameter, 67 gram precision steel ball.

4.3 When testing flexible circuits, the test specimen shall be placed on a hard smooth surface. Use of at least 0.6 cm cold rolled steel sheet stock.

5 Procedure

5.1 Preparation

5.1.1 Adjust the fall height by setting the solenoid core at 53 cm ± 0.3 cm from the top surface of the test specimen.

5.2 Test

5.2.1 Place the steel ball on the underside of the solenoid core with the solenoid energized.

5.2.2 Place the test specimen below the falling ball in such a manner as to strike the center of feature (L) on test specimen IPC-B-25.

5.2.3 Release the falling ball by de-energizing the solenoid magnet.

5.2.4 It is necessary to catch the ball immediately after impact so as not to permit more than one blow at a time.

5.2.5 Repeat this procedure for 10 cycles and observe the test specimen after each blow.

5.2.6 Perform the same test (also for 10 cycles) on any area of the test specimen having no circuitry.

5.2.7 Repeat the same test in such a manner as to strike the edge of the feature (L) 10 times.

5.3 Evaluation  Visually examine the test specimen for chipping, flaking, convolution, or other forms of separation of the polymer film.

6 Notes

6.1 The test apparatus shown in Figure 1 can easily be assembled using a standard laboratory stand and clamps, a 12 volt DC Solenoid, and a 12 Volt battery.
1 Scope  This method describes the test procedure required to perform the folding test for flexible flat cable.

2 Applicable documents  None

3 Test sample

3.1  The number of production samples shall be determined by the manufacturer and/or user and shall be a minimum of three specimens.

3.2  The test specimen shall be 0.6 meters minimum.

4 Apparatus

4.1  A mechanism that will produce 2.11 kg/cm² (the total force is based on the overlapping area included in the fold) of pressure between two metal plates and hold that pressure for a minimum of 15 minutes at room temperature

5 Procedure

5.1  The specimens of 3.1 and 3.2 shall be folded 180° transversely along a 45° angle to the conductors and pressed between two metal plates with a pressure of 2.11 kg/cm². See Figure 1.

Example: 7.5 cm wide cable

\[
FA = \frac{\text{width}^2}{2} = \frac{3 \times 7.5^2}{2} = 4.5 \text{ in}^2
\]

Total Force = \( FA \times 2.11 \text{ kg} \)
Total Force = \( 4.5 \times 30 \)
Total Force = 61.2 kg

After 15 minutes, the cable shall be unfolded and the pressure shall be reapplied for 15 minutes. This action constitutes one cycle of folding and unfolding. The cable shall be subjected to two complete cycles.

5.2 Evaluation  The samples shall be evaluated per the appropriate requirement of the applicable specification.

Figure 1  Applied Force on Folded Specimen
1 Scope
This method describes the procedure for fold temperature testing.

2 Applicable documents
None

3 Test sample
3.1 The number of production samples shall be determined by the manufacturer and/or user and shall be a minimum of three specimens.

3.2 The test specimen shall be 0.6 meters minimum.

4 Apparatus
4.1 Mechanism that will produce 2.11 kg/cm² (the total force is based on the overlapping area included in the fold) of pressure between two metal plates and hold that pressure for a minimum of 15 minutes at room temperature

4.2 Forced convection test chamber or chambers, capable of being maintained at the specimen rated high temperature and capable of being maintained at the specimen rated low temperature

5 Procedure
5.1 The specimens of 3.1 and 3.2 shall be folded 180° transversely along a 45° angle to the conductors and pressed between two metal plates with a pressure of 2.11 kg/cm². See Figure 1.

Example: 76 mm wide cable

\[
FA = \frac{\text{width}^2}{2}
\]

\[
FA = \frac{3X^2}{2} = 4.5 \text{ in}^2
\]

Total Force = FA x 2.11 kg
Total Force = 4.5 x 30
Total Force = 61.2 kg

5.2 After 15 minutes, the pressure shall be released. The folded specimen shall be placed in a forced convection oven at the elevated temperature. After four hours of exposure the specimen shall be placed in a test chamber at the low rated temperature (the transfer time shall be a maximum of five minutes between temperature extremes). The specimen shall be removed from the cold chamber and allowed to stabilize at room temperature.

5.3 Evaluation
The specimens shall be evaluated per the appropriate requirement of the applicable specification.
1 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 foil ductility by using a fatigue test is made necessary by the geometry and dimensions of the foil samples, which make tensile elongation and rupture tests inadequate for ductility determination.

2 Applicable Documents

2.1.1 Microsectioning
2.4.18 Tensile Strength and Elongation, Copper Foil

3 Test Specimen

Flat cable sections of 63.5 mm in length and containing at least four conductors shall be used.

4 Equipment/Apparatus

4.1 Ductility Flex Tester, Universal Mfg., Model FDF or 2FDF or equal (see Figure 2 and 6.3)
4.2 Micrometer tool capable of measurement to the nearest 0.0025 mm
4.3 Programmable Calculator, Hewlett Packard HP-67 or equal (see 6.3.2)
4.4 Sample holders, 203.2 x 12.7 mm, of very flexible material, e.g., epoxy-impregnated glass cloth, paper, etc.
4.5 Microscope

5 Procedure

5.1 Preparation of Samples

5.1.1 The samples should be smooth and undistorted.
5.1.2 Cut the samples about 63.5 mm long. Cut between conductors to obtain specimens with at least four parallel conductors. Care has to be taken to keep cut clear of conductors.

5.1.3 Use the micrometer to determine the specimen thickness, \( t \), and the conductor thickness, \( t_M \) (see Figure 1), to the nearest 0.0025 mm.

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: Most conductors in flat cables are smooth on both surfaces. If not, 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 the core values for all samples.

5.1.4 Connect all conductors to be tested and monitored in a series and attach thin relay leads to the two free ends.

5.1.5 Attach the test specimen to the ends of two sample holders with adhesive tape and clamp 224 grams of circuit weight to the free ends of the sample holders to form a loop (see Figure 2).

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 the specimen and sample holder as a result of the cyclic flexure movement.

5.2 Test Procedure

5.2.1 Mount mandrels to the flex tester and adjust the support roller positions for a clearance of 1.27 mm (shim provided) between rollers and mandrels.
Note: For the ductility test, it is important that the specimens fail between 30 and 500 cycles. The 6.35 mm diameter is suggested for mandrels but, for some samples, different mandrel diameters might be necessary. Larger mandrel diameters result in longer cyclic life and smaller diameters result in shorter life.

5.2.2 Mount the test specimen between mandrels, attach 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:

\[ N_f^{-0.6} D_f^{0.75} + 0.9 \frac{S_u}{E} \left[ \exp \left( \frac{D_f}{0.36} \right) \right]^{0.175 \log_{10} \frac{20}{N_f}} - \frac{2t_M}{2\theta + t} = 0 \]

where:
- \( D_f \) = fatigue ductility, \((x100\%)
- \( N_f \) = cycles-to-failure
- \( S_u \) = ultimate tensile strength
- \( E \) = modulus of elasticity
- \( t_M \) = core thickness
- \( t \) = specimen micrometer thickness
- \( p \) = mandrel radius of curvature, within 0.005 mm

\textbf{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.

5.3.1.2 Report the average 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 mandrels 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 Manon-Coffin plot \( \log \Delta \epsilon = \log N_f \) versus \( 2t_M/(2p + t) \) allows intra- and extrapolation to other bend radius 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 fatigue ductility determined in 5.3.1.2 and the desired bend radius.

6.0 Notes

For further technical details, reference the material shown below.

IPC-TP-204 "A New Ductility and Flexural Fatigue Test Method for Copper Foil and Flexible Printed Wiring," Engelmaier, W., Apr. 1 1978

6.1 Test Equipment Sources The equipment sources described in 6.1.1 and 6.1.2 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.

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

1.0 **Scope**  The test specifies a standard procedure for determining the viscosity of solder paste in the range of 300,000 to 1,600,000 centipoise.

2.0 **Applicable Documents**  None

3.0 **Test Specimen**  Paste to be tested shall be stabilized at 25° ± 1°C for a minimum of 24 hr. prior to testing. The paste volume shall be sufficient to fill a test container having a minimum diameter of 5 cm and a minimum depth of 5 cm.

4.0 **Equipment/Apparatus**  The equipment used shall be a spindle type viscometer (Brookfield RVTD or equivalent) with a reversible helipath stand and pen recorder. A TF spindle shall be used for tests and operated at 5 rpm. Other equipment may be used provided the results can be empirically correlated as mutually agreed upon with the following test. Additional shear rates may be specified by the user or supplier provided one data point is based as specified below.

5.0 **Procedure**

5.1 **Preparation**

5.1.1 Open the supply container(s); remove any internal cover(s), scrape off paste adhering to the lid(s), internal covers, and the container walls; and add this material to the paste in the supply container(s).

5.1.2 Using a spatula, stir the paste gently for 1 to 2 minutes to homogenize it; taking care to avoid the introduction of air.

5.1.3 If necessary, gently transfer the paste to the test container having the specified volume; without introducing air. **Note:** If the supply container meets the volume and size requirements a separate test container is not needed.

5.1.4 The test container shall be placed in a constant temperature environment at 25° ± 0.25°C. The solder paste shall remain stationary for a minimum of two hours to reach temperature and rheological equilibrium. For freshly manufactured products, products which require significant adjustment with thinner (greater than 1/2% by weight), or products having rheological characteristics requiring longer time to stabilize, the stabilization time shall be increased to four hours or as mutually agreed upon by user and supplier.

5.1.5 Set the bottom stop for helipath travel to position the T spindle at 2.8 cm below the surface of the solder paste in the test container. The bottom stop of the spindle shall be a minimum of 1 cm above the bottom of the container. Set the upper stop to position the spindle at 0.3 cm below the surface of the solder paste.

5.2 **Test**

5.2.1 Immerse the spindle in the solder paste and record data for 10 minutes (5 cycles). The temperature of the solder paste during the test shall be maintained at 25 ± 0.25°C.

5.3 **Evaluation**  Viscosity is to be expressed at the value calculated from the average of the peak and valley of the last two cycles. If the average for the first two cycles is more than 10% higher than the last two cycles, the test is invalid and additional equilibrium time is required. Record data and enter in Table 1, "Test Report on Solder Paste."

6.0 **Notes**

6.1 **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.

6.1.1 **Spindle Type Viscometer Equipment**
Brookfield Engineering Laboratories, Inc.
240 Cushing Street
Stoughton, MA 02072
(617) 344-4310
Table 1  Test Report on Solder Paste

Enter appropriate information in top portion of report and complete report by entering the test results or checkmarks in the appropriate spaces.

<table>
<thead>
<tr>
<th>Inspection Purpose:</th>
<th>QPL I.D. Number:</th>
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<th>__ Quality Conformance A Manufacturer’s Batch Number:</th>
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Material
Visual
Metal Content
Viscosity
Solder Ball
Slump
Alloy
Flux

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</table>

* P/F = PASS/FAIL; enter P if test results are within tolerance of actual requirement; otherwise, enter F
1.0 Scope  This test specifies a standard procedure for determining the viscosity of solder paste in the range of 50,000 to 300,000 centipoise.

2.0 Applicable Documents  None

3.0 Test Specimen  Paste to be tested shall stabilize at 25°C ± 1°C for a minimum of 24 hours prior to testing. The paste volume shall be sufficient to fill a test container having a minimum diameter of 5 cm and a minimum depth of 5 cm.

4.0 Equipment/Apparatus  Equipment used shall be a spindle type viscometer (Brookfield RVTD or equivalent) with a helipath stand and pen recorder. A TC spindle shall be used for tests. Spindle speed is 5 rpm. Other equipment may be used provided the results can be empirically correlated as mutually agreed upon with the following test. Additional shear rates may be specified by the user or supplier provided one data point is based as specified below.

5.0 Procedure

5.1 Preparation

5.1.1  Open the supply container(s); remove any internal cover(s); scrape off paste adhering to the lid(s), internal covers, and the container walls; and add this material to the paste in the supply container(s).

5.1.2  Using a spatula, stir the paste gently for 1 to 2 minutes to homogenize it; taking care to avoid the introduction of air.

5.1.3  If necessary, gently transfer the paste to the test container having the specified volume—without introducing air. Note: If the supply container meets the volume and size requirements, a separate test container is not needed.

5.1.4  The test container shall be placed in a constant temperature environment at 25°C ± 0.25°C.

5.1.5  After reaching 25°C ± 0.25°C, the solder paste shall be stirred and then tested within 20 minutes to minimize settling of the metal powder; while remaining at 25°C.

5.2 Test

5.2.1  Set the solder paste container below the spindle. Record data as the spindle penetrates the solder paste.

5.3 Evaluation  The viscosity is calculated from the value recorded after the bar of the spindle comes in contact with the surface of the paste. Record the data in Table 1 “Test Report on Solder Paste.”

6.0 Notes

6.1 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.

6.1.1 Spindle Type Viscometer Equipment  Brookfield Engineering Laboratories, Inc. 240 Cushing Street Stoughton, MA 02072 (617) 344-4310
Table 1 Test Report on Solder Paste

Enter appropriate information in top portion of report and complete report by entering the test results or checkmarks in the appropriate spaces.

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Date Inspection Completed: __________________________ Overall Results: __ Pass __ Fail
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* P/F = PASS/FAIL; enter P if test results are within tolerance of actual requirement; otherwise, enter F
1.0 Scope  The test specifies a standard procedure for determining the viscosity of solder paste in the range of 300,000 to 1,600,000 centipoise.

2.0 Applicable Documents  None

3.0 Test Specimen  Paste to be tested shall be stabilized at 25°C ± 1°C for a minimum of 24 hours prior to testing. The paste volume shall be sufficient to fill the viscometer receptacle to about 60% of its depth.

4.0 Equipment/Apparatus  The equipment used shall be a spiral pump viscometer (Malcom, Brookfield Viscometer or Rheometer with Spiral Adaptor accessory, or equivalent). Set the instrument rotational speed for 10 rpm. Other equipment may be used provided the results can be empirically correlated as mutually agreed upon. Additional shear rates may be specified by the user or supplier.

5.0 Procedure

5.1 Preparation

5.1.1 Open the container(s), remove any internal cover, scrape off paste adhering to the lids or internal cover(s) and the container wall(s) and add this to the paste in the container(s).

5.1.2 Using a spatula, stir the paste gently for 1 to 2 minutes to homogenize it, taking care to avoid the introduction of air.

5.1.3 Transfer sufficient paste to the viscometer receptacle to fill this to about 60% of its depth. Place the receptacle in the temperature controlled unit of the viscometer and allow it to stabilize at 25 ± 0.25°C for 15 minutes minimum.

5.2 Test

5.2.1 Immerse the instrument sensor into the sample in accordance with the equipment manufacturer’s instructions. The solder paste should not cover the pump outlet.

5.2.2 Turn on chart recorder and set instrument to run at one specific shear rate. Take reading when output has been stable for at least 1 minute. If additional shear rates are to be measured, adjust the speed vernier and repeat above.

5.2.3 Record the viscosity measured at the single shear rate value. By mutual agreement between user and supplier multiple shear rates must be used to develop the solder paste shear sensitivity factor.

5.3 Evaluation  Enter data in Table 1 “Test Report on Solder Paste.”

6.0 Notes

6.1 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.

6.1.1 Spiral Pump Viscometer Equipment  Brookfield Engineering Laboratories, Inc. 240 Cushing Street Stoughton, MA 02072 (617) 344-4310 Malcom Instruments Corp. 26226 Industrial Blvd. Hayward, CA 94545 (510) 293-0580 (510) 293-0584 - fax

6.2 Shear sensitivity factor is defined as the absolute value of the slope of a graph of the log viscosity versus log rpm.
Table 1 Test Report on Solder Paste

Enter appropriate information in the top portion of the report and complete the report by entering the test results or checkmarks in the appropriate spaces.

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__ Performance Revised Use-By Date: ____________________________

Date Inspection Completed: ____________________________ Overall Results: __ Pass __ Fail

Inspection Performed by: ____________________________ Witnessed by: ____________________________

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* P/F = PASS/FAIL; enter P if test results are within tolerance of actual requirement; otherwise, enter F
1.0 Scope
This test specifies a standard procedure for determining the viscosity of solder paste in the range of 50,000 to 300,000 centipoise.

2.0 Applicable Documents
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3.0 Test Specimen
Paste to be tested shall be stabilized at 25°C ± 1°C for a minimum of 24 hours prior to testing. The paste volume shall be sufficient to fill the viscometer receptacle to about 60% of its depth.

4.0 Equipment/Apparatus
The equipment used shall be a spiral pump viscometer (Malcom, Brookfield Viscometer or Rheometer with Spiral Adaptor accessory, or equivalent). Set the instrument rotational speed for 10 rpm. Other equipment may be used provided the results can be empirically correlated as mutually agreed upon. Additional shear rates may be specified by the user or supplier.

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5.2 Test
5.2.1 Immerse the instrument sensor into the sample in accordance with the equipment manufacturer’s instructions. The solder paste shall not cover the pump outlet.

5.2.2 Turn on chart recorder and set instrument to run at one specific shear rate. Take reading when output has been stable for at least 1 minute.

5.3 Evaluation
Record data in Table 1 “Test Report on Solder Paste.”

6.0 Notes
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Date Inspection Completed: __________________________ Overall Results: __ Pass __ Fail
Inspection Performed by: __________________________ Witnessed by: __________________________

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<td>% In Bottom Screen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% In Receiver Bottom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Powder Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powder Shape</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tack</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* P/F = PASS/FAIL; enter P if test results are within tolerance of actual requirement; otherwise, enter F
1.0 Scope
This procedure determines vertical and horizontal slump for solder pastes.

2.0 Applicable Documents
None

3.0 Test Specimen
A standard specimen shall be prepared using a clean frosted glass microscope slide measuring 7.6 cm x 2.5 cm, minimum 1 mm thick. An equivalent alumina or glass epoxy substrate may be used.

4.0 Equipment/Apparatus
Stencils
IPC-A-21, IPC-A-20
Steel Squeegee (razor blade)
Oven
Microscope

5.0 Procedure

5.1 Preparation

5.1.1 Specimen preparation using appropriate stencil pattern IPC-A-21 or IPC-A-20. (Figures 1 & 2) Deposit solder paste patterns on 2 substrates for each stencil pattern. The printed pattern shall be uniform in thickness with no solder particles separated from the pads. The vendor and user should use the same printing method.

5.1.2 One test specimen shall be marked as specimen #1 and one specimen as #2 and processed in accordance with paragraphs 5.2.1 and 5.2.2.

5.2 Test

5.2.1 The specimens shall be stored for 10 to 20 minutes at 25 +/-5°C and 50% relative humidity +/-10% and specimen #1 examined for slump.

5.2.2 Specimen #2 from 5.2.1 shall be heated to 150 +/-10°C for 10 to 15 minutes, cooled to ambient and examined for slump.

5.3 Evaluation
Enter data in Table 1 and/or Table 2 by entering spacings which have bridged with a suitable check mark.

### Table 1

<table>
<thead>
<tr>
<th>Stencil IPC-A-21 (0.2 mm Thick)</th>
<th>Pad size 0.63 x 2.03 mm</th>
<th>Pad size 0.33 x 2.03 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacing mm Hor. Vert. Spacing mm Hor. Vert.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.79</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>0.71</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>0.63</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>0.56</td>
<td>0.30</td>
<td></td>
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<tr>
<td>0.48</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>0.41</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>0.33</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>0.10</td>
<td>0.08</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Stencil IPC-A-20 (0.1 mm Thick)</th>
<th>Pad size 0.33 x 2.03 mm</th>
<th>Pad size 0.2 x 2.03 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacing mm Hor. Vert. Spacing mm Hor. Vert.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.45</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>0.40</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>0.35</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>0.30</td>
<td>0.175</td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>0.20</td>
<td>0.125</td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>0.10</td>
<td>0.075</td>
<td></td>
</tr>
<tr>
<td>0.08</td>
<td>0.075</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1 Slump test stencil, IPC-A-21
Figure 2  Slump test stencil, IPC-A-20

Pad Size: 0.20 x 2.03 mm
—16 identical pads per row
—Same spacings each row

Pad Size: 0.33 x 2.03 mm
—18 identical pads per row
—Same spacings each row
1 Scope  This test method is used to simulate the procedures for plated-through hole (PTH) component removal and replacement, in order to determine the effects of rework on the quality and integrity of the PTH barrel and conductor foil on bare rigid or flexible printed boards. The five steps are designed to simulate initial soldering after a preconditioning bake and two subsequent replacements.

2 Applicable Documents

2.1.1  Microsectioning
2.1.1.2  Microsectioning - Semi or Automatic Technique Microsection Equipment
J-STD-004  Requirements for Soldering Fluxes
J-STD-006  Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications
QQ-W-343  Wire, Electrical (Uninsulated)

3 Test Specimen

3.1  The standard test sample shall be as specified in the governing specification or standard. In certain situations, it may be necessary to perform this test on a production printed board. In this case, a minimum of three PTHs shall be selected. For military printed board(s), the selected holes shall contain the maximum number of internal layer connections, so that a complete quality evaluation can be made.

Note:  This is a destructive test.

4 Equipment/Apparatus

4.1  A soldering and/or desoldering iron with temperature control accurate within ± 6°C of the pre-selected idle temperature of 260°C, 315°C, or 371°C (see 6.2)

4.2  Tin coated solid copper wire, conforming to QQ-W-343

4.3  Liquid soldering flux conforming to J-STD-004, Flux Designator ROL1

4.4  Rosin fluxed solder Sn60Pb40A or Sn63Pb37A with Flux Designator ROL1 (Rosin, Flux activity Type L1) conforming to J-STD-006

4.5  Metallographic laboratory facilities, conforming with IPC-TM-650, Methods 2.1.1 or 2.1.1.2

4.6  Metallograph capable of up to 200X magnification

4.7  Forced air convection oven capable of maintaining 121°C to 149°C

4.8  Shear type wire cutters

4.9  System for solder removal (desoldering braid or vacuum assisted desoldering tool)

5 Procedure

5.1  Condition specimens in a forced air convection oven at 121°C to 149°C for a minimum of six hours to remove moisture. After conditioning, allow the specimens to cool to room temperature.

5.2  To aid in the addition or removal of solder, flux may be applied to both sides of the test specimen.

5.3  The hand soldering and desoldering operation of the wire shall be performed as follows:

Step 1:  Solder wire into PTH
Step 2:  Remove (desolder) wire from PTH
Step 3:  Resolder wire into PTH
Step 4:  Remove (desolder) wire from PTH
Step 5:  Resolder wire into PTH

During the desolder and solder steps, solder every other PTH in the row and allow the specimen to cool to room temperature. Then solder the remaining PTHs.

5.4  During the solder and desoldering steps, the soldering and/or desoldering iron shall have a tip temperature as follows (see 6.1):

Method A:  260°C - Default method
Method B:  315°C
Method C:  371°C
Create a solder bridge between the soldering iron tip, land area, and wire, avoiding direct pressure on the land area. The solder is to melt and form the connection within two to five seconds. Permit the wire and specimen to cool to room temperature.

If the solder connection cannot be formed within five seconds using the specified method the test shall be repeated using the subsequent method. This deviation shall be noted in the test report.

5.5 Position test wires in the PTHs and solder by hand. The test wires that are to be hand soldered in the PTHs shall have a diameter between 0.25 mm and 0.71 mm less than the diameter of the PTH.

5.6 During the desoldering step, form a solder bridge and remove the solder from the PTH within two to five seconds. Allow the specimen to cool to room temperature. Resolder the wire in the PTH using fresh solder.

5.5 Prepare a microsection specimen for metallographic evaluation per IPC-TM-650, Method 2.1.1 or 2.1.1.2. Evaluate the microsection in accordance with the requested standard or specification.

6 Notes

6.1 Those who require the use this test method will need to specify either Methods A, B, or C which affect the soldering iron tip temperatures that are to be used when performing the soldering and desoldering operations. If no method is specified then Method A [260°C] is to be used.

6.2 Users of direct power soldering irons with fixed temperature tip cartridges may substitute the appropriate series tip cartridge for the specified temperatures in Methods A, B, and C as follows:

- 260°C ≈ 500 series cartridges
- 315°C ≈ 600 series cartridges
- 371°C ≈ 700 series cartridges

The type of soldering iron technology used (direct power or stored heat) will affect the test results and therefore the repeatability of this method. The type of soldering iron technology used shall be specified in the test report.

6.3 Users of this method are cautioned to use good industry assembly soldering techniques when performing the operations specified herein. This includes, but is not limited to the handling of the specimens, lead cutting, and soldering/desoldering operations.
1 Scope  
The scope of this test method is to provide a means by which hand soldering tools may be evaluated under a standard, controlled set of conditions. This method may be used to either evaluate a single tool’s performance or for comparison of several tools.

This test method is to be used for the evaluation of hand soldering tools in the area of discrete terminals. A separate test method will be provided for evaluation of tools for printed wiring applications.

2 Applicable Documents

IPC-S-805  Solderability Test for Component Leads and Terminations

3 Test Specimens

3.1 Solder  
The solder type, diameter, and flux type used for this test should be selected to represent the in-house production task. The solder diameter, alloy type, flux volume, and type should be consistent throughout the test.

4 Equipment/Apparatus

4.1 Workpiece  
The workpiece shall be tin or solder plated turret terminals mounted on a 3.18 mm thick laminate base.

4.1.1 Terminals  
The terminals shall be one of three sizes shown in Table 1. The terminals shall be solderable per IPC-S-805.

4.1.2 Thermocouple Wire  
The thermocouple wire shall be insulated Type J. The wire size shall be 30 gauge. The working junction shall be formed by welding.

4.1.3 Data Recorder  
The data recorder or comparable means shall be capable of resolving a graph, which can be read to ± 3°C and ± 1 second of time. The normal response time shall be 10 cps or better.

4.1.4 Hookup Wire  
Solid, tinned hookup wire, which is non-insulated, is to be used. The wire shall be solderable per IPC-S-805. The size shall be 22 gauge for Type I terminals, 20 gauge for Type II terminals, and 18 gauge for Type III terminals (see Figure 1).

Table 1  Terminal Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Terminal Size</th>
<th>Weight Grams</th>
<th>Length L</th>
<th>Top Dia. D1</th>
<th>Stem Dia. D2</th>
<th>Base Dia. D3</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Small</td>
<td>0.180</td>
<td>7.62 mm</td>
<td>2.41 mm</td>
<td>1.14 mm</td>
<td>3.30 mm</td>
</tr>
<tr>
<td>II</td>
<td>Medium</td>
<td>0.259</td>
<td>9.53 mm</td>
<td>2.79 mm</td>
<td>1.40 mm</td>
<td>4.06 mm</td>
</tr>
<tr>
<td>III</td>
<td>Large</td>
<td>0.675</td>
<td>12.07 mm</td>
<td>3.68 mm</td>
<td>1.65 mm</td>
<td>4.83 mm</td>
</tr>
</tbody>
</table>

IPC-2-4-37-1a
5 Procedure

5.1 Preparation of Workpiece

5.1.1 Method A  A small hole shall be drilled vertically into the top of the terminal. This hole shall be of such depth and diameter to fully enclose the welded junction of the thermocouple. The thermocouple shall then be inserted in the hole and mechanically staked into place.

5.1.2 Method B  The tip of the thermocouple shall be welded to the center of the top of the terminal. The weld shall be secure enough to prevent dislodging during handling or the soldering test.

5.2 Preparation of the Soldering Tip  A thermocouple shall be attached to the tip to be used in the test. This attachment shall be to the tip face opposite the working face. The attachment to the tip can either be done by drilling a small hole in the tip, nominally 3 mm back from the tip end, inserting the thermocouple wire and securing it with a small copper wedge, or by welding the thermocouple directly to the tip, also nominally 3 mm from the end, but not on the tinned surface of the tip (see Figure 2). Once the thermocouple wire is attached to the tip, the wires leading from the junction shall be taped to the handle to prevent damage.

5.3 Test Preparation

5.3.1 Preparation  The workpiece shall be secured in such a way that it will not move during soldering. The workpiece or soldering tool thermocouple leads shall be attached to the recorder. Both should be attached if using a two-channel recorder. The recorder should be properly zeroed or adjusted for correct reading.

5.3.2 Test A—Single Terminal Evaluation  The tool tip should be wiped and prepared in the best commercial practice. Good soldering includes, but is not limited to, a solder bridge between a properly wetted tip and the terminal; then the tip of the iron and the end of the solder wire should be brought into opposite sides of the instrumented terminal at the wire location. The amount of solder used shall be consistent with the development of a full solder joint. The time of contact of the iron with the workpiece shall not exceed three seconds. After the contact period, the iron shall be removed and the recorder may be shut off after solder solidification.

5.3.3 Test B—Multiple Terminal Evaluation  Five terminals shall be soldered in sequence using the procedure in 5.3.2. The delay time between joints shall be minimized, consistent, and shall not exceed two seconds. The fifth terminal on the workpiece shall be the instrumented terminal.
1 Scope  The scope of this test method is to provide a means by which hand soldering tools can be evaluated under a standard, controlled set of conditions. This method may be used to either evaluate a single tool’s performance or for a comparison of several tools. This test method is to be used for the evaluation of hand soldering tools intended for use on PWBs. A separate test method is available for evaluation of tools for discrete terminals.

2 Applicable Documents

IPC-S-804  Solderability Test Methods for Printed Wiring Boards
IPC-S-805  Solderability Tests for Component Leads and Terminations
MIL-P-55110  Military Specification for Printed Wiring Boards

3 Test Specimen  The test specimen shall be a PWB. The laminate should typically be 1.57 mm thick FR-4 material, double-sided with plated through holes (PTHs). The land areas on the board should typically be 1 oz. copper (final copper thickness to be 0.005 mm to 0.01 mm on lands and 0.0025 mm min. in holes), and the land size will be 1.40 mm diameter. Land areas shall be nickel plated. The hole size shall be 0.97 mm finished. The board shall have tracks on both sides no greater than 1 mm wide and at least 12.7 mm long. The tracks shall connect from hole to hole and be daisy chained top to bottom, similar to the MIL-P-55110 test coupon. The board shall be solderable per IPC-S-804. The device to be soldered to the board is to be a 16 pin dual-in-line integrated circuit (IC). The IC can have either a ceramic or plastic body, but whatever the type used, it must be noted as a ceramic body that has a larger heat sinking effect. The IC shall be held secure to the board and be solderable to IPC-S-805.

3.1 Final configuration of the workpiece must be held constant throughout the test program.

4 Equipment/Apparatus

4.1 Solder  The solder type, diameter, and flux type used for this test should be selected to represent the in-house production task. The solder diameter, alloy type, flux volume, and type should be consistent throughout the test.

4.2 Thermocouple Wire  The thermocouple wire shall be insulated Type J. The wire size shall be 30 gauge or smaller. The working junction shall be formed by welding.

4.3 Data Recorder  The data recorder shall be capable of resolving a graph that can be read to ± 2.8°C and ± 1 second of time. The normal response time shall be 10 cycles per second or better.

4.4 Component leads  The finish on the leads shall be hot solder dipped. The leads shall be solderable per IPC-S-805.

5 Procedure

5.1 Preparation for Test  The test specimen shall be prepared by attaching the thermocouple wire to the PWB lands. The weld shall be nominally half way between the outer edge of the land and the edge of the hole (see Figure 1). A nickel plated surface is required for a proper weld of the thermocouple. Depending on the application and the information needed, the thermocouple wire can be attached to either the solder side or the component side (on double-sided boards with PTHs).

5.2 Preparation of the Soldering Tip  A thermocouple shall be attached to the tip to be used in the test. This attachment shall be to the tip face opposite the working face. The attachment to the tip can either be done by drilling a small hole in the tip, nominally 3 mm back from the tip end, inserting the thermocouple wire and securing it with a small copper wedge, or by welding the thermocouple directly to the tip, also nominally 3 mm from the end, but not on the tinned tip surface (see Figure 2). Once the thermocouple is attached to the tip, the wires leading from the junction shall be taped to the handle to prevent damage.

5.3 Test Procedure

5.3.1 Preparation  The test specimen shall be secured in such a way that it will not move during soldering. Both the test specimen and soldering tool temperatures shall be measured simultaneously. The recorder should be properly zeroed or adjusted for correct reading.
5.3.2 Test A - Single Termination Evaluation

The tool tip should be wiped and prepared in the best commercial practice. The tool tip and solder shall be brought in contact with the instrumented land, avoiding direct contact with the thermocouple. Good soldering includes, but is not limited to, a solder heat bridge between a properly wetted tip and the connection.

The amount of solder used shall be consistent with the development of a fully wetted solder joint. The time of contact of the iron with the workpiece shall not exceed two seconds. The recorder shall be shut off after solder solidification.

5.3.1 Test B - Multiple Termination Evaluation

All 16 terminations are to be soldered, and the terminations shall be temperature monitored. At a minimum, the 1st, 8th, and 16th terminations shall be monitored. The recording is completed when the solder is solidified. The delay time between joints shall be minimized, consistent, and shall not exceed two seconds.
1 Scope  This test method is to be used for the evaluation of hand soldering tools under a simulated heavy load such as that presented by PWBs with abnormally thick ground or power planes. Separate test methods (IPC-TM-650, Methods 2.4.37 and 2.4.37.1) are provided for evaluation of tools under normal operating conditions. The purpose of this test method is to provide a means by which hand soldering tools may be evaluated under a standard controlled set of conditions. This method may be used to either evaluate a single tool’s performance or for comparison of several tools.

Note: Tip geometry, mass, contact area (working face), contact angle, and idle temperature can significantly skew the test results.

2 Applicable Documents

J-STD-004  Requirements for Soldering Fluxes
2.4.37  Evaluation of Hand Soldering Tools for Terminal Connections
2.4.37.1  Evaluation of Hand Soldering Tools for Printed Wiring Board Applications

3 Test Specimen  The test specimen shall be a square, solder-plated, copper coupon, 1.58 mm thick, as listed in Table 1.

4 Equipment/Apparatus

4.1 Solder  The solder shall be flux-cored wire per J-STD-006. The alloy shall be composition Sn60/Pb40 or Sn63/Pb37. The core shall be nominally 2.2% by weight type F(RA) or D(RMA). The wire size shall be 0.8 mm.

4.2 Workpiece  The workpiece shall be an instrumented, square, solder-plated, copper coupon(s) mounted in or on a thermally insulated surface.

4.3 Fixture  The coupon shall be held solder side up in or on a thermally insulated surface that will not represent a thermal load to the coupon(s) under test. A thermally insulative covered laboratory tile or screen should be adequate.

Note: Dimensions listed are 1.27 mm. The bottom side of the coupon may be plated with nickel to aid thermocouple attachment.

4.4 Thermocouple Wire  The thermocouple wire shall be insulated Type J or K, as required by the selected test equipment. The wire size shall be 30 gauge. The working junction shall be formed by welding.

4.5 Data Recorder  Test results shall be recorded on a data or chart recorder capable of resolving ± 2.8°C and ± 1 second of time. The normal response time shall be 10 cps or better.

5 Procedure

5.1 Preparation of Workpiece  Prepare the workpiece in the following manner:

5.1.1  Place bare copper coupon(s) on a hot plate or other suitable surface. The temperature of the hot plate must be set at a temperature sufficient to achieve reflow of solder.

5.1.2  Coat the test surface with solder conforming to 4.1.

5.1.3  Clean the surface of any flux residue to ensure that excessive amounts of solder have not been added.

[Optional] Plate the surface opposite the test surface with nickel to aid thermocouple attachment.

5.1.4  Weld or imbed the thermocouple to the test coupon(s) at a point 2/3 the distance from the center of the coupon in the direction of one of the corners (see Figure 1).

Note: In Figure 1, A is defined as half the length of the diagonal.

5.1.5  Mount the coupon(s), solder side up, in or on the fixture to be utilized during the test.

5.2 Preparation of the Soldering Tool Tip  A thermocouple shall be attached to the tip(s) to be used in the test. This attachment shall be to the tip face opposite the working face. The attachment to the tip can either be done by drilling a small hole in the tip, nominally 6.85 mm back from the tip.
end, inserting the thermocouple wire and securing it with a small copper wedge, or by welding the thermocouple directly to the tip, also nominally 6.85 mm back from the tip end, but not on the tinned surface of the tip (see Figure 2). Once the thermocouple wire is attached to the tip, the wires leading from the junction shall be taped to the handle to prevent damage.

<table>
<thead>
<tr>
<th>Type</th>
<th>Specimen Size</th>
<th>Edge Dimension*</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Small</td>
<td>19 mm</td>
</tr>
<tr>
<td>II</td>
<td>Medium</td>
<td>25 mm</td>
</tr>
<tr>
<td>III</td>
<td>Large</td>
<td>32 mm</td>
</tr>
</tbody>
</table>

Table 1 Thermocouple Placement

Figure 1 Thermocouple Placement

5.3 Test Preparation  The workpiece shall be secured such that it will not move during soldering. The workpiece and the soldering tool thermocouple leads shall be attached to the data recorder. The recorder shall be properly zeroed or adjusted for correct reading.

5.4 Test A—Single Coupon Evaluation
5.4.1 Set the desired temperature on adjustable irons and record the idle temperature. Record the temperature of non-adjustable irons. To combine adjustable and non-adjustable irons on the same test run, the adjustable irons should be set at the temperature of the non-adjustable irons. Irons must idle within 11°C of one another.

5.4.2 (Optional) Apply a drop of D or F flux conforming to J-STD-004 to the coupon at the center point where the soldering tool will be applied.

5.4.3 Start the data recorder.

5.4.4 The soldering tool tip shall be wiped and prepared in the best commercial practice. Apply fresh solder to the contact surface area of the tip to provide a good solder heat bridge.

5.4.5 Place the contact area (working face) of the tip on the center of the coupon under test and record the time required to bring the test coupon to a predetermined temperature within the range of 190°C to 260°C.

5.4.6 Remove the soldering tool to its standby holder. Do not turn off the data recorder until the soldering tool has recovered to its idle temperature.

The test coupon may be used for successive testing. Prior to further use, the coupon must have any excess solder removed along with any flux residue. The coupon must be allowed to cool to ambient room temperature prior to any subsequent testing.

5.5 Test B—Dual Coupon Evaluation

5.5.1 On an adjustable soldering tool, select and record the desired idle temperature. On a non-adjustable tool, record the idle temperature. To combine adjustable and non-adjustable irons on the same test run, the adjustable irons should be set at the temperature of the non-adjustable irons. Irons must be within 11°C of one another.

5.5.2 (Optional) Apply a drop of D or F flux conforming to J-STD-004 to the coupons at the center point where the soldering tool will be applied.

5.5.3 Start the data recorder.

5.5.4 The soldering tool tip shall be wiped and prepared in the best commercial practice. Apply fresh solder to the contact surface area of the tip to provide a good solder heat bridge.

5.5.5 Place the contact area (working face) of the tip on the center of the first coupon under test and record the time required to bring the test coupon to a predetermined temperature within the range of 190°C to 260°C. The two coupons shall be thermally isolated from each other.

5.5.6 Immediately (within two seconds) place the soldering tool on the center of the second coupon under test and record the time required to melt the solder on the entire surface of the coupon.

5.5.7 Remove the soldering tool to its standby holder. Do not turn off the data recorder until the soldering tool has recovered to its idle temperature.

5.5.8 The test coupons may be used for successive testing. Prior to further use, the coupons must have any excess solder removed along with any flux residue. The coupons must be allowed to cool to ambient room temperature prior to any subsequent testing.

5.6 Reporting Table 2 lists the suggested reporting requirements.

6 Notes The temperature range identified in 5.4.5 and 5.5.5 is given so that an individual can select the predetermined temperature closest to the individual user requirements.
<table>
<thead>
<tr>
<th>Tool No.</th>
<th>Idle Temp °C</th>
<th>Coupon Type I,II,III</th>
<th>Time to Predetermined Temperature Coupon 1</th>
<th>Workpiece Temperature at Predetermined Temperature</th>
<th>Solder Tool Temperature at Predetermined Temperature</th>
<th>Time to Predetermined Temperature Coupon 2</th>
<th>Workpiece Temperature at Predetermined Temperature</th>
<th>Solder Tool Temperature at Predetermined Temperature</th>
<th>Recovery Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</table>

Date of Tests: Company Performing Tests: 

Technician Performing Tests:
1.0 Scope  This procedure defines a test method used to
determine the scaled flow parameters of an epoxy resin, pre-
impregnated glass fabric (prepreg). The test is appropriate for
checking material consistency, but is not solely intended for
defining the suitability of prepreg to be used in a specific
printed wiring board product or process.

2.0 Terms and Definitions

2.1 Scaled Flow Parameter Test  A test procedure
intended to measure multilayer lamination prepreg flow char-
acteristics.

3.0 Apparatus

3.1 Test Specimen  The prepreg specimen size shall be
5.50 ± 0.05 inches by 7.00 ± 0.05 inches. Specimens shall be
cut with the 7 inch dimension parallel to the machine (warp)
direction.

3.2 Release Material  The release material shall be polyvi-
nyl fluoride (PVF) or equivalent at least 7 x 9 inches in size.

3.3 Tape  Tape shall be suitable for holding the sample dur-
ing processing.

3.4 Press Plate  The press plate used shall be metal
between 0.125 to 0.250 inches thick, and 4.50 ± 0.01 x 6.00
± 0.01 inches in size. The plate shall be flat and parallel within
0.001 inches.

3.5 Lamination Press  A lamination press with a minimum
platen size of 8 x 8 inches, capable of applying a uniform
pressure of 840 lb force (31.0 PSI) ± 5% and capable of
maintaining a temperature range of 120-180°C with a toler-
ance of ± 2° of required temperature.

3.6 Prepreg Cutting Equipment  Cutter capable of main-
taining tolerances defined in 3.1.

3.7 Balance  A balance capable of weighing to ± 0.01
gram.

3.8 Micrometer  A measuring instrument for measuring
thickness to ± 0.0001 inch.

3.9 Desiccator  A stabilization chamber (drying cabinet)
with significant desiccant (calcium sulfate or equivalent)
capable of maintaining less than 10% relative humidity at 21 ±
2°C (70 ± 5°F).

4.0 Test Procedure

4.1 Specimen Conditioning  The specimens shall be cut
to size and then placed in a stabilization chamber (see 3.9) for
a period of 24 hours. Testing shall be performed within 15
minutes of removal from chamber. Note: Specimens tested
within 15 minutes of their manufacture need not be desic-
cated.

4.2 Specimens shall be gathered into a stack for test pur-
poses. Number of plies shall be determined from Table 1.

<table>
<thead>
<tr>
<th>Glass Thickness</th>
<th>Number of Plies (stack-up)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 0.0025 in. (i.e., style 104, 106, 108, etc.)</td>
<td>18-20</td>
</tr>
<tr>
<td>*Greater than 0.0025 in (i.e., style 112, 113, 116, etc.)</td>
<td>10</td>
</tr>
</tbody>
</table>

Note: Glass styles thicker than style 116 have shown some
difficulty in consistency of test results.

4.3 Weigh stack of prepreg to the nearest 0.01 gram, record
weight as Wo.

4.4 Center press plate (see 3.4) on the laminating press
platen. Close press and preheat lamination press (see 3.5)
and press plate to 150 ± 2°C. (Other temperature can be used
as agreed upon by user and vendor.)

4.5 Place the stack of prepreg on one of the release sheets
(see 3.2) which has been previously cut to a 7 x 9 inch size.
Use tape to hold the sample in place. Position tape on
opposite corners, such that it does not interfere with the 4.5 x
6.0 inch specimen center to be tested. The second release
sheet is placed on top of the stack to form a sandwich. See
Figure 1.

4.6 Open press and immediately place the stack sandwich
on the press plate, being careful to center the stack on the
press plate. Note: Make sure that the release material is in
place.
4.7 Unless otherwise specified, press the specimen with a force of 840 lb (31.0 psi) ± 5% for 10 minutes minimum. Full force is to be applied within 15 seconds after sample is placed on the press plate.

4.8 Carefully remove the hot specimen from the press, flip over onto a smooth flat surface and cool for 5 minutes or to a rigid state before making measurements.

4.9 Remove release material from stack. Using the template shown in Figure 2, mark the points to be measured. Cut the stack when required to facilitate measuring the specific points along the cut line shown in Figure 2.

5.0 Test Results

5.1 Measure the thickness to the nearest 0.0001 inch with a micrometer at the three intervals defined by the template. Record all three measurements for each test specimen. If there is a thickness variation between the three measurements of 0.003 inches or more, the test must be repeated. Average the three measurements to determine final measured thickness.

5.2 Use the initial weight, \( W_0 \), to determine the initial thickness \( (H_0) \) either from the formula in Appendix or from Table 2.

5.3 Final thickness per ply can be calculated by dividing the final measured thickness by the number of plies. Initial thickness and final thickness can be used to calculate thickness change.

Appendix

Determination of Initial Thickness: (See Table 2)

\[
ho = \frac{W_0}{n} (5.54 \times 10^{-2}) - 2.12 \times 10^{-2}
\]

Where:

- \( ho \) = Initial thickness per ply (mils)
- \( W_0 \) = Initial stack weight (g)
- \( W_g \) = Unit glass weight (g/in2)
- \( n \) = Number of plies

Unit Glass Weights: (Approximated from test results)

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<tr>
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Table 2  Initial Stackweight (Wo, grams) vs. Calculated Initial Thickness (ho, mils)

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Wo = grams, ho = mils; (n) for 104, 106, 108 = 18; (n) for 112, 113, 116 7628 = 10

Reference Documents
3. IPC-TP-281, The Use of Scaled Flow Testing for B-Stage Prepreg, C.J. Bartlett, D.P. Bloechle, W.A. Mazeika
4. IPC-TP-418, Application of Scaled Flow Testing as an Incoming Inspection Criteria, H.J. Brown
5. IPC-TP-420, Scaled Flow for Testing CRC Prepreg, J. Del, P. Marx, J. Sallo
1.0 Scope

This procedure defines a test method used to determine dimensional stability of glass reinforced, copper-clad, thin laminates intended for use in rigid multilayer printed boards.

The test is appropriate for checking material consistency. It is not intended for defining suitability of the raw material to be used in a specific printed board product or process.

2.0 Applicable Documents

IPC-TR-483 “Dimensional Stability Testing of Thin Laminates”

3.0 Test Specimen

The specimen shall be 300 mm x 280 mm [12 in x 11 in] in size with the warp direction in the 300 mm dimension. A minimum of three specimens is required per inspection lot. When evaluating laminate sheets, specimens should be taken from opposite diagonal corners and from the center of the sheet. For precut panels three randomly selected panels shall be used to obtain the test specimens.

4.0 Apparatus

4.1 The measurement apparatus shall be capable of measuring the specimen within an accuracy of 0.0125 mm [0.0005 in], over 250 mm [10.0 in] dimension. (Supergauge, or equivalent, may be used.)

4.2 Ovens used for baking must be of the air circulating type and capable of ± 2°C control. The recovery time of the temperature must be less than 15 minutes after specimens are placed in the oven.

4.3 A stabilization chamber (drying cabinet) containing calcium chloride or silica gel capable of maintaining less than 20 RH at 21 ± 2°C.

5.0 Test Procedure

5.1 Preparation of the Specimen

5.1.1 Mark the specimen for traceability in the identification area (see Figure 1). No mechanical or chemical pre-cleaning is permitted on the specimen.

5.1.2 Prepare the four location points (see Figure 1) by drilling or scribing.

5.1.3 Measure distances F1, F2, W1, and W2 utilizing the apparatus defined in paragraph 4.1. Define distances to the nearest 2.5 microns [0.0001 in]; the last digit of the reading may be estimated. Record all values as initial measurements.

5.1.3.1 If optical measurement must be used, a rigid plate shall maintain the test specimen in a flat and horizontal position.

5.1.4 Place a 12 mm [0.5 in] diameter tape dot over holes or scribe marks on side of laminate to be measured and a piece of 25 mm x 12 mm [1.0 in x 0.5 in] wide tape over identifying information.

Figure 1  All dimensions are in inches. Four measurements are required as indicated. Locate measuring points approximately 12.7mm [0.500 in] from each edge in the fill direction, and 25.4 mm [1.00 in] from each edge in the warp direction.
5.2 Copper Removal  Remove copper by etching in cupric chloride containing spray etcher at less than 50°C (122°F). Rack samples upon exit from etcher, rinse, remove the tape, and air-dry laminate. Submit to bake cycle (paragraph 5.3) within four hours. (Note: Do not use resist stripping solutions.)

5.3  If only the thermal stress cycle is to be used proceed to 5.5. If not, proceed to 5.4.

5.4 Bake Cycle

5.4.1  Bake specimens at 105°C ± 5°C for four hours ± 10 minutes. Vertically rack and place specimens in oven parallel to air flow with specimens being separated by a minimum of 1/2 inch.

5.4.2  After baking, immediately place the test specimens in a stabilization chamber (paragraph 4.3).

5.4.3  Remove from stabilization chamber after one hour ± ½ hour and, within 5 minutes, measure W1, W2, F1, and F2, using the apparatus defined in paragraph 4.1.

5.4.4  If the thermal stress cycle is to be included in this test, proceed to paragraph 5.5. If not, proceed to 5.6.

5.5 Thermal Stress Cycle  After the bake cycle measurement (5.4), if immediate further processing is not feasible, place specimens in a stabilization chamber until test is continued.

5.5.1  If a stabilization chamber is used, remove from the stabilization chamber and bake specimens at 150°C ± 5°C for two hours ± 5 minutes. Vertically rack and place specimens in oven parallel to air flow, with specimens being separated by a minimum of 1/2 in.

5.5.2  After baking, immediately place the test specimen in a stabilization chamber (paragraph 4.3).

5.5.3  Remove from stabilization chamber after 1 hour + 1/2 hour, -0 hours, and, within 5 minutes, measure W1, W2, F1, and F2, using the apparatus indicated in paragraph 4.1. Record values as W1, W2, F1, and F2.

5.6 Evaluation  Determine the change in dimensional stability using the following formulation:

### 5.6.1 Warp Evaluations

\[
Warp = \frac{W_{11} - W_1}{W_1} \times 10^3 = \text{Mils/} \text{per inch for W1 after bake}
\]

\[
W_{21} - W_2 \times 10^3 = \text{Mils/} \text{per inch for W2 after bake}
\]

Repeat for W1, and W2, for after stress

Where \( W_1/W_2 = \) initial dimensions,
\( W_{11}/W_{21} = \) after bake dimensions, and
\( W_{12}/W_{22} = \) after thermal stress.

### 5.6.2 Fill Evaluations

\[
Fill = \frac{F_{11} - F_1}{F_1} \times 10^3 = \text{Mils/} \text{per inch for F1 after bake}
\]

\[
F_{21} - F_2 \times 10^3 = \text{Mils/} \text{per inch for F2 after bake}
\]

Repeat for F1, and F2, for after stress

Where \( F_1/F_2 = \) initial dimensions,
\( F_{11}/F_{21} = \) after bake dimensions, and
\( F_{12}/F_{22} = \) after thermal stress.

### 5.6.3 Calculations

Take the warp dimensions made on all the measured specimens and determine the mean value for the warp dimensional stability characteristics of the laminate after bake. Follow similar procedures on the calculations for the fill dimensional stability characteristics after bake. Extreme values should be eliminated using the procedure defined in paragraph 5.6.4. Similar measurements are made to calculate the after thermal stress dimensional stability characteristics.

### 5.6.4 Extreme Value Eliminated

Take measurements in subgroup (warp or fill) and arrange in descending order of magnitude. Solve for D, using procedure detailed in Table 1. If calculated D is larger than the value of D shown in Table 2 for the number of measurements being evaluated, the outlier is significant and should be deleted.

### 6.0 Notes

The following is a checklist that should be used by personnel responsible for performing this method in order to provide repeatable/correlatable results. The IPC Dimensional Stability Task Group responsible for the technical report on dimensional stability has determined that checklist items 2, 5, 6, 9, 14, 15, 16 and 18 are critical to appropriate use of this procedure. (See IPC-TR-463.)
1. Is the specimen size 300 mm x 280 mm [12 in x 11 in]? ......................................................... ____
2. Is the warp direction properly identified? ................. ____
3. Were the four location points prepared by either drilling or scribing?................................................... ____
4. Were the measured points located approximately 12 mm [0.5 in] from each edge of the fill direction and approximately 25 mm [1.0 in] from each edge of the warp direction?.................................................... ____
5. Were the measurements taken from the same feature location, i.e., edge of the hole, center, scribe mark, etc?....................................................................................... ____
6. Were specimens processed without mechanical or chemical pre-cleaning?...................................................... ____
7. Was cupric chloride etching with spray used to remove the copper? ......................................................... ____
8. Was the temperature of the etching less than 50°C? ................................................................. ____
9. The specimens were not exposed to resist stripping solution?................................................................. ____
10. Were specimens racked after removal from etching cycle?................................................................. ____
11. Is the oven used for baking capable of ± 2°C control and has a recovery time of less than 15 minutes?................................................................................................. ____
12. Were specimens subjected to the bake cycle within 4 hours after etching?.............................................. ____
13. Were the specimens baked at 105°C ± 5°C for 4 hours and vertically racked?........................................... ____
14. Was the stabilization chamber capable of maintaining 20% RH maximum at 21 ± 2°C?......................... ____
15. Was each specimen removed from stabilization after 1 hour + 1/2 hour -0 hours and were all measurements taken within 5 minutes?......................................................... ____
16. Were samples stored in stabilization chamber between after bake and after thermal stress measurements if immediate processing not feasible?...................................................... ____
17. Were specimens thermal stressed at 150°C ± 5°C for two hours and vertically racked?............................... ____
18. Was each specimen removed from stabilization after 1 hour + 1/2 hour -0 hours and were all measurements taken within 5 minutes?............................................. ____

Note: When using the above checklist, all answers should be affirmative. The technician performing the test should sign the report, record the date and times of all actions taken, and report any deviations on the procedure.

Table 1  Calculation Procedure

<table>
<thead>
<tr>
<th>Subgroup Size</th>
<th>If Apparent Outlier is Largest Value</th>
<th>If Apparent Outlier is Smallest Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 3-7</td>
<td>D = Largest Value – 2nd Largest Value</td>
<td>D = 2nd Smallest Value – Smallest Value</td>
</tr>
<tr>
<td>n = 8-10</td>
<td>D = Largest Value – 2nd Largest Value</td>
<td>D = 2nd Smallest Value – Smallest Value</td>
</tr>
</tbody>
</table>

Table 2  Extreme Value Table

<table>
<thead>
<tr>
<th>n</th>
<th>D (Confidence Level 95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.941</td>
</tr>
<tr>
<td>4</td>
<td>0.765</td>
</tr>
<tr>
<td>5</td>
<td>0.642</td>
</tr>
<tr>
<td>6</td>
<td>0.560</td>
</tr>
<tr>
<td>7</td>
<td>0.507</td>
</tr>
<tr>
<td>8</td>
<td>0.554</td>
</tr>
<tr>
<td>9</td>
<td>0.512</td>
</tr>
<tr>
<td>10</td>
<td>0.433</td>
</tr>
</tbody>
</table>
1 Scope
This method is used to determine the inner layer bond strength of either a metal conductor or an individual dielectric.

2 Applicable Documents
None

3 Test Specimen
Laminate dielectric with or without copper foil, prepared in accordance with Figure 1.

4 Equipment/Apparatus

4.1 Unite-O-Matic tensile tester Model #FM 10 or equivalent

4.2 Scalpel

5 Procedure

5.1 Preparation for Testing
During layup of the test specimen panel, place “TEDLAR” (or other suitable material) release sheets that will disallow lamination at one end of each specimen, providing a 13 mm x 25 mm non-bonded tab. The tabs can then be used as gripping areas to perform bond strength testing. One can then evaluate the laminate-to-laminate bonds and the laminate-to-copper foil bond throughout the finished panel thickness.

5.1.1 Place an equal number of release sheets on the outer surface of the layup, covering all surfaces, except where internal release sheets have been placed. This is essential to provide proper and uniform lamination pressure.

5.1.2 After lamination and cure, cut the panel into 25 mm strips, as shown in Figure 1, and remove internal release sheets.

5.1.3 If steps 5.1.1 and 5.1.2 are not used, it will be necessary to chemically or thermally remove resins from the outer 25 mm, in order to provide a tab to initiate testing.

5.2 After cutting the samples to the designated size and lifting the 25 mm strip for testing, the layer to be tested shall be fastened into the clamping device of the tensile tester, allowing the wire connecting the clamp to the tensile tester to pull the specimen vertically within ± 5° angle.

5.3 The tester is then started. A force is applied in the vertical direction at a rate of 51 mm per minute until delamination (bond strength) is completed or the inner layer tears.

The minimum load is then recorded using the following formula:

\[
\text{Bond strength of the conductor width} = \frac{25 \text{mm}}{\text{sample width}} \times \text{total load}
\]
1.0 Scope

1.1 This method covers determination of the coefficient of linear thermal expansion of electrical insulating materials by use of a thermomechanical analyzer.

1.2 This method is applicable to materials that are solid over the entire range of temperature used, and that retain sufficient hardness and rigidity over the temperature range so that irreversible indentation of the specimen by the sensing probe does not occur.

1.3 Transition temperatures also may be obtained by this method.

2.0 Applicable Documents

ASTM D-618  Conditioning Plastics and Electrical Insulating Materials for Testing

ASTM D-696  Test for Coefficient of Linear Thermal Expansion of Plastics

3.0 Summary of Method

3.1 This method used a thermomechanical analyzer with an X-Y recorder to graph the change of dimension as a function of temperature of a small specimen of a solid electrical insulating material. Coefficients of linear thermal expansion can be calculated from the graph. Other thermal observations may also be made.

Note 1—Other rapid thermal analysis methods are being studied by ASTM Subcommittees D09.17 and D20.30.

4.0 Significance

4.1 Measurements of coefficient of linear thermal expansion are useful in evaluating the suitability of solid insulating materials for use in combination with other materials where mechanical stresses may develop as a result of differences in coefficients.

4.2 This method may be compared with Method D-696, but tests made with this method use much smaller specimens. This eliminates the need for large liquid baths and greatly reduces the time required to reach temperature equilibrium. As a result, the time required for making a test is less than for Method D-696, and the method can conveniently be used over a wider temperature range than for Method D-696.

5.0 Apparatus

5.1 The thermomechanical analyzer shall include:

5.1.1 A specimen holder and probe, into which the specimen can be placed. Changes in height of the specimen are sensed by movement of the probe. The shape and size of the probe shall be such that for the material tested the load applied to the specimen by the probe shall not cause indentation of the specimen within the range of temperatures of interest.

5.1.2 Means for sensing movement of the probe resulting from changes in height of the specimen and for translating these movements into a signal suitable for input to the recorder. The sensing element should be capable of producing a movement of the recorder pen of at least 1000 times the change in height of the test specimen, with provisions for less sensitive ranges when needed.

5.1.3 Means for uniformly heating the specimen holder at a predetermined rate over the range of temperatures of interest. This will consist of a furnace and temperature controller with provisions for precooking the furnace and specimen holder when measurements at subambient temperatures are to be made.

5.1.4 Means for measuring temperature in immediate proximity to the test specimen.

5.1.5 An X-Y recorder for recording changes in specimen height as a function of specimen temperature.
Note 2—Instruments from duPont and Perkin Elmer have been found suitable.

6.0 Test Specimens

6.1 The test specimen shall be between .05 and 0.3 inches thick. This thickness may be as received or may be laminated by the user from pre-impregnated “B” stage and copper free “C” stage material. It laminated by the user, the user shall be responsible to contact the manufacturer for the exact layup and process parameters used for quality acceptance at the manufacturer’s facility.

Note 3—Repeatability of Test Results will vary with layup, bake out, laminating pressure/ramp speed, press time, etc.

6.2 Specimens should be between 0.3 and 0.4 inches in height and have flat and parallel upper and lower surfaces. The surfaces to be measured shall be perpendicular to the fiber fillers and the identity of the direction of the fiber fillers shall be maintained throughout the test. The upper and lower surfaces shall be polished with 600 grit paper to remove burrs or strands of fiber filler. The specimens shall then be cleaned using isopropyl alcohol, and dried for 1 hour at 10°C above the maximum specified temperature of the run.

Note 4—The 1 hour prebake may be eliminated if Condition (7.), is performed immediately after final polish.

6.3 There shall be three specimens prepared from the same piece of material for each direction to be measured.

7.0 Conditioning

7.1 Conditioning of test specimen shall include immersion in isopropyl alcohol with agitation for 20 seconds, followed by Condition E-1/110 and C40/23/50 in accordance with D-618.

8.0 Calibration

8.1 Calibrate the apparatus in accordance with the instrument manufacturer’s recommendations.

9.0 Procedure

9.1 Measure the height of the specimen.

9.2 Place the specimen in the specimen holder under the probe. The thermocouple or other means for sensing specimen temperature should be in contact with the specimen, or as near to the specimen as possible.

9.3 Assemble the furnace to the specimen holder. If measurements at subambient temperatures are to be made, cool the specimen holder and furnace to at least 20°C below the lowest temperature of interest, using procedures as given by the instrument manufacturer. The refrigerant used for cooling shall not come into direct contact with the specimen.

Note 5—The temperature range to be tested shall be specified by the user, so that the manufacturer and user will test the same temperature range. If tested over different temperature ranges, the repeatability may be unacceptable.

9.4 Place weights on the sensing probe to ensure that the probe is in contact with the specimen with a 1 to 3-g load.

9.5 Increase the furnace temperature at 5 = 0.5°C/min. over the desired temperature range.

9.6 Record the specimen temperature and change in specimen height using appropriate ranges on the X-Y recorder.

Note 6—A gas purge may be used to replace the air around the specimen for measurement of expansion in different atmospheres.

9.7 Test at least three specimens of the same material. Retest of a specimen may be used only as reference and shall not be treated as an independent test of a new specimen.

10.0 Calculation

10.1 Calculate the average coefficient of thermal expansions, α, over the temperature intervals of interest as follows:

\[ \alpha = \frac{\Delta H/\Delta T}{H} \]

where:

\( H \) = original height of specimen,
\( \Delta H \) = change in height of the specimen (in the same units) over the temperature interval \( \Delta T \), and
\( \Delta T \) = temperature interval, °C (see Figure 1).

Note 7—\( \Delta H \) and \( \Delta T \) may on some instruments be read directly from the recorder chart. On other instruments constant factors may need to be applied to the chart readings to obtain these values.

11.0 Report
11.1 The report shall include the following:

11.1.1 Designation of the material, including the name of the manufacturer and information on composition when known.

11.1.2 Method of preparation of the test specimen.

11.1.3 Specimen orientation with respect to original sample, if applicable.

11.1.4 Sample size.

11.1.5 Temperatures between which the coefficient of linear thermal expansion has been determined.

11.1.6 Average coefficient of linear thermal expansion per degree Celsius.

11.1.7 Transition temperatures, if noted.

11.1.8 Instrument manufacturer and model number.

11.1.9 Purge gas, if used, and rate of gas flow, and

11.1.10 X-Y chart record.

**NOTE** The preceding test method was originally ASTM D3386-75, until modified for use by IPC for round-robin testing of organic substrate materials. Upon completion of the test program, recommendations for revision will be made to ASTM.
1.0 Scope

1.1 To describe the vitreous silica dilatometer method for determining the linear thermal expansion of laminated materials within the temperature range of –55°C to 100°C. Inorganic substrates (non-laminated) shall be tested within a range of –55° to 150°C.

2.0 Applicable Documents

ASTM-E-228 Standard Test Method for Linear Thermal Expansion of Solid Materials with a Vitreous Silica Dilatometer
ASTM-D-696 Test for Coefficient of Linear Thermal Expansion of Plastics
ASTM-E-831 Test for Linear Thermal Expansion of Solid Materials by Thermodilatometry
ASTM-E-77 Verification and Calibration of Liquid-in-Glass Thermometers
ASTM-E-220 Calibration of Thermocouples by Comparison Techniques
ASTM-E-644 Testing Industrial Resistance Thermometers

3.0 Test Specimen

3.1 Laminated materials which may or may not contain metal layers.

3.2 Nominal test specimen dimensions shall be 1/4 inch wide x 2 inch –4 inch long x 1/8 inch minimum thickness. End surfaces shall be ground parallel. Any deviation from nominal should recognize thermal gradients of the temperature chamber, thermal lag of specimen and any bending of specimen. Thicknesses under 1/8 inch shall be supported by adequate clamping devices unless it is certain that the specimen will remain straight during testing.

4.0 Apparatus

4.1 Vitreous silica dilatometer of either the tube or push rod type to determine the change in length of a solid material as a function of temperature. The temperature is controlled at a constant heating or cooling rate. The linear thermal expansion and the coefficients of linear thermal expansion (CTE) are calculated from the recorded data.

This device measures the difference in thermal expansion between a test specimen and the vitreous silica parts of the dilatometer (Figure 1).

4.2 Specimen holder (tube) and probe shall be made of vitreous silica. The probe contact shall be flat or be rounded to approximately a 10 mm radius.

4.3 Chamber for uniformly heating and cooling the specimen. The specimen temperature change rate shall be controlled. The temperature gradient in the specimen shall not exceed 0.5°C/cm.

4.4 Transducer, for measuring the difference in length between the specimen and the specimen holder with an accuracy of at least ± 0.5µm. The transducer shall be protected or mounted so that temperature changes will not affect the readings by more than 1.0µm.

4.5 Micrometer, for measuring the reference length, Lo, of the specimen with an accuracy of at least ± 25µm.

4.6 Thermocouple, types E, K, or T, for measurement of the specimen temperature. (Type E is NiCr versus constantan, type K is NiCr versus NiAl and Type T is Cu versus constantan.)

4.7 Recorder or data logger for collecting temperatures and lengths.

5.0 Procedure

5.1 Sample Preparation Rough cut with a band saw or metallurgical cut-off wheel and finish machining by grinding. Care must be exercised to remove roughness from specimen ends. The ends shall be parallel to ± .001 inch/inch.

5.2 Sample condition (only for laminated, organic specimens).

5.2.1 The specimen shall be immersed in isopropyl alcohol and agitated for twenty seconds.
5.2.2 Condition E-1/110.

5.2.3 Condition C1-40/23/50.

5.3 Calibration

5.3.1 The transducer shall be calibrated by imposing a series of known displacements with a precision screw micrometer or set of end gage blocks.

5.3.2 The temperature sensor shall be calibrated according to an appropriate ASTM method (E-220) or procedure recommended by the National Bureau of Standards.

5.3.3 The dilatometer, as a total system, shall be calibrated by measuring two reference materials of known thermal expansion. One of the materials should have an expansion close to the sample specimen, and the other close to that of the dilatometer.

5.3.4 Recommended standard reference materials:
- NBS Fused Silica – SRM 739; CTE ~ .55 PPM/°C (for calibration of dilatometer)
- NBS Single Crystal Sapphire - SRM 732; CTE ~ 5.5 PPM/°C (for use with "low expansion" materials)
- OFHC Copper; CTE ~ 17.3 PPM/°C (for use with "high expansion" materials)

5.3.5 The expansion of the dilatometer system, \( \frac{\Delta L}{L_0} \), and the calibration constant, for corrections of lead lag, temperatures, etc., are determined at 20°C intervals using the following equations:

\[
\frac{\Delta L}{L_0} = \frac{\Delta L}{L_{0t}} - \frac{\Delta L}{L_{0m}}
\]

\[
A = \frac{\frac{\Delta L}{L_{0t}}}{\frac{\Delta L}{L_{0m}}}
\]
where:

\[ L_0 = \text{specimen length} \]

\[ \left( \frac{\Delta L}{L_0} \right)_t = \text{certified expansion of the reference material.} \]

\[ (\Delta L/L_0)_m = \text{the measured expansion of the reference material.} \]

\[ \left( \frac{\Delta L}{L_0} \right)_s = \text{the expansion of the vitreous silica parts of the dilatometer.} \]

5.4 Test Procedure Following the conditioning steps per 5.2, two thermal cycles shall be conducted per test. The first is to normalize the specimen and the second to generate data for the calculation of CTE.

5.4.1 Measure the initial length of the specimen, using the micrometer to ± .001 inch.

5.4.2 Place the specimen in the dilatometer after making certain that all contacting surfaces are free of foreign material. Specimens with thickness 0.125 inch shall be supported with side plates. Care must be taken to assure good seating of the specimen against the bottom of the tube bottom and the push rod.

5.4.3 Place the thermocouple sensor in intimate contact with the specimen at midlength.

5.4.4 Mount the transducer to provide a stable contact with the probe. The sample loading force shall be the minimum necessary for proper contact between the rod and specimen, and the bottom of the tube and specimen. Set the transducer at a nominal initial reading.

5.4.5 Place the assembled dilatometer into the chamber and allow the temperature of the specimen to come to equilibrium.

5.4.6 Record the initial readings of the thermocouple and the transducer.

5.4.7 Heat and cool at a constant rate of 2°C/min.

5.4.8 Record length changes as a function of temperature.

5.4.9 Remove the specimen from the fixture and repeat the procedure per 5.4.1-5.4.8, following the first cycle. Remeasurement of the specimen length must not be omitted prior to start of the second cycle.

5.4.10 Test a total of four specimens, two prepared with the length in the machine direction of the laminate reinforcement and two cut in the transverse direction. This quantity is intended to represent the expansion characteristics of a 18 inch x 24 inch panel size.

6.0 Calculations

6.1 Linear thermal expansion (LTE), the change in length per unit length resulting from a temperature change is represented by:

\[ \frac{\Delta L}{L_0} = \lambda \left( \frac{\Delta L}{L_0} \right)_a + \left( \frac{\Delta L}{L_0} \right)_s \]

where:

\[ \left( \frac{\Delta L}{L_0} \right)_a \]

is the expansion as indicated by the transducer, \( \Delta L \) is the observed change in length (\( \Delta L = L_2 - L_1 \)). LTE is often expressed in μm/m (parts per million).

6.2 Mean coefficient of linear thermal expansion – the linear thermal expansion per change in temperature. Represented by:

\[ \alpha = \frac{\Delta L/L_0}{\Delta T} = \frac{(L_2 - L_1)}{L_0(T_2 - T_1)} \]

where \( L_1 \) and \( L_2 \) are the lengths of the specimen at the test temperatures \( T_1 \) and \( T_2 \).

6.3 Instantaneous coefficient of linear thermal expansion – the slope of the linear thermal expansion curve at temperature \( T \). Represented by:

\[ \alpha_T = \frac{1}{L_0} \frac{dL}{dT}, \]

6.4 Plots of the following are commonly used as required:

\[ \frac{\Delta L}{L_0} \text{ vs. } T; \alpha \text{ vs. } T \]

When reporting the mean coefficient of thermal expansion, the temperature ranges must be specified.
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

- 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/m² [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 Tg 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 be 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 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.

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 desig-
nated 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 sta-
bilize.

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 Expans-
ion, α, are:

\[ \alpha = \frac{\Delta R}{R \Delta T} \]

Where \( \alpha \) = the coefficient of thermal expansion
\( R \) = gage resistance reading
\( \Delta R \) = the change in resistance reading
\( \Delta T \) = the change in temperature
GF = the Gage Factor of a particular gage and gage con-
figuration 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

\[ \alpha = \frac{(353.40 - 352.39)}{(353.40 \times 2.11 \times 150)} = 9.03 \text{ ppm/°C} \]

Note: The graph plot of \( \Delta R/\Delta T \) will allow selection of any tem-
perature 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
1.0 Scope This test method establishes a procedure for determining the in-plane coefficient of linear thermal expansion of organic films from 0-200°C using thermal mechanical analysis (TMA).

2.0 Applicable Documents

ASTM D 618 Standard Practice for Conditioning Plastics and Electrical Insulating Materials for Testing
ASTM D 3386 Standard Test Method for Coefficient of Linear Thermal Expansion of Electrical Insulating Materials

3.0 Test Specimen The test specimen shall consist of a strip 15-20 mm long and 2 mm wide with a minimum thickness of 10 µm and maximum thickness of 200 µm.

4.0 Apparatus or Material Perkin-Elmer TMA-7 with a film fixture in extension mode or equivalent equipment capable of handling films less than 25 µm thick.

5.0 Procedure

5.1 The test specimens should be conditioned at 23 ± 2°C and 50 ± 5% relative humidity for not less than 24 hours prior to testing. Refer to ASTM D 618.

5.2 Follow the manufacturer’s recommendations for equipment startup and calibration.

5.2 Mount the test specimen in the film holder. The sample length (between the grips) should be between 11-13 mm. Refer to ASTM D 3386.

5.3 Set the force at 30 mN.

5.4 Perform a prescan by heating at a rate of 20°C/min. Under inert atmosphere from −10°C to either 10°C above the material glass transition temperature, Tg, or 10°C below the material decomposition limit, Tmax, determined under nitrogen. At least two temperature scans of the test specimen should be conducted without disturbing the specimen in the TMA to confirm repeatability of observed test results.

5.5 Hold the temperature for 60 min.

5.6 Cool at a rate of 5°C/min to −10°C.

5.7 Hold the temperature for 10 min.

5.8 Reheat the specimen at a rate of 5°C/min to a maximum temperature of 25°C below the glass transition temperature of the polymer or 10°C below the material decomposition limit, Tmax, determined under nitrogen. At least two temperature scans of the test specimen should be conducted without disturbing the specimen in the TMA to confirm repeatability of observed test results.

5.9 Calculate the average coefficient of thermal expansion, over the temperature intervals of interest as follows:

\[ \alpha = \frac{\Delta L}{L} \cdot \frac{1}{\Delta T} \]

where L is the length of the test specimen between the grips, \( \Delta L \) is the change in the length of the specimen (in the same units) over the temperature interval \( \Delta T \), and \( \Delta T \) is the temperature interval (normally 200°C) as illustrated in Figure 1. The units are°C⁻¹.

5.10 The coefficient of linear thermal expansion from 0 to 200°C (below the glass transition) is

\[ \alpha = \frac{(Length\ B - Length\ A)}{(Length\ A) (Temperature\ B - Temperature\ A)} \]
5.11 On some instruments ΔL and ΔT may be read directly from the recorder chart. On other instruments, constant factors (from the instrument calibration - see section 6.3) may need to be applied to the chart readings to obtain these values.

6.0 Notes

6.1 Calibration of the instrument must be carried out according to the manufacturer’s recommendations. Two calibrations are required, one to establish the baseline and the other to calibrate the TMA relative to a standard.

6.2 A quartz specimen of 11-13 mm in length (between the grips) is run at 5°C/min under inert gas purge (He) from −20 to 400°C to establish a baseline. The baseline is used to eliminate the effects of grip expansion on extension measurements. The coefficient of average thermal expansion of quartz is 0.57 x 10^-6/°C (16-500°C)1. This baseline procedure should be used to either correct the instrument performance to obtain the literature stated value of linear thermal expansion quartz, or, in the event the instrument cannot be adjusted to obtain this value, obtain an estimated correction factor which is then applied to results from test specimens.

6.3 Using a calibration standard with dimensions equivalent to the test specimen, a calibration standard is run between −10 and 200 °C and the observed coefficient of thermal expansion is calculated using the expression:

$$\alpha_{obs} = \frac{\Delta L}{\Delta T}$$

where L is the length of the test specimen between the grips. ΔL is the change in the length of the specimen (in the same units) over the temperature interval ΔT, and ΔT is nominally 200 °C. The units of $\alpha_{obs}$ are °C⁻¹. An estimated test specimen correction factor, $C$, is then determined by dividing $\alpha_{obs}$ by the literature value, $\alpha_{lit}$, for the standard(s). The estimated test specimen correction factor is then as a multiplication factor and applied to the observed linear thermal expansion results for the test specimens.

6.4 The maximum temperature used in this test should be at least 25°C below the glass transition temperature of the material being studied. Heating above the glass transition may alter the morphology of the specimen (e.g., change the molecular orientation) leading to erroneous results. For materials with glass transitions below 250°C, the temperature range over which the coefficient of linear thermal expansion was determined must be noted, e.g., 50 x 10^-6/°C (0-150°C).

1.0 **Scope**  This test method defines the procedure for determining the Volumetric Thermal Expansion of polymer coatings on inorganic substrates, such as polyimide on a silicon wafer. The expansion is measured using an apparatus designed for the determination of the Pressure/Volume/Temperature behavior of solid samples.

2.0 **Applicable Documents**  None

3.0 **Test Specimens**  See Sample Preparation 5.1.

4.0 **Apparatus or Material**  GNOMIX PVT or equivalent capable of providing PVT data over its pressure range 0-200 MPa (2000 bar or 29,000 psi), and from ambient temperatures to 400°C.

5.0 **Procedure**

5.1 **Sample Preparation**  Samples are prepared by forming a 25 mm thick film on a wafer and lifting the specimen free according to manufacturer’s recommendations. Sample is cut and folded to fit in the sample chamber of the PVT apparatus.

5.2 **Test Procedure**  The film sample (1 to 2 grams mass) is placed in a rigid stainless steel cell. The cell is surrounded by a “sample cup” which guarantees a hydrostatic state of stress in the sample at all times. Follow the testing protocol according to the PVT Operations Manual for the measurement of the volumetric expansion.

5.3 **Test Analysis**  Report the volumetric expansion of the material from room temperature to 300°C and the temperature of any observed transitions.

6.0 **Notes**

6.1 **Pressure/Volume/Temperature (PVT) Apparatus:** One source is Gnomix, 3809 Birchwood Drive in Boulder, CO (303) 444-3395.
1.0 Scope  This procedure establishes the performance and test guidelines for the break-off torque of adhesives used by placement equipment to attach surface mounted devices to printed wiring boards.

2.0 Applicable Documents  None

3.0 Test Specimen

- Apply a 1.25 mm [0.05 in] diameter circle of adhesive 0.1 mm [0.004 in] thick to a FR-4 substrate.
- Place a type 1206 resistor firmly onto the circle of adhesive.
- Cure adhesive according to manufacturers directions.

4.0 Equipment

4.1 Torque Tester  A Waters Manufacturing torque watch (or equivalent) with a 0 to 140 or 0 to 280 Nmm scale is to be used. The torque gauge must have a separate indicator needle to register maximum torque.

4.1.1 Torque Fixture  Use torque fixture modified per sample being tested.

5.0 Procedure

5.1 Sample Placement  Place the samples board in the test fixture.

5.1.1 Zeroing the Gauge  Rotate the face knob of the tester per until the maximum torque indicator needle is zeroed.

5.1.2 Testing Sample  Using the thumb and forefinger, and middle finger of the right hand slowly rotate the torque gauge in a clockwise direction until the component breaks off.

5.1.3 Torquing Techniques  Components to be torqued should be centered inside the probe. The component should not protrude from the probe when testing is begun.

5.1.4 Taking Reading  After the component has been torqued off, a reading of break-off torque shall be taken from the face of the torque tester. This reading is shown by the maximum torque indicator needle.

5.1.5 Completion of Torquing  Repeat until 5 components of the same type have been torqued off.

6.0 Notes  Do not raise or lower the gauge while turning. If the gauge is lowered the increased friction against the board will yield inaccurate readings. If the gauge is lifted it will lose contact with the component and yield an inaccurate reading as well.
1.0 Scope
The object of this test is to determine the component hold-down capability of the adhesive material at wave soldering temperatures due to material softening or degradation. Test coupons are assembled using the adhesive material and 1206 size chip resistors. The test coupons are preheated then floated on a solder pot, after which the loss of any components is noted.

2.0 Applicable Documents
MIL-F-14256 Flux, Soldering, Liquid (Rosin based)
QQ-S-571 Solder, Tin Alloy, Tin-lead Alloy, and Lead Alloy

3.0 Test Specimens
1. Bare FR-4 Test Coupon—approximately 50.8 mm [2.0 in] square
2. 1206 sized surface mount chip resistors

4.0 Apparatus
Solder pot Sn 60 Sn 62 Sn 63 per QQ-S-571—temperature controlled to provide 260 ± 5°C.

5.0 Procedures
5.1 Test Coupon Fabrication
A single test coupon is made by applying 20 adhesive dots or rectangles on to a bare FR-4 coupon. The thermal cure adhesive dots shall be stenciled providing a dot 0.1 mm [0.004 in] thick and 1.27 mm [0.050 in] in diameter. The ultraviolet cured adhesive deposits shall be stenciled into a 2.0 x 0.76 mm [0.080 x 0.030 in] rectangular slit of 0.1 mm [0.004 in] thickness.

The chip resistors are first centered over then securely pressed into the adhesive deposits. The resistors are aligned over the UV adhesive rectangles such that equal adhesive volumes are observed at both component sides.

The assembly is then cured per manufacturers recommended conditions.

5.2 Solder Float
The test coupon is fluxed with a type R per MIL-F-14256 flux and excess drained off. The coupon is then held approximately 12.7 mm [0.5 in] above the dross-free solder pot surface for 60 ± 5 seconds with the component side facing the solder surface. The coupon is then brought into contact with the clean solder surface and allowed to float for 10 + 1-0 seconds while being lightly but continuously agitated.

After cooling, the remaining flux residue is cleaned from the surface and the coupon examined for severely displaced components. A component is severely displaced if:
1. No longer on the test coupon.
2. It is rotated more than 30 degrees from its original position.
3. It is lifted or tilted away from the board’s surface leaving a gap between either component termination and the board of more than 1 mm [0.040 in]. A suitable thickness shim may be used in this determination.

5.3 Evacuation
Any evidence of severely displaced components on the processed test coupons shall be noted.

6.0 Notes
None
1.0 Scope  The purpose of this test is to determine the integrity of materials and procedures used to attach semiconductor die or surface mounted elements to package headers or other substrates. This determination is based on a measure of force applied to the die, the type of failure resulting from this application of force (if failure occurs) and the visual appearance of the residual die attach media and substrate/header metallization.

2.0 Applicable Documents  None

3.0 Test Specimens  Any die attach area on the finished mounting structure.

4.0 Apparatus or Material  The test equipment shall consist of a load-applying instrument with an accuracy of ± 5 percent of full scale or 50 grams, whichever is the greater tolerance. A circular dynamometer with a lever arm or a linear motion force-applying instrument may be used to apply the force required for testing. The test equipment shall have the following capabilities:

a. A die contact tool which applies a uniform distribution of the force to an edge of the die (see Figure 1).

b. Provisions to assure that the die contact tool is perpendicular to the die mounting plane of the header or substrate.

c. A rotational capability, relative to the header/substrate holding fixture and the die contact tool, to facilitate line contact on the edge of the die; i.e., the tool applying the force to the die shall contact the die edge from end-to-end (see Figure 2).

d. A binocular microscope with magnification capabilities of 10X minimum and lighting which facilitates visual observation of the die and die contact tool interface during testing.

5.0 Procedure  The test shall be conducted, as defined herein, or to the test conditions specified in the applicable specific acquisition document consistent with the particular part construction. All die strength tests shall be counted and the specific sampling, acceptance, and added sample provisions shall be observed, as applicable.
5.1 Shear Strength  A force sufficient to shear the die from its mounting or equal to twice the minimum specified shear strength, whichever occurs first, shall be applied to the die using apparatus of 4.0.

a. When a linear motion force-applying instrument is used, the direction of the applied force shall be parallel with the plane of the header or substrate and perpendicular to the die being tested.

b. When a circular dynamometer with a lever arm is employed to apply the force required for testing, it shall be pivoted about the lever arm axis and the motion shall be parallel with the plane of the header or substrate and perpendicular to the edge of the die being tested. The contact tooling attached to the lever arm shall be at a proper distance to assure an accurate value of applied force.

c. The die contact tool shall load against an edge of the die which most closely approximates a 90° angle with the base of the header or substrate to which it is bonded (see Figure 3).

d. After initial contact with the die edge and during the application of force, the relative position of the contact tool shall not move vertically such that contact is made with the header/substrate or die attach media. If the tool rides over the die, a new die may be substituted or the die may be repositioned, provided that the requirements of 5.1(c) are met.

5.2 Separation Categories  When specified, the force required to achieve separation and the category of the separation shall be recorded. Examples are as follows:

a. Shearing of die with residual silicon remaining
b. Separation of die from die attach medium.
c. Separation of die and die attach medium from package.

6.0 Notes  The following details shall be specified in the procurement documentation.

a. Number of devices to be tested and the acceptance criteria.

b. Requirement for data recording, when applicable (see 5.2).
1.0 Scope  The purpose of this test is to measure bond strengths, evaluate bond strength distributions, or determine compliance with specified bond strength requirements of the applicable acquisition document. This test may be applied to the wire-to-die bond, wire-to-substrate bond, or the wire-to-package lead bond inside the package of wire-connected microelectronic devices bonded by soldering, thermocompression, ultrasonic, or related techniques. It may also be applied to bonds external to the device such as those from device terminals-to-substrate or wiring board or to internal bonds between die and substrate in non-wire-bonded device configurations such as beam lead or flip chip devices.

2.0 Applicable Documents  None

3.0 Test Specimens  Any plated bonding area on the finished mounting structure.

4.0 Apparatus or Material  The apparatus for this test shall consist of suitable equipment for applying the specified stress to the bond, lead wire or terminal as required in the specified test condition. A calibrated measurement and indication of the applied stress in grams force (gf) shall be provided by equipment capable of measuring stresses up to twice the specified minimum limit value, with an accuracy of 25 percent or ± 0.25 gf, whichever is the greater tolerance.

5.0 Procedure  The test shall be conducted using the test condition specified in the applicable acquisition document consistent with the particular device construction. All bond pulls shall be counted and the specified sampling, acceptance, and added sample provisions shall be observed, as applicable. Unless otherwise specified, for conditions A, C, and D, the sample size number specified for the bond strength test shall determine the minimum sample size in terms of the minimum number of bond pulls to be accomplished. The required number of bond pulls shall be randomly selected from a minimum of 4 devices. Bond pulls in accordance with test conditions D, F, G, and H, while involving two or more bonds shall count as a single pull for bond strength and sample size number purposes. Unless otherwise specified, for conditions F, G, and H the sample size number specified shall determine the number of dice to be tested (not bonds). For hybrid or multichip devices (all conditions), a minimum of 4 dice or use all dice if four are not available on a minimum of 2 completed devices shall be used. Where there is any adhesive, encapsulant or other material under, on or surrounding the die such as to increase the apparent bond strength, the bond strength test shall be performed prior to application.

When flip chip or beam-lead chips are bonded to substrates other than those in completed devices, the following conditions shall apply.

a. The sample of chips for this test shall be taken at random from the same chip population as that used in the completed devices that they are intended to represent.

b. The chips for this test shall be bonded on the same bonding apparatus as the completed devices, during the time period within which the completed devices are bonded.

c. The test chip substrates shall be processed, metallized, and handled identically with the completed device substrates, during the same time period within which time the completed device substrates are processed.

5.1 Test Conditions

5.1.1 Test Condition A - Bond Peel  This test is normally employed for bonds external to the device package. The lead or terminal and the device package shall be gripped or clamped in such a manner that a peeling stress is exerted with the specified angle between the lead or terminal and the board or substrate. Unless otherwise specified, an angle of 90 degrees shall be used. When a failure occurs, the force causing the failure and the failure category shall be recorded.

5.1.2 Test Condition C - Wire Pull (Single Bond)  This test is normally employed for internal bonds at the die or substrate and the lead frame of microelectronic devices. The wire connecting the die or substrate shall be cut so as to provide two ends accessible for pull test. In the case of short wire runs, it may be necessary to cut the wire close to one termination in order to allow pull test at the opposite termination. The wire shall be gripped in a suitable device and simple pulling action applied to the wire or device (with the wire clamped) in such a manner that the force is applied approximately normal to the surface of the die or substrate. When a failure occurs, the force causing the failure and the failure category shall be recorded.
5.1.3 Test Condition D - Wire Pull (Double Bond) This procedure is identical to that of test condition C, except that the pull is applied by inserting a hook under the lead wire (attached to die, substrate or header or both ends) with the device clamped and the pulling force applied approximately in the center of the wire in a direction approximately normal to the die or substrate surface or approximately normal to a straight line between the bonds. When a failure occurs, the force causing the failure and the failure category shall be recorded. The minimum bond strength shall be taken from Table 1. Figure 1 may be used for wire diameters not specified in Table 1. For wire diameter or equivalent cross section >125 µm, where a hook will not fit under the wire, a suitable clamp can be used in lieu of a hook.

5.1.4 Test Condition F - Bond Sheer (Flip Chip) This test is normally employed for internal bonds between a semiconductor die and a substrate to which it is attached in a face-bonded configuration. It may also be used to test the bonds between a substrate and an intermediate carrier or secondary substrate to which the die is mounted. A suitable tool or wedge shall be brought in contact with the die (or carrier) at a point just above the primary substrate and a force applied perpendicular to one edge of the die (or carrier) and parallel to the primary substrate, to cause bond failure by shear. When a failure occurs, the force at the time of failure and the failure category shall be recorded.

5.1.5 Test Condition G - Push-Off Test (Beam Lead) This test is normally employed for process control and is used on a sample of semiconductor die bonded to a specially prepared substrate. Therefore, it cannot be used for random sampling of production or inspection lots. A metallized substrate containing a hole shall be employed. The hole appropriately centered, shall be sufficiently large to provide clearance for a push tool, but not large enough to interfere with the bonding areas. The push tool shall be sufficiently large to minimize device cracking during testing, but not large enough to contact the beam leads in the anchor bond area. Proceed with push-off tests as follows: The substrate shall be rigidly held and the push tool inserted in the through the hole. The contact of the push tool to the silicon device shall be made without appreciable impact (less than 0.25 mm/minute) and forced against the underside of the bonded device at a constant rate. When failure occurs, the force at the time of failure and the failure category shall be recorded.

5.1.6 Test Condition H - Pull-Off Test (Beam Lead) This test is normally employed on a sample basis on beam lead devices which have been bonded down on a ceramic or other

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Wire Composition and diameter</th>
<th>Construction</th>
<th>Minimum bond strength (grams force)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>-</td>
<td>Given in applicable document</td>
</tr>
<tr>
<td>C or D</td>
<td>AL 18 µm AU 18 µm</td>
<td>Wire</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>C or D</td>
<td>AL 25 µm AU 25 µm</td>
<td>Wire</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>C or D</td>
<td>AL 32 µm AU 32 µm</td>
<td>Wire</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>C or D</td>
<td>AL 33 µm AU 33 µm</td>
<td>Wire</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>C or D</td>
<td>AL 38 µm AU 38 µm</td>
<td>Wire</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>C or D</td>
<td>AL 76 µm AU 76 µm</td>
<td>Wire</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15.0</td>
</tr>
<tr>
<td>F</td>
<td>Any</td>
<td>Flip-chip</td>
<td>5 grams-force x number of bonds (bumps)</td>
</tr>
</tbody>
</table>
| G or H         | Any                           | Beam lead    | 30 grams force in accordance with linear millimeter of nominal undeformed (before bonding) beam width. 

1. For wire diameters not specified, use the curve of Figure 1 to determine the bond pull limit.
2. For ribbon wire, use the equivalent round wire diameter width which gives the same cross-sectional area as the ribbon wire being tested.
3. For condition G or H, the bond strength shall be determined by dividing the breaking force by the total of the nominal beam widths before bonding.
suitable substrate. The calibrated pull-off apparatus (see 4.0) shall include a pull-off rod (for instance, a current loop of nichrome or Kovar wire) to make connection with a hard setting adhesive material (for instance, heat sensitive polyvinyl acetate resin glue) on the back (top side) of the beam lead die. The substrate shall be rigidly installed in the pull-off fixture and the pull-off rod shall make firm mechanical connection to the adhesive material. The device shall be pulled within 5 degrees of the normal to at least the calculated force (see 5.2), or until the die is at 2.5 mm above the substrate. When a failure occurs, the force at the time of failure, the calculated force limit, and the failure category shall be recorded.

6.0 Notes The following details shall be specified in the applicable acquisition document:

a. Test condition letter (see 5.0)

b. LTPD or number and selection of bond pulls to be tested on each device, and number of devices, if other than 4.
1.0 Scope

This test is carried out to determine the reflow properties of the solder paste. The ability of the prealloyed solder particles in the paste to reflow into a sphere on a non-wettable substrate is determined under defined test conditions.

2.0 Applicable Documents

None

3.0 Test Specimen

Frosted glass microscope slide, alumina substrate or glass/epoxy printed circuit board with a thickness of 0.60 to 0.80 mm and a minimum length and width dimension of 76 mm and 25 mm, respectively.

4.0 Equipment/Apparatus

4.1 Metal Stencils

4.1.1 Stencil for Type 1-4  Stencil 76 mm x 25 mm x 0.2 mm provided with at least 3 round holes of 6.5 mm diameter apertures with a minimum distance between centers of 10 mm.

4.1.2 Stencil for Type 5-6  Stencil 76 mm x 25 mm x 0.1 mm provided with at least 3 round holes of 1.5 mm diameter apertures with a minimum distance between centers of 10 mm.

4.2 Spatula

4.3 Solder bath not less than 100 mm x 100 mm x 75 mm deep containing solder suitable to maintain a temperature of 25°C above the liquidus temperature of the solder paste being evaluated.

4.4 Flat hot plate

4.5 Surface temperature thermometer

4.6 Magnifying glass with a 10 to 20 times magnification.

5.0 Procedure

5.1 Preparation

5.1.1 Set the temperature of the solder bath or hot plate at a temperature of 25°C +/-3°C above the liquidus temperature of the solder alloy.

5.1.2 Homogenize the solder paste by hand stirring with a spatula.

5.1.3 Condition the paste to uniform temperature of 25°C +/-2°C.

5.1.4 Prepare two test specimens with either/or both stencils listed above (4.1.1 and 4.1.2). The solder paste should be squeegeed with the spatula to fill and level each hole.

5.2 Test

5.2.1 Test Conditions

5.2.1.1 Test one specimen within 15 +/-5 minutes after placement of solder paste on test coupon.

5.2.1.2 Test the second specimen 4 hours +/-15 minutes after placement of solder paste on test coupon. Storage for 4 hours shall be at 25°C +/-3°C and 50 +/-10% RH.

5.2.2 Conditioning Heating Equipment

5.2.2.1 Clean the surface of the solder bath with the scraper.

5.2.2.2 Remove all foreign material from the surface of the hot plate to ensure proper control.

5.2.3 Solder Reflow  Reflow specimens by one of the following two methods.

5.2.3.1 Lower the substrate, in a horizontal position with the paste deposit on top, into the solder bath at a speed of 25 +/-2 mm/second until the substrate is 50% submerged. It is important that good thermal contact is achieved between the molten solder and the substrate. As soon as the solder has melted, withdraw the substrate from the solder bath maintaining it in a horizontal position. The total time on the solder bath shall not exceed 20 seconds.
5.2.3.2 Place the substrate on the hot plate. As soon as the solder has melted, withdraw the substrate from the hot plate maintaining a horizontal position. The reflow shall occur within 20 seconds after the specimen is placed in contact with the hot plate.

5.3 Evaluation

5.3.1 Examine the reflowed specimens under 10X to 20X magnification.

5.3.2 Solder ball size and number should be compared with Figure 1.

5.3.3 Record the degree of reflow in comparison with Figure 1 for the 6.5 cm and 1.5 cm acceptance/reject conditions, respectively.
Figure 1 Solder ball test standards
1.0 **Scope**  This test is to determine the ability of a printed pattern of solder paste to retain a probe placed in the solder paste by measuring the force required to separate the probe from the paste. Time between printing and probe placement are progressively increased to simulate variables in a manufacturing process.

2.0 **Applicable Documents**  None

3.0 **Test Specimen**  A representative sample of this paste should then be printed out, using a stencil, onto clean plain glass slides. At least six paste deposits should be printed per required time data-point. The final deposits must be circular, 6.3 mm in diameter and 0.25 mm thick. Mark the test specimen in a suitable manner to identify the sample and the time after printing when tackiness is to be measured. The prepared samples shall be stored at 25°C ± 2°C and 50°C ± 10% relative humidity (RH) until evaluated. The samples shall not be stored in an enclosed cabinet or container, which allows the solder paste solvent vapors to saturate the environment surrounding the printed paste, thus preventing natural drying of the material.

4.0 **Equipment/Apparatus**  A Chatillon tackiness tester or other equipment may be used, providing it is capable of accurately measuring force when tested at a similar velocity. The equipment shall have a stainless steel test probe with a nominal 5.1 mm ± 0.13 mm diameter bottom surface, which is smooth, flat, and aligned parallel to the plane of the subject test specimen. The probe shall contact the test specimen at a controlled speed and apply a controlled, fixed initial contact force. Finally, a means shall be provided to withdraw the test probe from the surface of the test specimen at a controlled speed and record the peak force required to break contact with the test specimen.

5.0 **Procedure**  Place the specimen slide under the test probe and center the probe over one of the three printed patterns. Bring the test probe in contact with the printed paste specimen at a rate of 2.5 mm/min. ± 0.5 mm/min. and apply a force of 300 g ± 30 g to the specimen. Within five seconds following application of this force, withdraw the probe from the specimen at a rate of 2.5 mm/min. ± 0.5 mm/min. and record the peak force required to break the contact. Take at least five additional measurements under the same test conditions and average all the readings. Record both the tack force and time following paste printing.

5.1 **Evaluation**  Initial measurements are to be taken immediately after printing. Subsequent measurements of force shall be taken as needed to best define the rise and decline of the tack force. Tackiness data should be presented in graph form, provided that the graph with tack force is plotted as a function of time after printing. The data can also be reported as follows:

1. Time to reach 80% of the peak value.
2. The peak tack force in grams with the expected variation.
3. Time over which the peak value is maintained or for the tack force to decline to 80% of its peak value.

6.0 **Notes**

6.1 **Test Equipment Sources**  The equipment sources described in 6.1.1 and 6.1.2 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.

6.1.1  AMETEK/Chatillon  
8600 Somerset Drive  
Largo, FL 33773  
Phone: 1 (800) 527-9999

6.1.2  Malcom Instruments Corp.  
26226 Industrial Blvd.  
Hayward, CA 94545  
Phone: 1 (510) 293-0580
1.0 Scope  Determine the ability of a solder paste to wet an oxidized copper surface and to qualitatively examine the amount of spatter of the solder paste during reflow.

2.0 Applicable Documents  None

   2.4.43 Solder Paste—Solder Ball Test

3.0 Test Specimen
7.6 cm x 2.5 cm x 0.8 mm specimen of 1 ounce oxygen-free high conductivity (OFHC) copper.

4.0 Equipment/Materials/Apparatus
Flat hot plate
Specimen tongs
Beaker 400 cc
Magnifying glass with 10 times magnification
Liquid copper cleaner
Deionized water
Isopropyl alcohol
Solvent for residual flux removal

4.1 Stencil 76 mm x 25 mm x 0.2 mm provided with at least 3 round holes or 6.5 mm diameter aperture with a minimum between centers of 10 mm.

5.0 Procedure

5.1 Preparation
5.1.1 The specimen shall be cleaned with a liquid copper cleaner, washed thoroughly with water, rinsed with isopropyl alcohol, dried and then placed in boiling deionized water for 10 minutes and air dried

5.2 Test
5.2.1 Place stencil on test specimen and print solder paste test pattern.

5.2.2 Reflow using the procedure outlined in paragraph 5.2.3.2 of IPC-TM-650, Test Method 2.4.43.

5.2.3 After reflow, the residual flux shall be removed with a suitable solvent.

5.3 Evaluation  When examined visually at 10X, the solder shall uniformly wet the copper and there should be no evidence of dewetting or non-wetting of the copper and there shall be no solder spatter around the printed dots.
1.0 Scope
This test method will give an indication of activity of wave solder fluxes, core solder fluxes, and solder paste.

2.0 Applicable Documents
ASTM B-36  Brass Plate, Sheet, Strip, and Rolled Bar
J-STD-006  Requirements for Solder Wire

3.0 Test Specimen
3.1 A minimum of 10 ml of first article or production specimen of liquid flux furnished in a new clean glass container.
3.2 For paste flux and solder paste flux 10 ml of the diluted material (35%).
3.3 For preform and cored wire 10 ml of the extracted material.

4.0 Apparatus and Reagents
4.1 Five (5) replicates of 0.25 mm thick 70/30 brass (per ASTM-B-36 C2600 HO2) approximately 40 x 75 mm.
4.2 Degreased steel wool #00.
4.3 Sn60 1.5 mm diameter Type S solid wire solder per J-STD-006.
4.4 Solder pot containing at least 2 kg of solder and no less than 25 mm in depth.

5.0 Test
5.1 Specimen Preparation
5.1.1 Clean five (5) brass coupons with steel wool.
5.1.2 Using a flat strip of brass, bend the opposite ends parallel to the curve of the metal coil to stiffen and flatten the test coupon.
5.1.3 Cut a 30 mm length of solid wire solder
5.1.4 Wrap the cut length of solder around a 3 mm mandrel.
5.1.5 Cut the coil into individual rings to make a preform of the solder.

5.2 Test
5.2.1 Maintain solder pot at 260 +/-10°C.
5.2.2 Place the preformed solder in the center of the test coupon.
5.2.3 Place one drop (0.05ml) of flux in center of preform on the test coupon.
5.2.4 Carefully place the coupon on the surface of the solder bath for 15 seconds.
5.2.5 Remove the coupon in a horizontal position and place on a flat surface allowing the adhered solder to solidify undisturbed.
5.2.6 Remove all flux residue with a suitable solvent.

5.3 Evaluation
5.3.1 Measure the solder spread area by comparing to circles (pre-drawn) with areas similar to those listed in Table 1. The mean of the spread of all five samples tested is to be reported.

Table 1  Typical Spread Areas Defined in mm²

<table>
<thead>
<tr>
<th>Diameter in mm</th>
<th>Area in mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00</td>
<td>78.54</td>
</tr>
<tr>
<td>10.70</td>
<td>90.00</td>
</tr>
<tr>
<td>11.28</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Table 1 is intended as an aid in defining areas in mm².

6.0 Notes
6.1 Safety  Observe all appropriate precautions on MSDS for chemicals involved in this test method.
1.0 Scope  This test method specifies a qualitative method for assessment of the tackiness of soft soldering flux residues. The method is applicable to fluxes of types L and M, the method is particularly appropriate for applications where flux residues are left in place on soldered electronic and electrical equipment.

2.0 Applicable Documents

ISO 1634  Wrought-Copper and Copper Alloy Plate; Sheet and Strip
ISO 9453  Soft Solder Alloys
ISO 9455  Parts 1 and 2 Soft Soldering Fluxes

3.0 Test Specimen  A minimum of 0.035 grams by weight is required per test for fluxes in solid or paste form. For liquid fluxes, a volume sufficient to contain a minimum of 0.035 grams of non-volatile matter is required per test. For samples of flux cored solder, a minimum 1 gram is required per test and for solder paste, a minimum of 0.5 grams is required per test.

4.0 Apparatus and Reagents

4.1 General  In the test use only reagents of recognized analytical quality and only distilled, or deionized, water.

4.2 Acid Cleaning Solution  Add cautiously, with stirring, 75 ml of sulfuric acid (density 1.84 g/ml) to 210 ml of water and mix. Cool, add 15 ml of nitric acid (density 1.42 g/ml) and mix the solution thoroughly.

4.3 Degreasing solvent, such as 2-propanol, acetone, toluene or petroleum ether.

4.4 Powdered chalk.

4.5 0.5 mm thick copper sheet complying with ISO 1634: Part 1, grad Cu - ETP, condition HA.

4.6 Acetone

4.7 Solder wire, or pellets, complying with QQ-S-ALLOY XXX or ISO 9453 grade S-Sn60Pb40.

4.8 Solder bath, either circular with diameter not less than 120 mm, or rectangular with dimensions not less than 100 mm X 75 mm, containing tin-lead solder having a liquidus less than 200°C. The depth of the solder in the bath shall not be less than 40 mm. The bath shall be capable of being maintained at a temperature of 235 +/-5°C.

4.9 Cupping Device. This shall be fitted with a 27 mm diameter die and a 20 mm diameter ball.

4.10 Drying oven, suitable for use at 110 +/-2°C.

4.11 Tongs, or other suitable mechanical device, to lift the test piece from the surface of the molten solder bath.

4.12 Soft brush, of diameter approximately 7 mm.

4.13 Ordinary laboratory apparatus.

5.0 Procedure

5.1 Preparation of Copper Test Pieces

5.1.1 From the sheet of half hard copper, approximately 0.5 mm thick (4.5), cut test pieces each 50 mm X 50 mm.

5.1.2 Clamp each of the test pieces, in turn, centrally onto the 27 mm die of the cupping device (4.9). Using the 20 mm diameter ball, make a depression in the center of each test piece 3 mm deep, by forcing the ball into the die. One corner of the test piece may be bent up to facilitate handling with the tongs.

5.1.3 Immediately before the test, use the solvent (4.3) to degrease each test piece, and immerse the test pieces for 20 seconds in the acid cleaning solution (4.2). Remove the test pieces from the cleaning solution, wash well under running water, rinse in acetone (4.6) and dry by air blowing at room temperature.

5.1.4 Test For solid, paste and liquid flux samples:

5.1.4.1 Weigh 1.00 +/-0.05g of the solder wire or pellets (4.7), previously degreased in the solvent (4.3), and transfer it
to the center of the depression in one of the cleaned copper test pieces (5.1).

Note: This may conveniently be done, if solder wire is used, by forming the wire into a tight spiral.

5.1.4.2 If the flux under test is in solid or paste form—weigh between 0.035g and 0.040g of the solid or paste flux and add this to the solder in the depression of the test piece.

5.1.4.3 If the flux under test is in liquid form—first determine it’s non-volatile matter content by the use of the method described in ISO 9455: Part 1 or Part 2. Then add the appropriate volume of the liquid flux, to contain between 0.035g and 0.040g of non-volatile matter, to the solder in the depression of the test piece. Evaporate the solvent at 60°C for 10 minutes in the drying oven (5.3).

Note: If the liquid flux has low non-volatile content, it may be necessary to add the flux in two increments, carrying out the evaporation procedure after each addition.

5.1.5 For flux cored solder samples. Degrease the surface of a suitable length of the cored solder sample, using a cloth dampened with the solvent (4.3). Weigh 1.00 +/–0.05g of the degreased sample, form it into a small flat coil and place it in the center of the depression in one of the cleaned copper test pieces (5.1).

5.1.6 For solder paste samples. Weigh 0.50 +/–0.05g of the solder paste sample into the center of the depression in one of the cleaned copper test pieces (5.1).

5.2 Heating the test piece.

5.2.1 Using the tongs (4.11), or other suitable means, carefully lower the prepared test piece from 7.1 onto the surface of the molten solder, maintained at 235 +/–5°C in the solder bath (4.8).

5.2.2 Allow the test piece to float on the solder bath until the solder melts and leave the test piece in this position for a further 5 seconds. Remove the test piece carefully from the bath and allow it to cool, in air, in a horizontal position for 30 minutes.

5.3 Examination of the test piece. Dust the surface of the flux residue on the test piece liberally with the powdered chalk (4.4). Lightly brush the chalked surface with the soft brush (4.12).

5.4 Evaluation If the chalk powder is easily removed by brushing, the flux is deemed to be “not tacky.” If the chalk powder cannot be removed by brushing, or can be removed only with difficulty, the flux is deemed to be “tacky.”
6.0 Notes

6.1 Safety  Observe all appropriate precautions on MSDS for chemicals involved in this test method.
1.0 **Scope**  
This test method provides a measurement of the spitting characteristics of flux-cored wire and ribbon solder.

2.0 **Applicable Documents**

J-STD-006  Requirements and Test Methods for Electronic Grade Solder Alloys and Fluxed and Non-fluxed Solid Solders for Electronic Soldering Applications

3.0 **Test Specimen**  
One five meter length of the J-STD-006 flux-cored wire or ribbon solder (may be cut into several smaller lengths for convenient handling).

4.0 **Apparatus**

4.1 One laboratory stand with soldering iron support clamp and metal support ring or tray with a suitable hole in center.

4.2 One 20 by 20 cm piece of aluminum foil with 11 ± 0.5 mm diameter hole in center.

4.3 One small metal tray with suitable hole in center, for catching molten solder running down off of the soldering iron tip.

4.4 One soldering iron with a clean chisel point which has been coated with solder and wiped clean.

5.0 **Test Procedure**

5.1 **Preparation for Test**

5.1.1 Using additional pieces of solder identical to the test specimen, determine the flux content of the flux cored solder in accordance with IPC-TM-650, Test Method 2.3.34.1 and expressed in percentage units (%F).

5.1.2 Set up test configuration as shown in figure 1. The soldering iron should be positioned so that its tip extends approximately 6 mm through the aluminum foil.

5.1.3 Weight the aluminum foil (P1) and place it on the laboratory stand tray/ring so that the 11 mm hole is centered around the tip of the soldering iron.

5.2 **Test**

5.2.1 Apply the solder sample to the heated soldering iron tip approximately at an even rate, 1 cm at a time, keeping the soldering iron tip temperature steady.

5.3 **Evaluation**

5.3.1 Weight the stub(s) of the solder specimen not melted in the test (W2).

5.3.2 Weight the aluminum foil containing the spattered flux (P2).

5.3.3 Calculate the percent weight of spattered flux as follows:

\[
\text{Percent by weight of spattered flux} = \frac{(P2 - P1)}{\bar{F} \times (W1 - W2)}
\]

6.0 **Notes**

6.1 **Safety**  
Observe all appropriate safety precautions.
Figure 1 Test apparatus for spitting test

IPC-I-003166-
1.0 Scope
This solder pool test method provides a measurement of wetting characteristics of flux on/in flux-coated and/or flux-cored solder.

2.0 Applicable Documents
J-STD-006  Requirements and Test Methods for Electronic Grade Solder Alloys and Fluxed and Non-fluxed Solid Solders for Electronic Soldering Applications
ASTM B-36  Brass Plate, Sheet, Strip, and Rolled Bar

3.0 Test Specimen

3.1 Three approximately 30 mm long pieces of 1.5 mm diameter, flux-cored wire solder, three approximate 2 gram pieces of flux-coated, flux-cored, or flux-coated and flux-cored ribbon solder, or three approximately 2 gram quantities of flux-coated, flux-cored, or flux-coated and flux-cored solder preforms.

3.2 Approximately 10 ml of flux extracted and prepared in accordance with J-STD-006, and three pieces of 1.5 mm, non-fluxed wire solder per J-STD-006.

4.0 Apparatus and Reagents

4.1 Three flat pieces of 0.25 mm thick 70/30 brass (per ASTM B-36 C2600 H02) approximately 75 x 40 mm.

4.2 Degreased steel wool #00.

4.3 Solder pot containing not less than 4 Kg of molten solder at a stabilized temperature of 60 ± 10°C above the liquidus temperature of the alloy used in the solder specimens, and having a solder surface diameter of not less than 80 mm and a solder depth of not less than 25 mm.

4.4 Mandrel having a diameter of 3 ± 0.5 mm.

4.5 One pair laboratory forceps suitable for use in handling hot brass coupons.

4.6 Timer with a seconds display.

5.0 Test Procedure

5.1 Preparation for Test

5.1.1 Thoroughly clean three brass coupons with steel wool and bend one corner of each coupon up at an angle of approximately 60° to facilitate the handling of the coupons with forceps.

5.1.2 Preparation of Test Specimen

5.1.2.1 When using fluxed wire or ribbon solder specimens, individually coil each piece of the solder specimen around mandrel and place one coiled piece in the approximate center of each brass test coupon.

5.1.2.2 When using fluxed solder preform specimens, place one approximately 2 gram quantity in the approximate center of each brass test coupon.

5.1.2.3 When using extracted flux and non-fluxed wire solder, individually coil each piece of the non-fluxed solder specimen around mandrel, place one drop of flux (approximately 0.05 ml) in the approximate center of each brass test coupon, and place one coiled piece of non-fluxed solder in the center of the flux drop on each brass test coupon.

5.2 Test
CAUTION: When moving the brass test coupons, take extreme care to move coupons slowly and keep their test surface horizontal, so that the tests are not prejudiced by movement of flux or solder unrelated to the fluxing action.

5.2.1 Scrape the surface of the molten solder in the solder pot to remove any dross.

5.2.2 Carefully place one test coupon on the surface of the molten solder, leave for 15 ± 1 second, and remove it to a flat, level surface allowing the solder pool to solidify undisturbed.

5.2.3 Repeat step 5.2.2 with the remaining two test coupons.

5.3 Evaluation

5.3.1 Visually examine the surface of the test coupons for any evidence of flux spattering as evidenced by spots of flux and/or flux residue outside of the main pool of solder and flux residue.
5.3.2 Using a suitable solvent, remove the flux residues from the three coupons sufficient to clearly see the solidified solder pool and the remaining brass coupon surface.

5.3.3 Visually examine the thickness of the solder pool edge on the surface test coupons for any evidence of non-wetting or de-wetting.

5.3.4 The fluxed solder and/or the solder from which the flux was extracted shall fail this solder pool test if there is any evidence of non-wetting, de-wetting, or flux spattering or if the solder pool does not feather out to a thin edge.

Note: Irregularly shaped solder pools do not necessarily indicate de-wetting or non-wetting.

6.0 Safety Observe all appropriate safety precautions. Consult MSDS sheets for safety precautions for chemicals involved in this test method.
1.0 Scope  This test method defines the procedure for
determining the Thermal Conductivity of polymer coatings on
inorganic substrates, such as polyimide on a silicon wafer.

2.0 Applicable Documents
ASTM D 2766  Standard Test Method for Specific Heat of
Liquid and Solids

3.0 Test Specimen  See Sample Preparation 5.1.

4.0 Apparatus
4.1 CO₂ Laser capable of 5 Joules per pulse.
4.2 Mercury/Cadmium/Tellurium (MCT) Infrared Detector or
equivalent.

5.0 Procedure

5.1 Sample Preparation  Samples are prepared by form-
ing a structure on a silicon wafer consisting of 2 µm of sput-
tered carbon, 2 µm of sputtered Al metal, 25 µm of polymer
dielectric, and 2 µm of sputtered Al on wafer according to
manufacturer’s recommendations.

5.2 Test Procedure  Sample is placed between the laser
and the detector according to Figure 1.

5.3 Test Analysis  Heat rise is fit to the equation:

\[ T = 1 - \frac{4}{\pi} \sum_{n=0}^{N} \left( \frac{-1}{2n+1} \right)^{2} e^{-\left(\frac{2n+1}{2}\right)^{2} \pi^{2} \cdot L \cdot t / 4} \]

where \( T \) is the normalized temperature rise and \( t \) is the time in
seconds and \( L \) is the fitting parameter. The thermal diffusivity
\( k \) is given by:

\[ k = \frac{(L)(l)^{2}}{C_{p} P} \]

where \( l \) is the sample thickness. The thermal conductivity, \( K \), is
given by the equation:

\[ K = k \cdot C_{p} \cdot P \]

where \( C_{p} \) is the heat capacity (as determined by ASTM D
2766) and \( P \) is the density.
1.0 Purpose  To determine dispersion of glass microbeads in Self Shimming Thermally Conductive Adhesives, thus ensuring the proper self-induced gap. It is important for the beads to be well dispersed throughout the batch, since this adhesive is designed for bonding of electrical components to printed circuit boards where electrical isolation, provided by a consistent gap, is required. The testing is performed by measuring the gap induced by the adhesive placed between two flat metal surfaces.

2.0 Applicable Documents
None

3.0 Test Specimen
Two steel blocks; one with dimensions 1”x1”x5⁄16”, the second must be machined to equal the area of a TO-220 transistor (.605”x.405”x0.060”) on the center top of the block.

4.0 Apparatus and Reagents
4.1 Apparatus
4.1.1 Two steel blocks; one with dimensions 1”x1”x5⁄16”, the second must be machined to equal the area of a TO-220 transistor (.605”x.405”x0.060”) on the center top of the block. Both surfaces contacting the adhesive during the test must be highly polished. (See Figure 1).

4.1.2 Micrometer, accurate to the nearest 0.001”

4.1.3 Spatula

4.1.4 Clamp, Hargrave #1

5.0 Test Procedure
5.1 Preparation
5.1.1 Accurately measure to the nearest 0.001” the thickness of the two sandwiched steel blocks. Record.

5.1.2 Apply sufficient adhesive to ensure coverage of the TO-220 machines area.

5.1.3 Assemble blocks without twisting.

5.2 Test
5.2.1 Clamp blocks to induce vertical force.

5.2.2 Wipe off excess adhesive, if any.

5.2.3 Remove clamp.

5.2.4 Measure thickness of the sandwiched blocks with the adhesive in between. Record.

5.3 Evaluation
5.3.1 Gap Induced = Thickness measured in 5.2.4 − thickness measured in 5.1.1.

5.3.2 Report the average of three determinations.

Note: A hargrave #1 clamp produces approximately 20 lbs of clamping force.

Figure 1
1.0 Scope
This method describes a technique for evaluating a material to resist tracking when subjected to a low current arc just above the surface of the material. It can be used on materials of various thickness by stacking materials. This procedure is based on techniques described in ASTM D495.

2.0 Applicable Documents
ASTM D495 Standard Test Method for High Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation
Manufacturer’s Instruction Manual

3.0 Test Specimens
3.1 Number
Three specimens shall be used unless otherwise specified.

3.2 Form
Each specimen shall be 3.0 in. x 2.0 in. Material under 0.06 in. in thickness shall be built up to provide a specimen at least 0.06 in. but not exceeding 0.125 in. For very thin laminates a 1/16 in. laminate of the same type may be used under the actual specimen subjected to the arc, permitting a reduction of the material required without significantly affecting the results.

3.3 Location
Specimens may be cut from any location in a sheet (except from the outer 1 in. of full size sheets).

3.4 Foil Clad Materials
All foil clad materials shall have the foil removed by etching and shall be thoroughly cleaned prior to conditioning or testing.

4.0 Apparatus/Materials
4.1 Arc tester (Beckman ART-1 or equivalent, see ASTM D495).

4.2 Tungsten electrodes (Beckman or equivalent, see ASTM D495).

4.3 Constant temperature water bath capable of 50°C ± 2°C, filled with distilled water.

4.4 Beaker or pan filled with ambient temperature distilled water.

4.5 Racks for supporting specimens in the water bath with all surfaces exposed.

4.6 Shear, saw or paper cutter for cutting specimen.

4.7 Alcohol or other solvent for cleaning electrode.

4.8 Crocus cloth.

4.9 Gage blocks for checking electrode spacing 0.248 in. and 0.252 in.

4.10 Lint free paper towels.

4.11 Variac autotransformer type W10MT or equivalent.

5.0 Procedure
5.1 Preconditioning
Unless otherwise specified the specimens shall be conditioned for 48 hours (± 2 hours -0 hours) in distilled water maintained at 50°C ± 2°C. Following this step the specimens shall be immersed in ambient temperature distilled water for 30 minutes minimum, 4 hours maximum, to allow them to reach temperature equilibrium without loss of moisture.

5.2 Test Conditions
The test shall be run at ambient temperature 23°C ± 5°C and ambient humidity.

5.3 Equipment set up
5.3.1 The electrode assembly shall be cleaned thoroughly using alcohol or other suitable solvent and, if required, with crocus cloth. The electrode gap shall be adjusted if necessary to provide a gap of 0.250 in. ± 0.002 in. when the electrodes
rest on the test specimen.

5.3.2 The arc tester should be set up for operation in the automatic mode.

5.3.3 Set the Variac to the voltage which produces 12,500 volts based on the last calibration of the Instrument (generally 105V to 115V).

5.3.4 Reset the timer on the tester to ‘0’ seconds if required.

5.4 Test Procedure

5.4.1 Remove a preconditioned specimen from the ambient temperature distilled water and wipe dry with a lint free paper towel.

5.4.2 Place a specimen (individual or built up) in the electrode fixture.

5.4.3 Operate the tester in accordance with the manufacturer’s instructions such that an arc is generated and automatically switched as indicated below.

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>On/Off Time</th>
<th>Amperage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-60</td>
<td>0.25 sec/1.75 sec</td>
<td>10 milliamps</td>
</tr>
<tr>
<td>60-120</td>
<td>0.25 sec/0.75 sec</td>
<td>10 milliamps</td>
</tr>
<tr>
<td>120-180</td>
<td>0.25 sec/0.25 sec</td>
<td>10 milliamps</td>
</tr>
<tr>
<td>180</td>
<td>continuous</td>
<td>10 milliamps</td>
</tr>
</tbody>
</table>

5.4.4 Observe the arc carefully and, at the point which the arc disappears and tracking occurs, stop the timer and record the time for the specimen to the nearest second.

5.4.5 Remove the specimen, remove and clean the electrodes thoroughly using a solvent and if necessary the crocus cloth.

5.4.6 Replace the electrode and check the electrode gap.

5.4.7 Reset the timer and proceed as in 5.4.1 through 5.4.6.

5.5 Calculation

5.5.1 Average the values of the specimens tested from the same sample and round to the nearest second.

5.6 Report

5.6.1 Report the average value of the arc resistance in seconds.

5.6.2 Report the ambient temperature and relative humidity at the time of the test.

5.6.3 Report how the specimen was prepared, e.g. individual, # of plies built up, or with a spacer.

5.6.4 Report the preconditioning procedure.

5.6.5 Report any anomalies in the test or variations from procedures or tolerances specified.

6.0 Note

6.1 The results of arc tests may be significantly affected by contamination of the electrodes. Any irregularity of the arc in the early portion of the test may be an indication of contamination. If this occurs, the test should be stopped, the electrodes cleaned and a fresh specimen should be tested (or the test may be run in a different area of the same specimen).

6.2 While values for reinforced material may vary with the grain direction of reinforcement, the effect is generally insignificant with glass reinforced product. At least one specimen in both machine and transverse direction is recommended to verify this.
1 Scope  The purpose of this test is to measure the capacitance effects arising from plastic substrates, adhesives, or coatings, which may be critical to the reliable functioning of a circuit.

2 Applicable Documents  None

3 Test Specimen  Specimen thickness for all tests must be uniform within ±1% of the average thickness. At frequencies below 1 MHz the specimen shall be large enough to provide circular electrodes at least 10 cm in diameter and between 1.5 mm to 6.35 mm thick. At frequencies from 1.0 MHz to 1000 MHz, a micrometer electrode holder should be used with the test specimen.

4 Equipment/Apparatus

4.1 A bridge or resonant circuit capable of measuring the capacitance and dissipation factor with the required accuracy at the specified frequency may be used. The inherent accuracy of the measurement shall be ± 0.5%, ± 0.2% picofarad, unless otherwise specified. The electrode material may be thin foil, evaporated metal, sprayed metal, or air drying conductive paint.

4.2 The generating circuit may be any suitable source that can furnish sufficient current for the specified precision of measurement or voltage gradient in the dielectric.

5 Procedure

5.1 Preparation  The atmospheric conditions surrounding the specimen prior to and during test must be 23°C, ± 1.1°C and 50%, ± 4% RH.

5.2 Test  Place the test specimen in a suitable measuring cell or holder and measure its capacitance and dissipation factor with a suitable measuring circuit having required sensitivity and accuracy.

5.3 Evaluation  Record the shape and dimensions of the specimen, type and dimensions of electrodes and measuring cell, test conditions, method of measurement, applied voltage, voltage gradient, and frequency and capacitance.

5.4 Calculation

\[ C = \frac{Q}{V} = \frac{GA}{4\pi d_o} = \frac{A}{4\pi d_o} \]

where:

- \( C \) = capacitance in Farads
- \( Q \) = total charge in coulombs
- \( V \) = potential difference between plates in volts
- \( GA \) = area of plates
- \( 4\pi d_o \) = distance between plates

6 Notes

6.1 Suitable measurement techniques must be used to minimize errors due to the connections between the measuring apparatus and the specimen.

6.2 The AC voltage actually impressed across the specimen must be as low as possible. When DC polarizing voltages are required, it must be as specified.
1.0 Scope To determine if the plated through-holes are sufficiently plated to withstand a relatively high current potential.

2.0 Applicable Documents None

3.0 Test Specimen Any plated through-holes on a test coupon or finished printed wiring boards.

4.0 Apparatus Power supply capable of generating 10 amperes and having a suitable load resistor.

5.0 Procedure

5.1 Test Select a load resistor, such that when the resistor shunts the positive and ground terminals at a regulated amperes power supply, a current of 10 amps will flow through each plated through-hole in the circuit in series with the resistor, for 30 seconds.

5.2 Evaluation Examine for breakdown (opens) when the current is applied to each plated through-hole.

6.0 Notes The power supply unit should have a safety interlock mechanism because of the relatively high current required for this test.
1.0 Scope
This test method is to determine allowable current load for conductors.

2.0 Applicable Documents

3.0 Test Specimen
Test coupon “G” on test pattern in section 5.8.3 of this publication or production boards.

4.0 Apparatus
Regulated power supply, load resistor, and suitable meter.

5.0 Procedure

5.1 Test

5.1.1 Apply required current for a period of 3 minutes to terminal A-1 and E-13 of specimen.

5.1.2 Select a load resistor such that when positive and ground terminals of a regulated power supply are shunted by the resistor, a current of 2 amps will flow.

5.1.3 The circuitry to be tested is placed in series with the shunt resistor.

5.1.4 After 3 minutes of current flow, observations should be made to see if there is a reduction of current flow.

5.1.5 Note should also be made to see if there has been a temperature rise in excess of 20°C. Refer to Fig. 1.

5.2 Evaluation. Observe and record meter readings and visual results.

Figure 1  Conductor Thickness and Width
1.0 Scope
This method is to comparatively determine the effects of printed conductor materials, conductor cross sectional measurements, substrate materials, and processes on the temperature D.C. current characteristics of printed wiring boards on a standard test sample. The temperature rise must be given for each conductor materials for a particular value of current, for a specified conductor cross sectional area, approximate geometry and substrate material. The results are reported as a plot of temperature rises versus current for each of the conductor materials, cross sectional areas, approximate geometry, and a substrate material.

2.0 Applicable Documents
ASTM B 193  Conductor Materials, Electrical, Resistivity of
QQ-S-571  Solder, Tin Alloy, Tin-lead Alloy, and Lead Alloy

3.0 Test Specimens
Standard test specimen, see Figure 1 Test Pattern. Only one test pattern may be tested at one time, with current passing through only one conductor at one time.

4.0 Apparatus
4.1 Potentiometer (0.02% or better accuracy), Leeds and Northrup type K3 or equivalent.
4.2 Resistors (0.1 ohm ± 0.01 ohm) (Caution: Do not use low voltage because of fluctuation.)
4.3 Current leads, #12 AWG stranded wire.
4.4 Potential leads, #26 AWG magnet wire.
4.5 Sn60, Sn62, or Sn63 solder per Federal Specification QQ-S-571.
4.6 Temperature chamber capable of maintaining required temperatures in specification.
4.7 Thermometer or other temperature measuring device suitable for measuring laboratory ambient to the nearest 0.5°C [0.9°F].
4.8 Apparatus for performing cross sections.

4.9 A power supply with range of at least 0-40 volts.
4.10 Digital Multimeter capable of taking current and voltage in specification.

5.0 Test
5.1 Preparation
5.1.1 Extraneous surface coating shall be removed without affecting the dimensions of the conductor. The sample shall represent the materials and processes under investigation.
5.1.2 Current leads shall be secured by soldering to the terminal area. Pretinning of parts prior to soldering is advisable.
5.1.3 Potential leads shall be secured to the test tabs by soldering. Pretinning of parts prior to soldering is advisable.
5.1.4 The ambient air temperature measured at approximately 101.6 mm [4"] perpendicularly from the center of the conductor side of the board shall be 25°±5°C [77°±9°F]. The temperature shall be recorded at each measurement.

5.2 Procedure
5.2.1 The test sample shown in Figure 1 shall be suspended by the four corners, and centrally located within an enclosure free of forced air movement. The sample shall be so oriented that the conductors are horizontal.
5.2.2 To achieve 3-figure significance in temperature rise measurements, all potentials should be measured accurately to four significant figures.
5.2.3 The resistance of the conductor at the reference temperature (Rt1) should be determined with a test current not to exceed 100 milliamperes applied for as short a time as possible. (Caution: Do not use low voltage because of fluctuation.)
5.2.4 Pass the conductor current through an external series resistor (Rs) having a maximum temperature coefficient of resistance of 0.00002 per degree C at 25°C. The function of
this resistor is to provide a reference for measuring the current. Its value should be of the same order of magnitude as that of the conductor under test to minimize scale changes in measurements.

5.2.5 Measurements at specific currents are to be made after thermal stabilization. The elapsed time between these two measurements should be as small as possible.

5.2.6 Measure the voltage drops across the external series resistor and the test section of the current carrying conductor (R).

5.3 Evaluation

5.3.1 The value of the temperature coefficient of resistance (α) shall have been determined and identified. Temperature coefficients for various electrical conductor materials are given in American Society for Testing Materials-B193-65.

5.3.2 When the temperature coefficient of resistance of the conductor is unknown, it may be determined by measuring the resistance of the conductor at different oven temperatures, and calculated by the formula:

\[
\alpha_i = \frac{R_{t_2} - R_{t_1}}{R_{t_1} (t_2 - t_1)}
\]

and adjusted to the desired ambient temperature by:

\[
\alpha_i = \frac{1}{\alpha_{t_1}} + (t - t_1)
\]

5.3.3 Determine the cross sectional area of the conductor under test by use of the formula for volume resistivity.

\[
\rho_v = \frac{A}{L} R
\]

where \(\rho_v\) = volume resistivity in ohm-circular mil/ft
A = cross sectional area in circular mils
L = gage length, used to determine R in feet
R = measured resistance in ohms (R,, see calculations)

\[
A = \frac{\rho_v L}{R}
\]

where \(\rho_v = 11,529\) ohm cir mil/ft @ 25°C for 1/2 oz. of copper
= 10,827 ohm cir mil/ft @ 25°C for 1 oz. and over

5.4 Calculations The temperature rise of a conductor is determined by measuring the change in resistance of the test length of conductor and using the relationship:

\[
R_t = R_{t_1} [1 + \alpha_i (t - t_1)]
\]

R_t = Resistance of conductor at the desired current.
R_{t_1} = Resistance of conductor at reference temperature (t_1).
\(\alpha_i\) = Temperature coefficient of resistance of conductor at reference temperature (t_1).
t_1 = Reference temperature; that ambient temperature at which R_{t_1} was measured.

The following relationship can be derived from the foregoing using voltage drops:

\[
\Delta t = \frac{1}{\alpha_{t_1}} \left[ \frac{R_{t_1}}{R_t} - 1 \right]
\]

\[
R_t = \frac{E_{R_t} R_S}{E_{S_t}}
\]

\[
\Delta t = \frac{1}{\alpha_{t_1}} \left[ \frac{R_{R_t} R_S}{E_{S_t} R_{t_1}} - 1 \right] = \frac{1}{\alpha_{t_1}} \left[ \frac{E_{R_t} E_{S_t}}{E_{S_t} R_{t_1}} - 1 \right]
\]

E_{R_t} = Voltage drop across test conductor at the desired current.
E_{R_{t_1}} = Voltage drop across test conductor at the reference current.
E_{S_t} = Voltage drop across the external series resistor at the desired current.
E_{S_{t_1}} = Voltage drop across the external series resistor at the reference current.

R_s = Resistance of external series resistor.
R_{t_1} = Resistance of test conductor at the reference temperature. Determined by measuring voltage drop with less than 100 mA current passing through conductor and determined from

\[
R_{t_1} = \frac{E_{R_{t_1}}}{I_1} \quad \text{where} \ I_1 = \frac{E_{S_{t_1}}}{R_s}
\]
Subject: Conductor Temperature Rise Due to Current Changes in Conductors
Date: 8/97
Revision: A

Notes:
1. Terminal Area Diameter = 5mm [.2]
2. Test Tabs = .5 x 10mm [.020 Wide x .4] to Center-Line of Conductor
3. Other widths of specific interest may be used.

Figure 1 Test Pattern

Figure 2 Test Circuit
1 Scope  The purpose of this test method is to provide a procedure to determine the dielectric constant at 1 MHz of laminate or substrate material.

2 Applicable Documents  None

3 Test Specimen

3.1 Each specimen shall be 10 cm x 10 cm by the thickness of the laminate or substrate material. Remove copper foil from both sides by etching using standard commercial practices. At least three specimens are required.

4 Equipment/Apparatus

4.1 A standard capacitance bridge, generator, null detector, and accessories

5 Procedure

5.1 Preparation

5.1.1 Remove foil from both sides of specimens using standard copper etching practices. Rinse in tap water until clean.

5.1.2 Condition specimens in distilled water for 24 hours at 23°C, then air dry.

5.1.3 Coat both sides of the specimens with silver conductive paint, dry, and file all edges to prevent a conductive path.

5.1.4 Calibrate the capacitance bridge assembly.

5.1.5 Set the Method dial on “Substitute” and connect the balancing capacitor to the unknown direct terminals.

5.1.6 The balancing capacitor must be 100 picofarads greater than the test specimen.

5.1.7 Turn the Method switch to the “Substitute” position.

5.2 Test

5.2.1 Set the Voltage dial for maximum output and obtain a null on the detector by balancing the Capacitance and Dissipation dials, then take the reading of the capacitance of the dissipation.

5.2.2 Proceed by connecting the test specimen to the unknown substitute terminals.

5.2.3 Obtain a null on the detector by balancing the capacitance bridge, then read the capacitance and the dissipation factor as before.

5.3 Calculation  The dielectric constant is computed by using the following equation:

\[ K = \frac{4.45t (C_1 - C)}{A} \]

where:

\( t \) = thickness of specimen
\( A \) = area of specimen
\( C_1 \) = capacitance of balancing capacitor
\( C \) = capacitance of test specimen

5.4 Report  The results should be recorded in a written report, which contains the following as a minimum:

- Certification that the test was performed in accordance with this test method
- Identification of specimens tested
- The dielectric constant of each specimen tested and the average of the specimens tested for each material

6 Notes  The dielectric constant is defined as the ratio of the capacitance with the test material between the two plates to the capacitance of air between the two plates.
1.0 Scope This method describes a technique to determine the volume permittivity (dielectric constant) and loss tangent (dissipation factor) of insulating materials at 1 MHz using contacting electrodes. Several techniques are described using the actual thickness of the material measured, the geometry of the test specimen and values for capacitance and conductance of material to calculate the desired properties. The accuracy of this test is inherently limited by the ability to measure thickness accurately, however, use of an estimated value for effective electrode area, stray capacitance and equipment tolerances may also result in significant errors. Use of the preferred method (A) on metal clad materials should reduce errors on permittivity to those associated with thickness measurement (which should be under 2% for material over .005 inch), and an error (under 1%) associated with the effective area determination. Values determined with method B, C or D can be 5% or more from the actual value. Except for thickness determination, errors increase with specimen thickness due to the reduction in actual specimen capacitance. Method B and C are intended for thin materials while Method D is primarily for materials over .020 inch. For more accurate measurement of permittivity (dielectric constant) the two fluid method1 easily permits measurement to better than 1%. For thin films under .005 inch, the two-fluid method IPC-TM-650, Method 2.5.5.3 is recommended.

2.0 Applicable Documents

ASTM-D-150 Standard Test Method for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Material

3.0 Test Specimens

3.1 Number Three specimens shall be prepared unless otherwise specified.

Method A Etched pattern silver painted with 1/2 inch soldered leads, see Figure 1.

Method B and C 2.0 inch diameter silver painted disks (from which 1.000 inch diameter disks are punched after painting).

Note: For thin films, samples may be cut into smaller specimens if capacitance exceeds instrument capacity.

3.3 Location One specimen from each edge and one from the center of a sheet. (This normally will provide the highest and lowest values of dielectric properties of a reinforced material.)

3.4 Metal Clad Materials Foil shall be removed by etching, leaving a metal outline for method “A”.

3.5 Uncured Materials Materials which are not fully cured must be cured under normal conditions. Two ply minimum laminations are recommended for testing of bonding sheets while coverlays and similar materials may be tested in single ply or may be laminated together to produce a thicker specimen reducing the error induced by thickness measurement. Films coated on one side shall be laminated such that one coated side remains on the exterior.

4.0 Apparatus/Materials

4.1 All Methods Paper Cutter Silver Paint (DuPont 4929, or DuPont 4817 if material is attacked by cellosolve acetate) Micrometer with .00005 inch resolution Optical measuring device capable of measuring 1.0 inch to 1.2 inch with .001 inch resolution.

1. Two Fluid Method, IPC-TM-650, Method 2.5.5.3.5
4.2 Method A and Method D
1 MHz three terminal capacitance bridge with 100-1000 PF capacity
#20 tinned copper wire
Rosin flux solder
Soldering iron
Remote test fixture or binding post electrodes directly attached to the bridge

4.3 Method B
1 MHz capacitance bridge, two or three terminal Test fixture (Figure 2) Punch and die set, 1.0 inch diameter.

5.0 Procedure

5.1 Preconditioning Unless otherwise specified the prepared painted sample shall be maintained at 23°C ± 5°C and 50% RH ± 10% RH for a minimum of 24 hours.

5.2 Test Conditions Unless otherwise specified specimens shall be tested at 23°C ± 2°C. Testing may be performed at 50% ± 10% RH or may be performed at ambient humidity within 5 minutes of removal from the 50% conditioning chamber.

5.3 Equipment Set Up

5.3.1 Warm up the capacitance measuring device in accordance with the manufacturer’s recommendation.

5.3.2 Set the equipment to measure capacitance and conductance (or Q for Method C) at 1 MHz.

5.4 Test

5.4.1 Determine the thickness of the test specimen to the nearest .00005 inch or better at four locations (use corners for Figure 1 specimen used in Method A and make measurements prior to painting the specimen used for Methods B, C and D). Note: For films under .005 inch the known or measured density and the specimen weight and geometry may be used to determine effective thickness.

5.4.2 Measure the diameter (or length and width) of the electrode to the nearest .001 inch using a suitable device. For Figure 1 specimen record both the outer diameter of the inner electrode D₁ and inner diameter of the outer guard electrode D₂.

5.4.3 Determine the capacitance and conductance or Q using Method A, B, C or D depending on equipment and test specimen type.

5.4.3.1 Method A capacitance bridge with Figure 1 specimen.

5.4.3.1.1 Connect the low terminal to the guarded (center) electrode shown as D₁ on the specimen.

5.4.3.1.2 Connect the guard electrode, shown as D₅ in Figure 1, to the bridge or fixture ground.

5.4.3.1.3 Zero the bridge for capacitance and conductance.

5.4.3.1.4 Connect the solid electrode shown as D₃ to the “high” terminal.

5.4.3.1.5 Determine and record the specimen capacitance as Cₛ and Conductance as Gₛ.²

5.4.3.2 Method B Capacitance Bridge with Fixture (Figure 2).

² Gₛ—For many bridges the loss tangent (dissipation factor) may be read directly from the meter eliminating the need to calculate it from the conductance.
5.4.3.2.1 Connect the fixture in Figure 2 to the bridge.

5.4.3.2.2 With the spring removed (or set at a right angle with the free end at least one half inch from the specimen support), zero the bridge for capacitance and conductance.

5.4.3.2.3 Insert the specimen on the fixture and place the free spring such that the specimen is in the circuit.

5.4.3.2.4 Determine the capacitance and conductance of the specimen and record as \( C_s \) and \( G_s \).

5.4.3.3 Method C - Q Meter with Fixture (Figure 2)

5.4.3.3.1 Connect a coil to the Q meter which will result in resonance at a suitable value of capacitance at 1 MHz. **Note:** The value at which the Q meter resonates with the coil and electrode assembly in place must exceed the minimum capacitance of the meter (20 pf.) by at least the capacitance of the specimen. The higher the capacitance is at resonance without the specimen the larger the capacitance that can be measured. The highest possible capacitance that can be measured is 455 pf., however, this is seldom achievable. Smaller or thicker specimens may be required.

5.4.3.3.2 Connect the fixture to the Q meter.

5.4.3.3.3 With the spring removed (or set at a right angle with the free end at least 1/2 inch from the specimen support), adjust the capacitance until a resonance (maximum Q) is reached.

5.4.3.3.4 Record the capacitance as \( C_n \) and the Q as \( Q_n \).

5.4.3.3.5 Insert the specimen into the fixture and place the free end of the spring such that the specimen is in the circuit.

5.4.3.3.6 Determine the capacitance and Q of the specimen and record as \( C_s \) and \( Q_s \) respectively.

5.4.3.4 Method D Capacitance Bridge two terminal measurement.

5.4.3.4.1 Connect one side of the specimen to the low terminal of the capacitance bridge.

5.4.3.4.2 Zero the bridge for capacitance and conductance on the appropriate range for the specimen. Connect the free lead of the specimen to the high terminal of the bridge.

5.4.3.4.3 Determine and record the specimen capacitance and conductance as \( C_s \) and \( G_s \) respectively.

6.0 Calculations

6.1 Calculate the average thickness of the specimen to the nearest .00001 inch.

6.2 Calculate the diameter of the electrode

\[
D_e = \frac{D_1 + D_2}{2}
\]

\( D \) in inches for the Figure 1 specimen used in Method A. Use the measured diameter for the 1.0 inch diameter specimen used in Method B and C.

6.3 Calculate the effective area of the electrode in square inches:

\[
A = \frac{\pi (D_e^2)}{4}
\]

or \( A = L \times W \) for square or rectangular specimens

6.4 Calculate the permittivity and loss tangent\(^2\) of the specimen using the following equation.

For Methods A, B and D

\[
\text{Permittivity} = \frac{C_s t}{225 A}
\]

\( C_s \) = capacitance in picofarads

\( t \) = avg. thickness of specimen in inches

\( A \) = effective area of specimen in square inches

\[
\text{Loss Tangent} = D = \frac{G_s}{wC_s} \times 10^6
\]

\[
= \frac{G_s \times 10^6}{6.28 \times 10^3 \times C_s}
\]

\( G_s \) = conductance in microsiemens

\( w = 2\pi \times \) frequency in Hz

\( = 6.28 \times 10^6 \) (at 1 MHz)
For Method C

\[
\text{Permittivity} = \frac{C_t}{.225 A} = \frac{C_n - C_s}{.225 A} t
\]

\[
\text{Loss tangent} = D = \frac{C_n |Q_n - Q_s|}{|C_n - C_s| Q_s Q_n}
\]

C = Capacitance in picofarads

\( t \) = Average thickness of specimen in inches

A = Effective area of specimens in square inches

\( C_n \) = Capacitance in picofarads of circuit without specimen

\( C_s \) = Capacitance in picofarads of circuit with specimen

\( Q_n \) = Q of circuit without specimen

\( Q_s \) = Q of circuit with specimen

7.0 Report

7.1 Report the average value of the permittivity to the nearest .1, e.g., 4.7.

7.2 Report the average value of the dissipation factor to two significant figures, e.g., .026.

7.3 Report the Method used A, B, C or D and the size of the specimen if Method D is used.

7.4 Report the preconditioning.

7.5 Report actual test temperature and humidity.

7.6 Report any anomalies in the test or variations from prescribed procedures or tolerances.

8.0 Notes

8.1 The capacitance of the specimen depends on the thickness, electrode area and dielectric constant. For thin plastic films under .005 inch with permittivity of 3 - 5, the 1.0 inch diameter specimen may exceed 1000 pf, hence, a smaller specimen is often required. Due to the high capacitance, the errors associated with edge and stray capacitance are not normally significant.

8.2 The capacitance of thicker materials may be quite low, for example, a typical .062 inch laminate with a permittivity of 4 will be under 20 pf/in². Small errors due to edge or stray capacitance may result in very significant errors in permittivity. Errors can be reduced by using proper correction factors (see ASTM-D-150).

Table 1

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>( D_1 )</th>
<th>( D_2 )</th>
<th>( D_3 )</th>
<th>( D_4 )</th>
<th>( D_5 )</th>
<th>Length of one side of specimen (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (t)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.020 or less (.79)</td>
<td>1.000</td>
<td>1.020</td>
<td>1.375</td>
<td>0.010</td>
<td>0.177</td>
<td>2.000</td>
</tr>
<tr>
<td></td>
<td>(25.40)</td>
<td>(25.91)</td>
<td>(34.93)</td>
<td>(.25)</td>
<td>(4.50)</td>
<td>(50.80)</td>
</tr>
<tr>
<td></td>
<td>±0.005</td>
<td>±0.005</td>
<td>±0.005</td>
<td>±0.001</td>
<td>±0.005</td>
<td>±.015</td>
</tr>
<tr>
<td></td>
<td>(.13)</td>
<td>(.13)</td>
<td>(.13)</td>
<td>(.03)</td>
<td>(.13)</td>
<td>(.38)</td>
</tr>
</tbody>
</table>

1. Outlines for \( D_1, D_2, D_3, D_4 \) and \( D_5 \) are .062 inches wide.
2. Interior of electrodes defined by \( D_1 \) and \( D_3 \) are silver painted.
3. Short lengths of #20 tinned copper wire are soldered to each of the 3 electrodes. Use of small copper pads are recommended to facilitate soldering without damaging the specimen.
Table 2

<table>
<thead>
<tr>
<th>Electrode Size (in.)</th>
<th>.5 diameter</th>
<th>1 diameter</th>
<th>2.0 x 2.0</th>
<th>3.16 x 3.16</th>
<th>7.07 x 7.07</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode area sq. in.</td>
<td>.2</td>
<td>.79</td>
<td>4</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Thickness Property</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.001 inches</td>
<td>C (pf)</td>
<td>180</td>
<td>700</td>
<td>3600</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>G (µs)</td>
<td>11</td>
<td>44</td>
<td>230</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>R (ohms)</td>
<td>88K</td>
<td>23K</td>
<td>4K</td>
<td>–</td>
</tr>
<tr>
<td>.0101 inches</td>
<td>C (pf)</td>
<td>18</td>
<td>70</td>
<td>360</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>G (µs)</td>
<td>1</td>
<td>4</td>
<td>23</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>R (ohms)</td>
<td>880K</td>
<td>230K</td>
<td>44K</td>
<td>18K</td>
</tr>
<tr>
<td>.060</td>
<td>C (pf)</td>
<td>NR</td>
<td>11</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>G (µ)</td>
<td>NR</td>
<td>.7</td>
<td>3.7</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td>R (ohms)</td>
<td>NR</td>
<td>1.4M</td>
<td>2.70K</td>
<td>106K</td>
</tr>
<tr>
<td>.125 inches</td>
<td>C (pf)</td>
<td>NR</td>
<td>NR</td>
<td>28.8</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>G (µs)</td>
<td>–</td>
<td>–</td>
<td>1.8</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>R (ohms)</td>
<td>–</td>
<td>–</td>
<td>550K</td>
<td>220K</td>
</tr>
</tbody>
</table>

NR = Not recommended
K = x 1,000
M = x 1,000,000

Appendix A

Approximate Specimen Capacitance and Conductance

Permittivity = DK = 4  (For DK = 8 double C value)
Loss Tangent = DF = .01  (For DF = .02 [DK = 4] multiply R by 2 or divide JG by 2)
1.0 Scope  This test method is to determine the dielectric constant and dissipation factor of raw printed wiring board material at 1 MHz.

2.0 Applicable Documents  None

3.0 Test Specimens Each specimen shall be 50.8 ± 0.076 mm [2.0 ± 0.003 in] in diameter by thickness of laminate or substrate material. Remove copper of metal-clad specimens by etching using standard commercial practices. At least three specimens are required.

4.0 Equipment/Apparatus

4.1 Meter  A 1 MHz Digital LCR Meter, Hewlett Packard Mdl 4271A or equivalent.

4.2 Test Fixture  Hewlett Packard Mdl 16022A test fixture or equivalent.

4.3 Specimen Holder  A special specimen holder made as shown in Figure 1. This holder is designed to be compatible with the H/P test fixture, Mdl 16022A.

4.0 Procedure

5.1 Preparation

5.1.1 Prepare the specimens as specified in paragraph 3.0.

5.1.2 Calculate the effect thickness (inches) =

\[
\frac{0.01942 \times \text{Mass}}{\text{Density}}
\]

\[
\text{Mass} = \text{Measured weight in grams}
\]

\[
\text{Density} = \text{Grams per cubic cm (as per ASTM-D-792, Method 1A)}
\]

5.1.3 Coat both sides of specimens with one uniform coating of silver conductive paint.

5.1.4 Air-dry the specimens until dry to touch, then oven-dry at 50° ± 2°C for 1/2 hour and cool in a desiccator.

5.1.5 Punch or machine a 25.4 mm [1.0 in] diameter disc from the 50.8 mm [2.0 in] specimens. (Assure that there is no carry over of the paint from one side to the other.)

5.1.6 Condition the 25.4 mm [1.0 in] specimens for a minimum of 40 hours at 23° ± 5°C at a relative humidity of 50%.

5.2 Testing

5.2.1 Turn meter on and allow to warm up for 60 minutes minimum.

5.2.1.1 Set the controls on the meter as follows:

- Function – C-D
- Range – Manual
- Trigger – Internal
- Rate – FCW
- Test Signal Level – Low

5.2.2 Plug the special specimen holder into the test fixture.

5.2.3 The digital display on the meter will show the capacitance value and the dissipation factor of the unknown dielectric specimen.

5.3 Calculation

5.3.1 Dielectric Constant  The dielectric constant shall be determined by using the following formula:

\[
K = \frac{Ct}{0.225 A}
\]

\[
K = \text{Dielectric constant}
\]

\[
C = \text{Capacitance reading from Mdl 4271A Meter}
\]

\[
A = \text{Area of a 1-inch disc (square inches)}
\]

\[
t = \text{Effective thickness (inches)}
\]
5.3.2 Dissipation Factor  
The dissipation factor value is read directly from the digital display.

5.4 Report  
The report shall contain the following:
1. Measurement of effective thickness of specimens tested.
2. Capacitance values of the specimens tested.
3. Calculated dielectric constants and averaged measurement.
4. Dissipation factor values and averaged measurement.

6.0 Notes  

6.1 The dielectric constant is defined as the ratio of the capacitance with the test material between the two plates to the capacitance of air between two plates.

6.2 The dissipation factor of a dielectric material is the relationship between the permittivity (capacitance of material) and conductivity (ability to conduct or the reciprocal of the electrical resistivity) measured at a given frequency.
1.0 Scope

1.1 Purpose This method is suitable for determining the volume permittivity, (dielectric constant) and loss tangent (dissipation factor) of insulating materials at 1 MHz. It is not dependent on either direct or indirect measurement of specimen thickness and therefore is very useful for thin films and laminates but may also be used on specimens up to approximately 6.35 mm [0.25 in] thick.

It is useful for all ranges of permittivity and for loss tangent as low as 0.0005 providing the range and accuracy of the bridge used are adequate.

1.2 Description of Method The two fluid method utilizes air as one fluid and a suitable liquid, normally Dow 200 1.0CS silicone fluid, as the second. Using an established value for the permittivity of air, the values for the permittivity of the fluid and the sample may easily be calculated. The cell spacing is fixed during all readings but does not need to be known accurately for the series of readings required. Since specimens do not require any electrodes to be applied and since many specimens can be measured at one time without changing any spacings or machine settings, the method is not only very accurate but very rapid.

The method has been used for measurement of PTFE and epoxy glass laminates and flexible films, e.g., polyimide.

Reproducibility lab to lab is excellent for permittivity provided minimal precautions are observed and bridge accuracy is appropriate. On most materials, the effects of small changes in moisture or temperature are larger than any error due to the method. Lab to lab correlation on stable material such as PTFE have shown results to be consistently within 0.005 or (0.2%).

2.0 Applicable Document

3.0 Test Specimens

3.1 Number Unless otherwise specified in the material specification, one specimen is adequate for materials which are uniform, e.g., unreinforced plastics. For woven reinforced materials where resin content may vary, at least 2 specimens, representing the thinnest and thickest part of the sample, should be tested. For material with random reinforcement, a minimum of three specimens from the edge and center of the sheet are recommended to characterize variation within the sheet.

3.2 Form Individual specimens shall be 81.3 mm ± 1.3 mm x 81.3 to 101.6 mm [3.2 in ± 0.05 in x 3.2 in to 4.0 in] x thickness.

For materials under 0.254 mm [0.010 in], individual specimens should be stacked to a minimum of 0.381 mm [0.015 in] to maximize accuracy. Thinner specimen buildups may be used if the correlation with the 0.381 mm [0.015 in] specimen is within the required accuracy for the particular equipment, cell spacing and material being tested.

3.3 Foil Clad Materials All foil clad materials shall have the metal cladding completely removed by etching and shall be rinsed and dried prior to conditioning.

3.4 Marking Mark each specimen in the upper left corner with an engraving pencil or an ink which is not soluble in the Dow Corning 200 fluid.

4.0 Apparatus/Materials

4.1 1 MHz Capacitance Bridge with 0-200 (or 0-100) pf range.1

4.2 Cell Balsbaugh LD-32 or equivalent (see Figure 1) three terminal cell. Note: For accuracy of 1% or better, room temperature must not vary more than 1°C during measurements. Temperature control is necessary if laboratory variation exceeds these limits.

---

1. Capacitance Bridge—Suggested is Boonton 76A automatic capacitance bridge. This model has adequate capacitance range and adequate conductance resolution (0.001 microsiemen) to permit measurement of dissipation factors down to approximately 0.0005. Other bridges, e.g., Boonton 75D, are also adequate for low loss materials and some other bridges may be suitable for higher loss materials, such as epoxy where dissipation factors exceed 0.01 and resolution of 0.01 microsiemen or even 0.1 microsiemen may be adequate.

2. Balsbaugh LD-3 Gillian and Co., Watertown, MA, (617) 624-5688 or Zincast Corporation, 44 Homestead Ave., Stanford, CT 06902, (203) 359-0109
4.3 **Test Leads**  2 RG 58/U coax cables approximately 304.8 mm [12 in] long with suitable connectors for the bridge. One lead shall have a banana plug (high lead) and the low lead should have a GR874 at the cell end. (Note: The use of a G874-QBJA instead of the standard GR874 will permit a BNC connector to be used for the cell connection of the low lead, reducing the chances of damaging the 874 connector.)

4.4 **Flask with stopper** (for silicone fluid storage).

4.5 **Beaker** for cell overflow.

4.6 **Funnel**.

4.7 **Filter paper (coarse)**.

4.8 **1 Centistoke Dow Corning 200 Fluid** (500 ml minimum).  
*Note:* Fluid must be at the same ambient temperature as the test cell and should be stored in close proximity to the test cell.

4.9 **Forceps or large tweezers**.

5.0 **Procedure**

5.1 **Conditioning**  All materials which are affected by moisture, including all reinforced laminates and most films, should be conditioned at 23°C ± 2°C 50 ± 5% RH for a minimum of 24 hours prior to testing. If required by the specification, specimens may be tested after humidity or water immersion or tested after desiccation.

5.2 **Test Conditions**  For ambient temperature tests the temperature should be 23°C ± 2°C.  
*Note:* Variation should not exceed 1°C during the test. Ambient humidity is not critical for most materials. The exception is very thin, very hydroscopic material such as polyimide film, where moisture content may be well over 1%. Such material must be tested at the desired humidity since the dielectric constant will increase measurably with moisture content and changes may occur very rapidly after removal from a controlled environment. For materials which experience glass transitions in the room temperature region, e.g., PTFE, some acrylics, the temperature should be 23°C ± 1°C.

5.3 **Set Up**

5.3.1 Open the electrode on the cell. Blow out the cell using clean compressed air to remove any dust or silicone fluid.

5.3.2 Warm up the bridge for at least the minimum amount of time recommended by the manufacturer.

5.3.3 Attach the low lead to the guarded electrode of the cell and the bridge.

5.3.4 Attach the high lead to the bridge and place the banana plug in the vicinity of, but not touching, the banana plug jack of the test cell.  
*Note:* Be certain the shielding on the high lead does not contact the banana plug.

5.3.5 Set the bridge up on appropriate ranges:  
- Capacitance: 200 pf (or 100 pf)  
- Conductance: microsiemens  
- 0-2 PTFE and very low loss material.  
- 0-20 Epoxy and other moderate loss materials.  
- 0-200 Some phenolic and very high loss materials.  
*Note:* For very thick specimens >3.18 mm (>0.125 in) the 0 to 20 pf range can often be used, increasing the precision of the measurement. All values must be obtained on the same range for both capacitance and conductance.

5.3.6 Set the cell spacing on the LD-3 to approximately 125% of the material thickness 0.51 mm minimum to 7.62 [0.020 in minimum to 0.3 in]  
*Note:* The spacing may be as little as 10% or as much as 50% greater than specimen thickness without a significant effect on results.

5.3.7 Zero the bridge for both capacitance and conductance.

5.4 **Measurement**

5.4.1 Connect the banana plug of the high lead to the cell.

---

3. GR874—Catalogue #874-9414 Gilbert Engineering, Glendale, AZ, (602) 245-1050  
4. G874-QBJA—Catalogue #874 QBJA Gilbert Engineering, Glendale, AZ  
5. BNC—Catalogue #999-225 Amphenol
5.4.2 Record the capacitance of the air filled cell as C1 to the nearest .01 pf (or nearest .001 pf if the 0-20 pf scale is used).

5.4.3 Remove the specimen from the humidity controlled environment.

5.4.4 Insert the first specimen to be tested with the marked corner remaining in the upper left and the right side of the test specimen against one side of the test cell. Note: This will ensure that subsequent measurements are taken using the same area of the specimen.

5.4.5 Read and record the value of capacitance with the specimen in the cell as C3.

5.4.6 Remove the first specimen and obtain C3 for any other specimens to be measured with same cell spacing.

5.4.7 After removing the last specimen from the cell, fill the cell with Dow Corning 200 Fluid using the funnel and a filter to remove any small particles from the fluid and collect any excess fluid from the overflow pipe on the cell with the small beaker. Allow a few seconds for the temperature of the cell and fluid to equilibrate and record the capacitance of the liquid filled cell as C2. Note: If the capacitance is drifting consistently in one direction, the fluid is not at equilibrium.

5.4.8 Record the conductance of the fluid filled as cell G1. Note: The value obtained will vary somewhat with cell spacing and humidity but should not exceed 500 microsiemen (200 microsiemen if low loss material, with a loss tangent under .001 is being tested). Values beyond this are generally indicative of problems with the leads, contamination of the fluid or bridge error and must be corrected if correct dissipation factor is to be determined.

5.4.9 Insert the first specimen in the fluid filled cell exactly as in the dry reading and record the value of the capacitance as C4, and the value of the conductance as G2. Note: Values should stabilize within a few seconds after specimen insertion. If they do not there is very likely air trapped in the cell. This is quite common if multiple thin specimens are used to form one test specimen. If this occurs presoaking the specimen with fluid before immersion and inserting one ply at a time should eliminate the problem.

5.4.11 Remove the first specimen and insert each subsequent specimen in the same order as the dry values were obtained and record the C4 and G2 values for each.

5.4.12 After the last specimen is measured and removed from fluid, check and record the values of the capacitance and conductance. Note: If the level of the fluid with the specimen removed does not cover the electrodes, fill the cell before checking the final values. This check on C2 will be used to verify the amount of influence that changes in ambient temperature have had on the values obtained.

6.0 Calculation

6.1 Calculate the value of the permittivity (dielectric constant) of each specimen tested using the equation:

\[
DK = \frac{1.00058}{C1} \left( C1 + \frac{(C3-C1)(C2-C1)C4}{(C3-C1)C4-(C4-C2)C3} \right)
\]

Round the value obtained to the nearest .01.

6.2 Calculate the value of the loss tangent (dissipation factor) of each specimen tested using the equation:

\[
DF = \frac{G2}{6.2832C4} + \frac{DK \cdot 0.99942 C1-C4}{C4-C2} \left( \frac{G2}{6.2832 C4} - \frac{G1}{6.2832 C2} \right)
\]

Round the value to the nearest .0001. Note: Values should be calculated using a computer and must not be rounded prematurely.

6.3 If the value of C2 changed during the course of the measurements, use the final values of C2 and G2, the value of C1, and the values on the last specimen for C4 and G2 to recalculate the DK and DF of the final specimen. If the difference in DK values is significant, the temperature of the cell must be controlled more precisely during the measurement period.

6.4 Calculate the average permittivity (dielectric constant) (if more than one specimen was tested).

6.5 Calculate the average loss tangent (dissipation factor) (if more than one specimen was tested).

7.0 Report
7.1 Report the minimum, maximum and average values of the permittivity (dielectric constant).

7.2 Report the average value of the loss tangent (dissipation factor).

7.3 Report the specimen preconditioning, e.g., C-24/23/50.

7.4 Report the actual test conditions for temperature and humidity.

7.5 Report if the specimen was built up.

7.6 Report the approximate cell spacing.

7.7 Report any anomalies in the test or variations from the prescribed procedures or tolerances.
1.0 Scope  The purpose of this test method is to provide a usable test procedure to determine the dielectric constant and dissipation factor of printed wiring materials at various frequencies (from 22kHz to 70mHz).

2.0 Applicable Documents  None

3.0 Test Specimens  Each specimen shall be between 38 and 55 mm in diameter by thickness of substrate material. The copper-clad must be completely removed, using standard commercial procedures. Three specimens are required for this test.

4.0 Equipment/Apparatus

4.1 Meter  A Hewlett-Packard Q Meter, model 4342A or equivalent.

4.2 Test Fixture  Hewlett-Packard model number 16451A test adapter or equivalent.

4.3 Inductor  A reference inductor capable of resonating at the desired measurement frequency.

5.0 Procedure

5.1 Depress the appropriate frequency range button and set frequency dial control for the desired measurement frequency.

5.2 Connect desired reference inductor to 4342A measurement coil (HI and LO) terminals.

5.3 Adjust L/C dial and ΔC dial controls for a maximum Q meter deflection. Note sum of the C dial and ΔC dial readings as C₁ and panel meter reading as Q₁.

5.4 Let the reference inductor remain in place (as is) and attach the 16451A to 4342A measurement capacitor (HI and GND) terminals.

5.5 Set 16451A electrode spacing as desired. However, if possible, it is best to set the electrode spacing dimension to about the same as the thickness of the material to be measured.

5.6 Again resonate the measurement circuit by adjusting the L/C and ΔC dial controls. Note C dial and ΔC dial readings as C₂ and panel meter reading Q₂.

5.7 Depress ΔQ button and adjust ΔQ zero (course and fine) controls so that meter pointer indicates zero (full scale) on ΔQ scale.

Note: Press ΔQ button to release ΔQ function and recheck for current resonance. Again depress the ΔQ button and recheck for ΔQ zero indication.

5.8 Place the sample material between 16451A electrodes. The sample material should be in close contact with electrodes. Note 16451A micrometer reading TX (as thickness of sample).

5.9 Again adjust the L/C and ΔC dial controls for resonance. Note sum of the C dial and ΔC dial readings as C₃ and panel meter ΔQ reading. If meter pointer scales out at the left end of the scale (ΔQ full scale), reset the function for normal Q measurement. The difference in Q is calculated from the two Q values as ΔQ = Q₂ – Q₃.

5.10 Remove the sample material from between the 16451A electrodes.

5.11 Let the L/C and ΔC dial settings remain as is, and reduce space between the 16451A electrodes until resonance again occurs. Note the micrometer reading too.

6.0 Calculations  The Dielectric Constant shall be calculated as follows:

\[ D.C. = \frac{TX}{TO} \times 8.855 \times 10^{-12} \text{ (F/M)} \]

Where:

D.C. = Dielectric Constant
TX = Micrometer reading (thickness of sample)
TO = Micrometer reading at resonance after reduction of spacing between test fixture electrodes.
(F/M) = Farads per meter
The Dissipation Factor shall be calculated as follows:

\[ D.F. = C_1 \times \frac{\Delta Q}{C_2 (Q_2 - Q_3)} \times 100 \]

Where:

- **D. F.** = Dissipation Factor
- **C_1** = Capacitance reading without fixture or sample (in picofarads)
- **TO** = Micrometer reading at resonance after reduction of spacing between test fixture electrodes
- **Q_2** = Q reading with test fixture attached (no sample)
- **\( \Delta Q \)** = \( Q_2 - Q_3 \)

**TEST FIXTURE**
1.0 Scope

1.1 Summary This method is intended for the rapid measurement of the X-band (8.00 to 12.40 GHz) apparent relative stripline permittivity (see 9.1) and loss tangent of metal clad substrates. Measurements are made under stripline conditions using a resonant element pattern card, which is separated from the ground planes by sheets of the material to be tested. Further information about this method may be found in ASTM D3380-75.

1.2 Definitions Terms used in this method include:

Complex Relative Permittivity The values for relative permittivity and dissipation factor considered as a complex number.

Permittivity Dielectric constant (see IPC-T-50) or relative permittivity. The symbol used in this document is \( \varepsilon_r \). \( K' \) or \( \kappa' \) are sometimes used.

Relative Permittivity A dimensionless ratio of absolute permittivity of a dielectric to the absolute permittivity of a vacuum.

Loss Tangent Dissipation factor (see IPC-T-50), dielectric loss tangent. The symbol used in this document is \( \tan \delta \) (see 9.2).

1.3 Limitations The following limitations in the method should be noted. Users are cautioned against assuming the method yields permittivity and loss tangent values that directly correspond to applications. The value of the method is for assuring consistency of product, thus reproducibility of results in fabricated boards.

1.3.1 The measured effective permittivity for the resonator element can differ from that observed in an application.

Where the application is in stripline and the line width to groundplane spacing is less than that of the resonator element in the test, the application will exhibit a greater component of the electric field in the X, Y plane. Heterogeneous dielectric composites are anisotropic to some degree, resulting in a higher observed \( \varepsilon_r \) for narrower lines.

Microstrip lines in an application may also differ from the test in the fraction of substrate electric field component in the X, Y plane.

Bonded stripline assemblies have air excluded between boards, thus tend to show greater \( \varepsilon_r \) values.

1.3.2 High degrees of anisotropy of some composites can result in an increased degree of coupling of the resonant element, resulting in a falsely lower Q value. If a correction is not applied either mathematically as in 7.2.2 or by deviating from the probe gaps specified for the test pattern, an upward bias in the calculated loss tangent will result.

1.3.3 The sensitivity of the method to differences in \( \varepsilon_r \) of specimens is impaired by the fact that the resonator pattern card remains as part of the fixture and at the same time constitutes a significant part of the dielectric involved in measurements.

1.3.4 The method does not lend itself to use of stable referee specimens of known electric properties traceable to The National Institute of Standards and Technology (NIST).

2.0 Applicable Documents

2.1 IPC

IPC-T-50 Terms and Definitions
IPC-MF-150 Metal foil for Printed Wiring Application
IPC-TM-650 Method 2.3.7.1, Cupric Chloride Etching
IPC-TM-650 Method 2.5.5.3, Permittivity (Dielectric Constant) and Loss Tangent (Dissipation Factor) of Materials (Two Fluid Cell Method)
ASTM D3380-75 Standard Method of Test for Permittivity (Dielectric Constant) and Dissipation Factor of Plastic-Based Microwave Circuit Substrates

3.0 Test Specimen All metal cladding shall be removed from the material to be tested by any standard etching process, including rinsing and drying; however, IPC-TM-650, Method 2.3.7.1, shall be used as a referee procedure. The test specimen shall consist of a set of two sheets (or two packets of sheets) of a preferred size of at least 51 mm x 69 mm.

3.1 A smaller size may be used if it has been shown not to affect results. The minimum vertical dimension must extend...
from the base boards to the top of the 25.4 mm x 51 mm area to which clamping pressure is applied. The minimum horizontal dimension must be enough to extend at least 6.5 mm beyond the center line of the vertical portion of the probe line on either side. For the pattern card of Figure 4 and fixture of Figure 12, these minimums are 38.1 mm x 68.6 mm. For the smaller size, the clamp force in 6.1 or Table 1 is not changed because the effective area over which the force is applied is not reduced. The test fixture is designed to accommodate a total specimen thickness of either 3.18 mm ± 0.22 mm or 2.54 mm ± 0.18 mm from an even number of layers.

NOTE: Testing of built-up specimens introduces error, which can exceed 5% due to air gaps. Exact correlation factors and techniques must be agreed upon or other methods of test used. The 1 MHz method of IPC-TM-650, Method 2.5.5.3, can be used with a correction factor based on tests of samples of the nominal thickness of Table 1 using both techniques.

With some material types not based on woven fabric reinforcement, it is possible to machine specimens to achieve the nominal thickness for test.

4.0 Suggested Electronic Apparatus The principal components required for the test setup consist of the test fixture described in 5.0, a microwave signal source, an accurate means of measuring the signal frequency, an accurate means for detecting power level, and an accurate method of determining frequency values above and below the resonant frequency at the half-power level for the test fixture loaded with the specimen.

The microwave signal source must be capable of providing an accurate signal. During the required time period and range of frequency needed to make a permittivity and loss tangent measurement, the source must provide a leveled power output that falls within a 0.1 dB range. When the source is set for a particular frequency, the output must be capable of remaining within 5 MHz of the set value for the time required to make a measurement.

The means for measuring frequency shall have a resolution of 5 MHz or less and an accuracy of 8 MHz or less. An error of +8 MHz in measurement of a resonant frequency for a material with nominal permittivity of 2.50 represents a -0.004 error in permittivity.

The means for detecting the power level shall have a resolution of 0.1 dB or less and be capable of comparing power levels within a 3 dB range with an accuracy of 0.1 dB. An error of 0.1 dB in estimating half power frequency points can result in an error in the loss tangent of about 0.0001 for a material with 2.5 permittivity. See 7.2, equation 5.

4.1 Manual Test Setup The method of determining the half-power points depends partly on the type of signal source used. If the power input to the test fixture is maintained constant as the frequency is varied, then an SWR meter may be used to determine the half-power points at the output of the test fixture. This may be accomplished by using a leveled sweep generator or by using a tunable klystron (at a considerable savings) and manually adjusting the power input to the test fixture to a prescribed level by use of a variable attenuator. A typical equipment list is shown below. Equivalent makes and models of equipment may be substituted where it can be shown that equivalent results are obtained. For example, if a leveling system is not used and the power output of the source varies widely with frequency, a ratiometer may be substituted for the two SWR meters. If only permittivity is desired, it is not necessary to level the input.

The following equipment, or equivalent, may be used.

- Sweep Frequency Generator H.P. 8350B or 8620C
- X-Band Frequency Plug in Unit H.P. 83545A or 86251A
- Frequency Meter H.P. X532B
- Crystal Detector (2) H.P. 423B (Neg)
- Matched Load Resistor for one Crystal Detector H.P. 11523A, opt. 001
- SWR Meter (2) H.P. 415E
- Directional Coupler HP 779D
- 10 dB Attenuator H.P. 8491B
- 8.9 kN Dillon Force Gauge, Compression Model X, Part Number 381612301, with ± 1% full scale accuracy
- Vise or press that is able to exert controlled 4.45 kN force on the test fixture and that opens at least 127 mm to accept the force gauge and test fixture
- Semi-rigid Coaxial Cable and Connectors
- Waveguide to Coaxial Adapters (2) H.P. X281A
- The measuring equipment shall be connected as shown on Figure 1.

4.2 A Test Setup for Computer Automation of Data The following components or equivalent, properly interconnected, can be used most effectively with a computer control program for automated testing.
• Sweep Frequency Generator Mainframe H.P. 8350B
• RF Plug-In, 0.01 to 20 GHz H.P. 83592A. A plug-in of narrower frequency range (X-band) may be selected at considerable cost savings. 83545A 5.9 12.4 GHz.
• Power Splitter H.P. 11667A
• Automatic Frequency Counter H.P. 5343A
• Source Synchronizer H.P. 5344A. Obtained as an interconnected assembly with the counter.
• Coaxial cables and adapters.
• 10 dB Attenuator H.P. 8491B
• 8.9 kN Dillon Force Gauge, Compression Model X, Part Number 381612301, with ±1% full scale accuracy.
• Vise or press that is able to exert controlled 4.45 kN force on the test fixture and that opens at least 127 mm to accept the force gauge and test fixture.
• Programmable Power Meter H.P. 436A
• Power Sensor H.P. 8484A with 70 to 10 dBm range.
• IEEE 488 (GPIB) cables
• Controlling computer with GPIB interface.

The above equipment is connected as follows as illustrated in Figure 2:

• **RF connections.** The power splitter connects directly to the RF plug-in output. One output of the splitter connects by RF cable to the counter input. The other output is connected by RF cable to the attenuator which connects to one of the test fixture probe lines.

• **Control connections.** Connections between counter and synchronizer are provided as specified by the manufacturer. The FM output from the synchronizer connects by BNC to the FM input on the sweeper. GPIB cables connect in parallel to sweeper, synchronizer, power meter, and computer interface.

• **Other connections.** The power sensor is connected to the other probe of the fixture and its special cable connects into the power meter.

• A synthesized CW generator can be used to replace the sweeper, plug-in, power splitter, connector, and source synchronizer for the simpler set-up shown in Figure 3.

### 4.3 Automated Network Analyzer for the Test Setup

The instrumentation described in 4.1 or 4.2 may be replaced with either a scalar or vector network analyzer with test cables connected to the test fixture of 5.0 as the device under test (DUT). Examples of automated network analyzers known to be suitable include the Hewlett-Packard 8510 vector network analyzer or the Wiltron Model 561 scalar network analyzer. These or equivalent may be used.

Such instruments may be operated either manually or under computer control with suitable programming to locate the resonant frequency and the frequencies above and below resonance where transmitted power is 3 dB below that at resonance. Network analyzers have several advantages over the instrumentation described in 4.1 and 4.2. Data collection is rapid and may be continuously refreshed with averaging. The log magnitude response curve for ratio of transmitted to incident power (the S21 parameter) as dB versus frequency is visible on a screen for easy verification of a valid resonance. A large number of dB frequency data points near the resonance are readily available for optional use of non-linear regression analysis techniques to determine the frequency and Q values with statistically better degrees of uncertainty than those attainable by the three point (f<sub>r</sub>, f<sub>1</sub> and f<sub>2</sub>) method in either section 6.2 or 6.3.

### 5.0 Test Fixture

#### 5.1 Recommended Fixture Design

An improved test fixture design is shown that facilitates changing test pattern cards and lends itself to control of temperature. The test fixture shall be constructed as shown in Figure 4 through Figure 14.

The resonator circuit shown in Figure 4 is an example of a test pattern designed for a material with a permittivity of 2.20. For other permittivity values, different pattern dimensions will be required as outlined in Table 1. It shall be defined on one side of a material of similar type to that being tested, a laminate with dielectric thickness of 0.216 mm ± .018 mm. The cladding thickness is normally specified as MF-150F designation 1 copper (nominal thickness of 0.036 mm but designation down to Q (0.010 mm) may also be used. Designation Q is preferred for high permittivity materials as covered in 4.2 and 9.7. Note. The reverse side of the circuit board has all copper removed. The copper foil shall be of IPC-MF-150, type 1, electrodeposited, type 5, wrought, or type 7, wrought-annealed. The type of copper foil and the treatment for adhesion will affect the Q measurement. The 1/Qc values in Table 1 do not take into account surface treatments or higher resistivity values for the conductor that are encountered with the specified foil types.
The test pattern card shall have a permittivity equal to the nominal value of the type being tested with a tolerance of ±2.5% of the nominal value (measured by stacking sufficient plies to the total thickness requirement of a specimen as above. Use a photo resist and etching method capable of reproducing circuit dimensions with ±0.025 mm tolerance. All copper shall be removed from the other side of the test pattern card. See 9.7, Note, for special treatment of ceramic-PTFE substrate types.

The pattern card of Figure 4 is 68.6 mm wide by 55.4 mm high and is designed for the fixture hardware in Figure 5 through Figure 14. The length is cut so that when the pattern card is clamped for the lap joint with the striplines on the base card, the resonator is centered in the 51 mm high area above the base plates of the fixture. For materials with permittivity values higher than the nominal 2.50 shown in Table 1, please see 5.2 for a discussion of recommended fixture modifications.

Probe line widths are based on ground plane spacing taken as twice the nominal thickness of the two specimens plus thickness of the pattern card and its 0.034 mm copper foil pattern and computed as if the stripline were centered between ground planes\(^1\)\(^3\). Chamfer values are based on published design curves\(^2\).

The length of the four node resonator is given in Table 1. Resonators of lower node values for the purpose of measuring \(\Delta L\) according to 6.1, will be proportionately shorter with the probe lengths modified so that the gap is the same.

The values for conductor loss, \(1/Q_c\), in Table 1 are calculated from known properties of copper, the test frequency, the calculated characteristic impedance of the section of stripline comprising the resonator, and its cross-sectional geometry using published formulas\(^1\). The values shown are usually biased low giving a high bias to loss tangent results, because conductor actually used may not have a smooth surface and may include oxides, microvoids, or other sources of higher resistivity.

**5.2 Fixture Modifications for High Permittivity Materials**

Modification of the fixture design of Figure 5 through Figure 14 and pattern card dimensions in Figure 4 are recommended to overcome problems experienced with extraneous transmissions and resonances at frequencies near the desired resonant peak.

5.2.1 Replace the coax-stripline launcher shown in Figure 7. The part suggested has a tab width of 1.27 mm and may be replaced with Omni-Spectra Part No. 2070-5029-02, or equivalent, intended for 1.57 mm ground plane spacing and with a tab width of 0.635 mm. A further acceptable alternative is to redesign the base plates to accept another type of coaxial fitting such as a flange mount jack, which can be modified to provide a smooth, low-reflection transition from 3.0 mm semirigid cable with \(Z_0 = 50\) Ohm, low permittivity insulation into stripline with \(Z_0 = 50\) Ohm, and high permittivity insulation in the fixture.

5.2.2 If the stripline launcher in 5.2.1 is used, the edge at the step to accommodate the launcher body on the base plate should be machined with a slight undercut for an acute included angle of about 80°. This, combined with a means to press the launcher body axially against the edge, will assure a well-defined ground connection from coax to stripline. A poorly defined ground connection with ground current path length varying or longer than that of the signal conductor has been found to give rise to scattering, reflections, and resonances in the open ended probe line that are evident as extraneous fixture transmissions that may distort the resonant peak to be measured.

5.2.3 Omit the conductor lap joints but keep the extended base cards in the fixture assembly. See figures 13 and 14.

With high permittivity materials, the lap joint also gives rise to unwanted scattering, reflections, and resonances in the open-ended probe line, as discussed in 5.2.2. For this purpose the resonator pattern card will have a longer vertical dimension to extend down to the launcher pin replacing the spacer board in Figure 13. It should still center the resonator in the clamping block area. The base dielectric boards will be etched free of metal. The ground plane foils will also extend down to the launcher.

The feature of extending the base dielectric boards upward above the base plates is to be retained as a means to prevent premature damage to the resonator pattern card with repeated loading and unloading of the fixture. The base plate with the deeper step will be on the side toward which the resonator pattern faces to avoid straining the offset launcher tab during assembly.

5.2.4 Scale down the fixture dimensions to move remaining probe line resonances away from the resonant frequency of interest. For \(\varepsilon_r = 10.5\) material, the following dimensions were found effective.
Table 1 Dimensions for Stripline Test Pattern Cards in Millimeters

<table>
<thead>
<tr>
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<td>2.13</td>
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<td>2.54</td>
<td>5.08</td>
<td>31.8</td>
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<td>2.03</td>
<td>2.54</td>
<td>17.3</td>
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</tr>
</tbody>
</table>

Height of base plate from step to top edge mm 8.53
Height of clamp block and specimen 25.4
Height from launcher body to resonator center line 21.23
Width of clamp block and specimen 55.9
Horizontal center line distance between probe lines 30.5
Probe length from launch to gap 25.81

5.2.5 Thinner copper cladding (weight Q) for the resonator pattern card is recommended as mentioned in 5.1. If weight Q is used, the embedding process discussed in note 9.7 can be avoided. Experience has indicated that this reduction in thickness has not impaired the loss tangent values obtained by the method.

5.3 Older Fixture Design An older acceptable alternate test fixture design is shown in Figure 15. This is included since fixtures of this type are in service at various laboratories. Compared to 5.1, fixtures of this design depend on ambient conditions for temperature control. Changing resonator test pattern cards is less convenient.

5.4 Temperature Control It is a well-known fact that PTFE and composites containing it show a room temperature transition in the crystalline structure that produces a step-like change in the permittivity. This temperature region should be avoided.

In practice, control of ambient temperature is adequate for routine measurements. A means other than ambient temperature to control fixture temperature facilitates collecting data on the variation of permittivity with temperature. With the test fixture of 5.1., use 6 mm inside diameter tubing for circulating fluid to control temperature. The following items are needed to complete the temperature control system.

5.4.1 Laboratory Immersion Heating Bath/Circulator, such as Haake Model D1, Lauda Model MT, or equivalent and a small capacity bath. The Immersion Heating Bath/Circulator shall be connected to the clamping blocks in series with a return line to the bath.

5.4.2 Two fine diameter thermocouple probes with leads and suitable instrumentation for readout or recording of temperature. A digital thermometer, such as Ohmega Model DSS 115 or equivalent, is used for monitoring temperature.

6.0 Measuring Procedure

6.1 Preparation for Testing The actual length of the resonator element shall be determined by an optical comparator or other means capable of accuracy to 0.005 mm or smaller.

Unless otherwise specified, specimens shall be stored before testing at 23°C ± 1-5°C/50% ± 5% relative humidity (RH). The referee minimum storage time is 16 hours. Shorter times may be used if they can be shown to yield equivalent test results.

If electronic equipment, as listed in 4.2, is used, it shall be turned on at least one half hour before use to allow warm-up and stabilization. The automatic frequency counter listed in 4.2 is provided with temperature control of the clock crystal that operates even when the power switch is off. Care should
be taken to assure that power is continuously supplied to this unit to avoid a longer warm-up time. Other equipment using vacuum tube devices will require a longer warm-up time as specified in the manufacturer’s literature.

The temperature of the test fixture shall be in the range of 22°C to 24°C, unless otherwise specified. If this standard temperature is to be used and the temperature of the fixture is to be controlled by the ambient conditions in the testing laboratory, then the laboratory shall be maintained at 22°C to 24°C and the fixture shall be stored in the laboratory for at least 24 hours prior to use.

If non-standard temperature is specified and the fixture of 4.1 is used with the temperature control apparatus described in 4.2, then the rest of this paragraph applies. Prior to making electrical measurements, the circulator is started and adjusted to within 1°C of the desired test temperature. The time required for stabilization depends on the specific temperature control apparatus in use, the size of the circulation bath tank, and the temperature selected. Additional stabilization time will be required for each specimen to come to the set temperature after it has been clamped in the fixture.

The test fixture containing the test specimens shall be placed in the clamping fixture and the specified force of 4.45 ± 0.22 kN is applied through the calibrated force gauge to the 1290 mm² area centered directly over the resonant circuit as shown in the assembly of Figure 12, Figure 13, or Figure 15.

6.2 Manual Measurement of the Specimen  The following procedure is applicable where equipment as described in 4.1 is available. The equipment of 4.2 could also be operated manually. The stripline resonator formed by the fixture pattern card and ground planes with the specimen cards inserted is referred to as a cavity. The sweep oscillator is referred to here as the sweeper.

6.2.1 Determination of Cavity Resonant Frequency  The resonant frequency of the circuit shall be found by scanning the sweeper over the expected transmission range of the test resonator. The sweeper shall be precisely adjusted to the frequency that produces a maximum reading of the SWR Meter No. 1. The frequency meter shall then be adjusted for a minimum reading of the SWR Meter No. 2. Record the resonant frequency. The input selector of the SWR Meter No. 1 should be set for low impedance input for proper square law detection.

6.2.2 Determination of Cavity Half-Power Points  With the incident signal having been set to maximum resonator transmission, adjust the gain of the SWR Meter No. 1 until the meter reads 0 dB. The frequency of the sweeper shall then be adjusted to give 3 dB readings both above and below the maximum transmission frequency. Measure each frequency with the frequency meter and record the results:
- f1: above the maximum transmission frequency
- f2: below the maximum transmission frequency

6.3 Automated Measurement of the Specimen  For an automated system to be used in performing the measurement, computer software is needed that will collect paired values of frequency and transmitted power. From this data, the frequency for maximum power transmission and the frequencies of the half power points are determined. The computer program may optionally include computation of permittivity and loss tangent as described in 7.0. Results and collected data may be displayed on the screen, stored in a disk file, sent to a printer, or any combination of these.

In one possible mode of operation with the equipment described in 4.2, the following sequence of steps is performed as many times as necessary to get enough data to complete the test procedure. The computer is designated as the controller on the GPIB.

6.3.1 The computer sets the sweeper to a selected carrier wave frequency without an AM or FM audio signal to a desired output power level, such as 10 dBm.

6.3.2 The same frequency is given to the synchronizer with instructions to lock the frequency of the sweeper to the specified value.

6.3.3 The computer checks the synchronizer for status until the status value drops to zero, indicating the frequency is locked.

6.3.4 The power meter reading is obtained by the computer. Since it takes a finite amount of time for the power sensor to stabilize, either a delay is used or the reading may be taken repeatedly until consecutive readings meet a given requirement for stability.

6.4 Use of the Network Analyzer for Measurement of the Specimen  An automated network analyzer may be used either by operating the front panel controls manually or under computer control with suitable specialized software. The fixture with the specimen is connected by test cables and adapters as a device under test. Set up the instrument so the
Cartesian screen display shows the S21 parameter and the transmission/incident power ratio in negative dB vertical scale units versus frequency on the horizontal scale. Select the start and stop frequency range to sweep across the resonance peak and at least 3 dB below the peak. Adjust the start and stop frequency values as narrowly as possible, but still include the resonant peak and the portions of the response curve on both sides of it that extend downward 3 dB.

6.4.1 The first option is to get the three points \( f_r, f_1, \) and \( f_2 \) as described in 6.2 and 6.3. Determine the resonant dB, and frequency \( f_r \) values for the highest point (maximum) on the response curve. With manual operation, instrument program features are available to do this very quickly. On the response curve to the left and right of \( f_r \), locate the \( f_1, dB_1 \) and \( f_2, dB_2 \) points as near as possible to 3 dB below \( dB_r \). These may then be used in the calculations shown in 7.2.

6.4.2 A second option requires a computer external to the instrument. Collect from the network analyzer all of the \( f, dB \) data points represented by the response curve between \( f_1, dB_1 \) and \( f_2, dB_2 \) and apply non-linear regression analysis techniques to statistically determine values for \( Q, f_r, \) and \( dB_r \) that best fit the \( F_i, dB_i \) paired data points to the formula.

\[
dB_i = dB_r - A \log_e \left( 1 + 4Q^2 \left( \frac{f_i}{f_r} - 1 \right)^2 \right)
\]

where

\[
A = 10 \log_{10} (10) = \text{constant for converting from } \log_e \text{ to } dB
\]

This formula may be derived from combining equation 4 and equation 6 as corrected in 7.2, with the reasonable assumption that \( f_r - f_1 \) equals \( f_2 - f_r \). The statistically derived values for \( f_r \) and \( Q \) would then be used in equation 2 of 7.1 and equation 4 of 7.2 respectively.

This has been found to fit the collected data points very well at all regions across the entire \( f_1 \) to \( f_2 \) range. It is a simplified version of the non-linear regression method for complex S21 parameters.

7.0 Calculations

7.1 Stripline Permittivity At resonance, the electrical length of the resonator circuit is an integral number of half wavelengths. The effective stripline permittivity, \( \varepsilon_r \), can be calculated from the frequency of maximum transmission as follows:

\[
\varepsilon_r = \left( \frac{nC}{(2f_1(L + \Delta L))} \right)^2
\]

Where \( n \) is the number of half wavelengths along the resonant strip of length \( L \), \( \Delta L \) is the total effective increase in length of the resonant strip due to the fringing field at the ends of the resonant strip, \( C \) (the speed of light) is \( 3.000 \times 10^{11} \text{ mm/s} \), and \( f_r \) is the measured resonant (maximum transmission) frequency.

The more exact value for \( C \) of \( 2.9978 \times 10^{11} \text{ mm/s} \) would give a lower permittivity value, differing for example by 0.003 for 2.5 permittivity material. This method does not use the more exact value to avoid confusion with specifications for materials and proven component designs based on older versions of this method where \( 3.000 \times 10^{11} \) has been in use.

For example, for a specified 38.1 mm long resonator, the parameters at X-band are \( n = 4 \), \( L = 38.1 \text{ mm} \). For a given material with \( \Delta L = 1.397 \text{ mm} \), the formula for \( \varepsilon_r \) becomes:

\[
\varepsilon_r = 2.30764 \times 10^{20} / f_r^2
\]

7.1.1 Determination of \( L \) \( \Delta L \), a correction for the fringing capacitance at the ends of the resonator element, is affected by the value of the ground plane spacing and the degree of anisotropy of permittivity of the material being tested. The degree of anisotropy is affected by the amount and orientation of fiber and the difference between permittivity of fiber and matrix polymer. Because of this, a \( \Delta L \) value for use with a particular type of material must be determined experimentally by the following procedure.

7.1.1.1 Prepare a series of resonator circuit cards having patterns in which only the resonator element length is varied to provide \( n \) values of 1, 2, 3, and 4 at close to the same frequency. For example, lengths of 9.5 mm, 19.0 mm, 28.6 mm, and 38.1 mm may be used.

7.1.1.2 For each of at least three sets of typical specimen pairs of the material to be measured, measurements of \( f_r \) are obtained at each \( L \) value. Plot \( L f_r/n \) on the Y axis versus \( f_r/n \) on the X axis or preferably use a numeric linear regression analysis procedure to determine the slope of the least squares fit through the four data points. The slope is equal to the negative value of \( \Delta L \).

7.1.1.3 The \( \Delta L \) values for each of the specimen pairs may then be averaged to provide a suitable working \( \Delta L \) value. For a given material type, a \( \Delta L \) value should be agreed upon as standard for testing to a specification.

7.1.2 Determination of Effect of Specimen Thickness on \( L \) The \( \Delta L \) correction for end fringing capacitance will vary
with specimen thickness, increasing as specimen thickness increases. Ignoring this effect by use of a fixed $\Delta L$ value for calculating test results will bias the permittivity values upward for thicker specimens, downward for thinner ones. For low permittivity materials where the resonator is longer, this bias is quite small and only of interest for close tolerance applications. For high permittivity materials, the smaller resonator length makes this correction more important.

There are two ways in which this thickness effect may be handled: by an empirical determination of $\Delta L$ for various thicknesses or by assuming a proportionality to the published prediction of $\Delta L^{(4)}$.

### 7.1.2.1 For the empirical method, use the 7.1.1 procedure to obtain $\Delta L$ with specimens at extremes of thickness variation expected in day to day testing. Use numerical linear regression of the collected $\Delta L$-specimen thickness data pairs to derive a linear formula of the form

$$\Delta L = B_0 + B_1 \times \text{thickness}$$

Specification values for $B_0$ and $B_1$ for a given material must be agreed upon for a particular material type.

### 7.1.2.2 A $\Delta L$ correction factor can be derived for a given material type in a range of permittivity values by determining for specimens of known thickness the ratio of $\Delta L$ derived according to 7.1.1 to that predicted by equation 3 when $R=1$. An average of ratios so determined must be agreed upon as the specified correction factor for the formula. From this, $\Delta L$ is calculated by:

$$\Delta L = R \frac{(K^2 + 2KW)}{(2K + W)}$$

where

- $R$ = the average ratio of observed to predicted $\Delta L$
- $K = B \log_2(2) / \pi$
  = 0.2206356 $B$
- $W$ = width of resonator in mm
- $B = 2$ (specimen thickness) $+$ (test pattern card thickness)
  = total ground plane spacing in mm

### 7.2 Calculation of Effective Dielectric Loss Tangent

A value for loss tangent for the dielectric is obtained by subtracting the appropriate conductor loss value, $1/Q_c$, in Table 1 from the total loss value, $1/Q$, as shown

$$\tan \delta = \frac{1}{Q} - \frac{1}{Q_c} \quad [4]$$

or

$$\tan \delta = \frac{f_2 - f_1}{f_r} - \frac{1}{Q_c} \quad [5]$$

where

- $1/Q$ or $f_2 - f_1$ $f_r$ is the total loss due to the dielectric, copper, and copper-dielectric interface.

A more exact calculation can be used that does not require that the values of $f_1$ and $f_2$ be at exactly half the power level of the maximum at resonance. This is especially suited for automated testing. The formula is

$$\tan \delta = \left( 1 - \left( \frac{f_1}{f_r} \right) \right) \left( 10^{\frac{\alpha_c C}{\pi f \varepsilon_{r0.5}}} - 1 \right)^{0.5} +$$

$$\left( \frac{f_2}{f_r} \right) \left( 10^{\frac{\alpha_c C}{\pi f \varepsilon_{r0.5}}} - 1 \right)^{0.5} - \frac{1}{Q_c} \quad [6]$$

d$B_1$ is the dB below the peak power level at $f_1$

and
d$B_2$ is the dB below the peak power level at $f_2$

### 7.2.1 Calculation of $1/Q_c$

The following calculation scheme is used$^{(1)}$

$$1/Q_c = \frac{\alpha_c C}{(\pi f \varepsilon_{r0.5})} \quad [7]$$

where

- $\alpha_c = 4 R_s \varepsilon_r Z_o Y / (377^2 B)$
  = attenuation constant, nepers/mm
- $R_s = 0.00825 f^{0.5}$ = surface resistivity of copper, Ohm
- $Z_o = 377/(4 \varepsilon_{r0.5} (C_i + (W/(B - T)))$)
  = characteristic impedance of resonator, Ohm
- $377 = 120 \pi$, = free space impedance, Ohm
- $C_i = (2 \log_2(X+1)-(X-1))log_2(X^2-1)/ \pi$
- $Y = X + 2 W X^2 / B$
- $X = B / (B - T)$
- $\varepsilon_r = \text{nominal permittivity}$
- $B = \text{ground plane spacing, mm}$
- $C = 299.796 \text{mm/ns} = \text{speed of light}$
- $f = \text{nominal resonant frequency, GHz}$
NOTE: GHz is equivalent to cycles/ns to keep units consistent in this section 7.2.1.

\[ W = \text{resonator width, mm} \]
\[ T = \text{resonator conductor thickness, mm} \]

Where combinations of resonant frequency, resonator width, ground plane spacing, and nominal permittivity are encountered other than those listed in Table 1, a calculated \( 1/Q_c \) must be agreed upon. Data is not currently available for correcting this calculated value to account for increased conductor loss due to surface treatments or type of copper foil used.

7.2.2 Corrections to the Loss Factor

Corrections in the total loss value, \( 1/Q \), may be needed for materials of high anisotropy of \( \varepsilon_r \) as mentioned in 1.2.2. The \( Q \) actually measured is \( Q_{\text{loaded}} \), but is often assumed to be \( Q_{\text{unloaded}} \). The probe gap given in Table 1 is intended to provide insertion loss at a resonance high enough to make \( Q_{\text{loaded}} \) approximately equivalent to \( Q_{\text{unloaded}} \).

When materials with high anisotropy of permittivity are measured, probe coupling is affected and the insertion loss becomes small, making a correction useful before applying the above calculations. Insertion loss is determined by comparing transmitted power at resonant frequency of the fixture and specimen with the resonator pattern card and with a similar card having a straight through 50 Ohm line. The dB, difference as dB, is related to the power ratio by

\[ \frac{P_2}{P_1} = e^{[10 \text{ log}(10) \text{ dB}_2 / 10]} \]

and the unloaded \( Q \) is determined from the measured \( Q \) by

\[ Q_{\text{unloaded}} = \frac{Q_{\text{loaded}}}{[1-\sqrt{P_2/P_1}]} \]

The following values illustrate this relationship:

\[
\begin{array}{cccccccc}
\text{dBr} & 60 & 50 & 40 & 30 & 20 & 15 & 10 & 5 \\
Q_{\text{unloaded}} & 1.00 & 1.00 & 1.01 & 1.03 & 1.11 & 1.22 & 1.46 & 2.28 \\
Q_{\text{loaded}} & & & & & & & &
\end{array}
\]

8.0 Report

The report shall contain the following:

- The measured length of the resonator and \( \Delta L \) value.
- The measured thickness of specimen stacks.
- The maximum transmission (resonant) frequency, \( f_r \).
- If the three point method of 6.2, 6.3 or 6.4.1 is used, report the frequencies of the two 3 dB points on the resonance curve or the frequency and actual dB value of the two points.

- If the non-linear regression (NLR) method of 6.4.2 is used, then optionally report the number of data points used, NLR uncertainty values for \( f_r, Q_{\text{loaded}}, \text{dB} \),
- The calculated effective stripline permittivity.
- The calculated effective dielectric loss tangent.
- If the test was not done in the X or machine direction, give the direction in which test was performed. That is, orientation of the resonator with respect to the X or Y axis of the specimen.
- The temperature of the test fixture during the test.
- The grade of copper foil used in the test pattern card.

9.0 Notes

9.1 Permittivity

The dielectric of a stripline circuit affects the electrical response of all the circuits printed on it. Velocity of propagation, wavelength, and characteristic impedance all vary with permittivity. If the permittivity varies from the design value, the performance of such circuits is degraded.

Throughout this document, the term “permittivity” refers to relative permittivity of the dielectric material, a dimensionless ratio of the absolute permittivity of the material to that of a vacuum.

9.2 Loss Tangent

The attenuation and Q (figure of merit) of stripline circuits are a function of combined copper and dielectric loss. An excessively high loss tangent leads to loss in signal strength and to degraded performance of frequency selective circuits such as filters. In this method, a great saving in time and cost of testing is achieved by using a permanent stripline resonator, which is part of the test fixture. With this fixture, variations in loss tangent due to the dielectric can be monitored but not the additional loss due to the type of metal and bonding treatment used in laminating.

9.3 Measurements at Other Frequency Bands

The test equipment of 4.1 can be modified for L, S, and C band measurements at some additional cost. The test equipment of 4.2 will be able as is to handle other bands.

9.4 Frequency Ranges

Accepted frequency ranges for the various bands are:
L 1.12 1.70 GHz
S 2.60 3.90 GHz
C 3.95 5.85 GHz
X 8.00 12.40 GHz

9.5 Other Metal-Clad Dielectrics This method can be adapted for measurements of other metal-clad dielectric materials. \( \Delta L \) must be determined for each new material. Materials that are not somewhat compliant may yield significant errors due to air gaps resulting from the conductor thickness of the resonator.

9.6 Anisotropic Materials For anisotropic materials, test methods in which the electric field is not imposed on the dielectric in a stripline configuration can give misleading values of effective stripline permittivity and loss tangent. This test method measures an effective stripline permittivity.

9.7 High Permittivity Soft Substrates Soft substrates consisting of PTFE highly filled with ceramic filler require additional steps in the preparation of resonator pattern cards to embed the conductor pattern into the substrate so that thickness of the card is uniform and the same in both the pattern and non-pattern areas.

The following embedding procedure is needed when the resonator pattern card has copper foil cladding of IPC-MF-150, designation 1. If the weight of the foil is reduced to Q (0.010 mm), as recommended in 4.2.5 and mentioned in 5.1, then the embedding procedure is not needed and consistency of fixture performance with pattern card replacements is improved. It appears that a soft substrate specimen is able to accommodate the thinner pattern without excessive stress concentration and bias in permittivity value.

When this preparative step is omitted or inadequately done for designation 1 copper, it has been observed that for a given resonator pattern card in the fixture, there will be a bias in the permittivity value observed. For a specimen held in the fixture for a period of time, there will be an initial high bias that drifts downward over a period of several hours. When removed, the specimen will have an embossed image of the resonator pattern. When repeated testing is done among several specimens with comparatively short clamp times of one or two minutes before reading resonant frequency, the bias is initially high and then decreases with frequency of test runs. This drift in performance is observable when reference specimens are repeatedly tested.

This drifting bias is believed to be due to the concentration of the clamp force to the smaller resonator area used for these materials combined with their higher degree of conformance. Initially, the clamping excessively compresses material on both sides of the resonator element raising its permittivity. With time, the material in both pattern card and specimen conforms by deformation flow away from the high stress area so that the bias decreases.

Use a card with embedded pattern leads to distribute stress more evenly over the specimen for little or no drift in bias. Embedding is done by clamping the pattern card between stainless steel or aluminum foil release layers between accurately planar metal blocks at about 0.69 to 1.38 MPa, while heating the blocks above the polymer melt point long enough to allow permanent conformance followed by cooling and declamping.

10.0 References
Figure 1  X-Band Permittivity Test Setup

SWEEP OSCILLATOR
HP 8350B OR HP 8620A
RF PLUG-IN
HP 83545A OR HP 86251A

DIRECTIONAL COUPLER
HP 779D

FREQUENCY METER
HP X532B

CRYSTAL DETECTOR
HP 423B

SWR METER NO. 2
HP 415E

TEST FIXTURE

10 dB ATTENUATOR
HP 8491B

CRYSTAL DETECTOR
HP 423B

MATCHED LOAD RESISTOR
HP 11523A

SWR METER NO. 1
HP 415E
Figure 2  Automated Permittivity Test Setup
Figure 3  Simplified Automated Permittivity Test Setup

Figure 3A  Automated Network Analyzer for Permittivity Test Setup
Figure 4  Generalized Resonator Pattern Card Showing Dimensions of Table 1 and Made of Laminate Matching the Nominal Permittivity of Material to be Tested

Figure 5  Base Stripline Board with Copper Foil and Dielectric Matching the Nominal Permittivity of the Material to be Tested
3.4 diameter holes, 4 places, use base plate as template

Machine 0.025 less than minimum thickness specimen
11.1 area left clad with foil
12.7 area left unmachined

Nominal thickness of specimens

Figure 6 Base Cover Board with Copper Foil Ground Plane

Supplied unit has holes drilled and tapped for #1-72 screws.

Note: Replace the #1-72 flat head screws supplied with the launcher with #1-72 cap screws cut to a length of 6.35 mm plus specimen nominal thickness. Use these to fasten the launcher body (2 required) between the base plates.

Figure 7 Detail of the Supplied Launcher Body, Omni-Spectra Part No. 2070-5068-02 or Equivalent
Drill through for #1 screw (1.86 mm), 4 places
Drill through for #5 screw (3.18 mm), 4 places

Note: Base plates 1 and 2 differ in dimension "A" to accommodate the fact that the stripline trace on one side of the pattern card is not centered between the ground planes.

Specimen nominal thickness 1.27 1.57
Dimension "A" for base plate 1 1.57 1.27
Dimension "A" for base plate 2 1.88 1.57

Figure 8  Brass or Aluminum Base Plate for Clamping the Base Cards and Connecting Launcher Bodies to the Base Card
Figure 9  Aluminum Clamping Plate Provided with Tapped Holes for the Pressure Block and a Thermocouple Well

Drill and tap blind hole for #5–40 screw, 2 places
1.59 diameter thermocouple well, 25.4 deep

3.18
6.35
17.5
33.3
50.8
13.7
34.3
54.9
68.6
Figure 10  Slider and Block for Connecting Pressure Block and Base Plate with Allowance for Opening the Fixture

When the slider is placed inside the block and fastened to the bottom of the clamp block, it should allow total movement of 0.25 mm vertically, 0.5 mm sideways and 2.5 mm along the slider length.
Figure 11  Aluminum Block for Temperature Control and Transfer of Pressure to the Clamp Plates, Fitted with Tapped Holes for Slide, Embedded Steel Ball, and Tapped for Tubing Fittings for Circulating Fluid
Figure 12  Face View of Fixture Assembly
Figure 13 Exploded Side View of Assembly
Figure 14  Enlarged Exploded Side View Sectioned Through a Probe Line Showing a Lap Conductor Joint
Figure 15  Test Fixture Construction, Older Design
Figure 16  Test Fixture Construction, Older Design (Continued)
Figure 17  Test Fixture Construction, Older Design (Continued)
1.0 Scope

1.1 Summary This method is for measurement of relative permittivity ($\varepsilon_r$) and dissipation factor or loss tangent ($\tan \delta$) of circuit board substrates under stripline conditions. Measurements are made by measuring resonances of a length of stripline over a wide frequency range from below 1 GHz to about 14 GHz. The method permits a wide variety of specimen configurations, varying in dielectric thickness, width of center conductor, and use of clad or laid up conductor foil. Sensitivity to differences in $\tan \delta$ are enhanced by the ability to adjust the degree of coupling to the resonator by adjusting an air gap between probes and the resonator ends. Many of the principles used in IPC-TM-650, Method 2.5.5.5, are applied in this method.

1.2 Terminology Terms used in this method include:

Complex Relative Permittivity—The values for relative permittivity and dissipation factor considered as a complex number.

Permittivity—Dielectric constant (see IPC-T-50) or relative permittivity. The symbol used in this document is $\varepsilon_r$. $K$ or $\kappa$ are also sometimes used.

Relative Permittivity—A dimensionless ratio of absolute permittivity of a dielectric to the absolute permittivity of a vacuum.

Loss Tangent—Dissipation factor (see IPC-T-50), dielectric loss tangent (see 9.2). The symbol used in this document is $\tan \delta$.

1.3 Limitations The limitations in described in 1.3.1 through 1.3.4 should be noted.

1.3.1 The measured effective permittivity for the resonator element can differ from that observed in an application. Where the application is in stripline and the line width to ground plane spacing is less than that of the resonator element in the test, the application will exhibit a greater component of the electric field in the X, Y plane. Heterogeneous dielectric composites are anisotropic to some degree, resulting in a higher observed $\varepsilon_r$ for narrower lines.

Microstrip lines in an application may also differ from the test in the fraction of substrate electric field component in the X, Y plane.

Bonded stripline assemblies have air excluded between boards and thus tend to show greater $\varepsilon_r$ values than would be obtained with this method using specimen types A or, to lesser extent, B, as discussed in 3.0.

1.3.2 As with IPC-TM-650, Method 2.5.5.5, with specimen type A, or, to a lesser extent, with B (see 3.0), we expect the method to show a downward bias in measured $\varepsilon_r$. This is caused by the electric field crossing clamped dielectric-conductor interfaces with air included in the surface roughness.

1.3.3 With specimen type B, C, or D, the method shows an upward bias in measured $\tan \delta$. This is caused by the surface roughness and/or surface treatment of the clad copper foil required for adequate adhesion to the dielectric.

1.3.4 Compared to IPC-TM-650, Method 2.5.5.5, both done with computer automated data collection, this method requires a greater degree of operator skill and more time to prepare specimens and perform measurements.

1.4 Advantages

1.4.1 The sensitivity of the method to differences in $\varepsilon_r$ of specimens should be superior to that of IPC-TM-650, Method 2.5.5.5 since the specimen comprises all of the dielectric affecting the measurement.

1.4.2 The method is known to be more sensitive to differences in $\tan \delta$ than IPC-TM-650, Method 2.5.5.5. We believe the ability to adjust the degree of probe-to-resonator coupling to a low enough value that $Q_{\text{loaded}}$ is close to $Q_{\text{unloaded}}$ (see 7.2.2) makes this possible.

1.4.3 The method is expected to lend itself to use of stable referee specimens of known electric properties traceable to NIST (National Institute of Standards and Technology).

2.0 Applicable Documents

IPC-MF-150 Metal Foil for Printed Wiring Applications

IPC-TM-650 Method 2.5.5.5, Stripline Test for Permittivity and Loss Tangent (Dielectric Constant and Dissipation Factor) at X-Band
3.0 Test Specimen  Specimen length corresponds to an available fixture length \( L \). Longer \( L \) values enable lower minimum resonant frequencies to be achieved. \( L \) is also the length dimension of the copper plates described in 5.0. Four types of specimens can be used for this method, as shown in Figure 1.

3.1 Type A  Two 25.4 mm wide by \( L \) long cards etched free of copper cladding. These are placed on either side of a center strip of smooth copper foil of specified thickness and width and will be assembled between 25.4 mm wide by \( L \) long copper foil cards.

3.2 Type B  One 25.4 mm wide by \( L \) long card with clad copper on one side and copper etched off the other side, and a second card of matching size with clad copper on one side and copper etched off the other side except for a centered strip of specified width extending to both ends of the card. The copper free surface of the first card is assembled against the etched strip of the other to form the stripline resonator.

3.3 Type C  Two 25.4 mm wide by \( L \) long cards with clad copper on one side and copper etched off the other side except for a centered strip of specified width extending to both ends of the card. The etched strip surfaces of both cards face together to form the stripline resonator.

3.4 Type D  Oversize cards similar to type B are bonded together with a selected bonding film and then trimmed to size to form the stripline resonator assembly. For types B, C, and D, the specimen card should first be prepared with about 5 mm or more excess length. Wide pressure sensitive adhesive (PSA) tape can be used to mask the ground plane side, and a narrow PSA tape can be used to mask for the centered strip before etching off exposed copper. Trimming the excess length after etching removes any undercut areas at the ends. Trimming to length should be done in a way that leaves the end surfaces with sharp edges and no conductor edge distortion or smears over that surface. Sanding specimens clamped between paper-phenolic laminate drill-entry boards is an advised method for finishing the end surfaces.

Type A specimens with untreated smooth copper foil will provide the most accurate values for \( \tan \delta \), but will tend to have a low bias on \( \varepsilon_r \). Type C eliminates all clamped interfaces with the air layer between the dielectric and the conductor to give the most accurate \( \varepsilon_r \) value but, with the copper surfaces treated for adhesion, tends to have a high bias on dissipation factor. Type D gives a good measure of practical performance in an application.

4.0 Suggested Electronic Apparatus  The principal components required for the test setup consist of the test fixture described in 5.0 combined with the components described in 4.1, Figure 2, Type A and Type B, or preferably with the system in 4.2, Figure 2, Type C.

4.1 A Test Setup for Computer Automation of Data  This requires a microwave signal source, an accurate means of measuring the signal frequency, an accurate means for detecting power level, and an accurate method of determining frequency values above and below the resonant frequency at the half-power level for the test fixture loaded with the specimen.

4.1.1 The following components or equivalent, properly interconnected, can be used most effectively with a computer control program for automated testing:

- Sweep Frequency Generator Mainframe HP8350B
- RF Plug-In, 0.01 to 20 GHz HP83592A
- Power Splitter HP11667A
- Automatic Frequency Counter HP5343A
- Source Synchronizer HP5344A
  Obtained as an interconnected assembly with the counter.
- Coaxial cables and adapters
• 10 dB Attenuator HP8491B
• Programmable Power Meter HP436A
• Power Sensor HP8484A with 70 to 10 dBm range
• IEEE 488 (GPIB) cables
• Controlling computer with GPIB interface

The above equipment is connected as explained in 4.1.1.1 through 4.1.1.3, and as illustrated in Figure 2, Type A.

4.1.1.1 RF Connections The power splitter connects directly to the RF plug-in output. One output of the splitter connects by RF cable to the counter input. The other output is connected by RF cable to the attenuator which connects to one of the test fixture probe lines.

4.1.1.2 Control Connections Connections between counter and synchronizer are provided as specified by the manufacturer. The RF output from the synchronizer connects by BNC to the FM input on the sweeper. GPIB cables connect in parallel to the sweeper, synchronizer, power meter, and computer interface.

4.1.1.3 Other Connections The power sensor is connected to the other probe of the fixture, and its special cable connects into the power meter.

4.1.2 The microwave signal source must be capable of providing an accurate signal. During the required time period and range of frequency needed to make a permittivity and loss tangent measurement, the source must provide a leveled power output that falls within a 0.1 dB range. When the source is set for a particular frequency, the output must be capable of remaining within 5 MHz of the set value for the time required to make a measurement.

The means for measuring frequency shall have a resolution of 0.05% or less and an accuracy of 0.08% or less. An error of +8 MHz in measurement of a resonant frequency near 10 GHz for a material with nominal permittivity of 2.50 represents a -0.004 error in permittivity.

The means for detecting the power level shall have a resolution of 0.1 dB or less and be capable of comparing power levels within a 3 dB range with an accuracy of 0.1 dB. An error of 0.1 dB in estimating half power frequency points can result in an error in the loss tangent of about 0.0001 for a material with 2.5 permittivity. See equation 5 in 7.2.

4.1.3 A synthesized CW generator can be used to replace the sweeper, plug-in, power splitter, connector, and source synchronizer for the simpler set-up shown in Figure 2, Type B.

4.2 Automated Network Analyzer for the Test Setup The instrumentation described in 4.1 may be replaced with either a scalar or vector network analyzer, with test cables connected to the test fixture of 5.0 as the device under test (DUT), as shown in Figure 2, Type A. Examples of automated network analyzers known to be suitable include the Hewlett-Packard 8510 vector network analyzer or the Wiltron Model 561 scalar network analyzer. These or equivalent may be used.
Such instruments may be operated either manually or under computer control with suitable programming to locate the resonant frequency and the frequencies above and below resonance where transmitted power is 3 dB below that at resonance. Network analyzers have several advantages over the instrumentation described in 4.1. Data collection is rapid and may be continuously refreshed with averaging. The log magnitude response curve for ratio of transmitted to incident power (the S21 parameter) as dB versus frequency is visible on a screen for easy verification of a valid resonance. A large number of dB, frequency data points near the resonance, are readily available for optional use of non-linear regression analysis techniques to determine the frequency and Q values with statistically better degrees of uncertainty than those attainable by the three point (f1, f2, and f3) method in either section 6.2 or 6.3.

5.0 Test Fixture

5.1 Fixture Parts for Clamping  

L is the selected length for the specimen. A fixture may include hardware for more than one value of L. Suggested L values are 50.8, 76.2, 152.4, and 304.8 mm. Since the fundamental resonant frequency and its harmonics are inversely proportional to the value of L for a given εr, the selection of an L value determines the low frequency at which the material may be measured for εr and tan δ. Figure 1 shows the end views of a series of specimen configurations and includes the parts for clamping.

5.1.1 For each L value, two ground tool steel clamping bars 25.4 mm x 28.58 mm x (L-6.35), as shown in Figure 3. These are intended to provide uniformly distributed force along the length of the specimen, transferred through part 5.1.2. A recommended practice is to provide these with a small diameter threaded rod, such as #4-40, centered on each end and extending about 20 mm to serve as a means for attaching the probe assembly of 5.2 used in 6.1.5 or the alignment jig of 5.1.3 used in 6.1.1.

5.1.2 For each L value, two pure copper ground plates 25.4 mm x 9.52 mm x L with all edges sharp as in Figure 4. These provide at the ends a copper surface perpendicular to the specimen length direction, which serves as a contact area over a range of specimen thicknesses for making ground continuity to the coaxial probe. When these are clamped with 5.1.1 as described in 6.1.1, the inside corners at each end between the outer face of 5.1.2 and the end surface of 5.1.1 form reference locations equidistant from the center line of the stripline resonator element that are used by the probe assembly 5.2 to align the coaxial probe with that center line.

5.1.3 A stacking alignment jig as used in 6.1.1 of an appropriate design. Figure 5 shows a suggested design.

5.1.4 A low profile mechanical force gage with 4.45 kN compression capacity such as a Dillon Model U, PN 30482-0053, available from Dillon Quality Plus, Inc., 1140-T Avenida Acaso, Camarillo, CA 993012. One is needed for each of part 5.1.5.

5.1.5 A clamping arrangement with 5.1.4 properly mounted in the line of force and with alignment parts for assuring the line of force is properly located through the stack assembled
according to 6.1.2. This can be a manually adjustable mechanical screw fixture such as a vise, clamp, or a pneumatic cylinder fixture with a pressure regulator. One of component 5.1.5 with 5.1.4 is needed for every 152 mm of specimen length L. See Figure 6.

5.2 Probe Assembly  Two probe assemblies are needed; one for each end of the clamped stack. They can be designed to be attached to the ends of the clamp bars 5.1.1. The following items are needed for each assembly.

5.2.1 Semi rigid coaxial cable 1.8 mm size about 230 mm long with 3 mm connector and adapters to the electronic instrumentation. The probe end of the cable has the center conductor extending 1.8 mm.

5.2.2 Copper fitting with reversed bevel soldered to the end of the coaxial cable jacket, as shown in Figure 7.

5.2.3 A means for effecting ground contact between 5.2.2 and both of 5.1.2. Figure 8 shows a suggested beryllium-copper alloy wire part. Two are required, as shown in the sectional views of Figure 9.

5.2.4 Mechanical assembly capable of attaching to the ends of 5.1.1 and using the locations of the inside corners of 5.1.1 and 5.1.2 to align parts 5.2.1 through 5.2.3 with the center line of the stripline resonator. It must accommodate various specimen thicknesses, provide alignment of 5.2.1 through 5.2.3, make contact pressure of 5.2.3 to 5.1.2, provide controlled adjustment of the gap between specimen end and 5.2.1, and provide support for the coaxial cable connector to the instrumentation.

A wide variety of hardware designs for accomplishing the alignment required in 6.1.5 are acceptable if the following conditions are met for each of the two probes:

---

Figure 5  Five Assembly Views for a Suggested Two Member Stacking Alignment Jig (See 5.1.3)

Note: Only the right-handed member is shown. Part A with 3.175 mm deep recessed area on the face towards the clamp blocks assures 6.1.1 items b, c, and d. Its notched out area allows 6.1.1 item 5. Part B assures 6.1.1, item a. Part C eases mounting the jig member to the end of the lower steel bar (see 5.1.1). Knurled #4-40 nut D, retained by E, fastens A against the steel bar with its extended threaded rod. Part F assists in meeting 6.1.1, item e.
The center line of the coaxial cable end and the centerline of the stripline resonator in the specimen are aligned within a tolerance of 0.2 mm vertically and horizontally.

Both parts 5.2.3 (Figure 8) are held aligned so they are centered in a vertical plane through the probe axis, each making firm electrical contact to 5.2.2 (Figure 7) and to the end edge surface of part 5.1.2 (Figure 4).

The coaxial probe end longitudinal position is adjustable so that the gap between it and the specimen center conductor is controllable to a tolerance of ± 0.03 mm.

### 6.0 Measuring Procedure

#### 6.1 Preparation for Testing

The actual length of the specimen and resonator element shall be determined by a vernier caliper or other means capable of accuracy to ± 0.03 mm or smaller.

Unless otherwise specified, specimens shall be stored before testing at 18°C to 24°C and 50% ± 5% relative humidity. The referee minimum storage time is 16 hours. Shorter times may be used if they can be shown to yield equivalent test results.

If electronic equipment as listed in 4.1 is used, it shall be turned on at least one half hour before use to allow warm-up and stabilization. The automatic frequency counter listed in 4.1 is provided with temperature control of the clock crystal that operates even when the power switch is off. Care should be taken to assure that power is continuously supplied to this unit to avoid a longer warm-up time. Other equipment using vacuum tube devices will require a longer warm-up time, as specified in the manufacturer’s literature.
This method is best suited for measurements at ambient temperatures in a controlled laboratory atmosphere. It may be possible to adapt it for measurements at other temperatures.

6.1.1 The steel clamping bars, copper clamping plates, and the specimen assembly with copper foil are stacked with the help of a jig (Figure 5) to assure the following:

a) One side surface or edge of each steel bar, copper plate, specimen card, and ground plane copper foil lie in a common plane.

b) The end surfaces of the steel bars lie in a common plane within a 0.1 mm tolerance.

c) The ends of the copper plates extend beyond the steel bars equally on both ends within a 0.1 mm tolerance.

d) The ends of copper plates, specimen cards, and copper foil ground planes lie in a vertical plane within a 0.1 mm tolerance.

e) In the case of specimen type A, the center conductor, whose length extends enough beyond both ends of the specimen cards to be gripped in tension and positioned, is centered across the width of the specimen cards.

6.1.2 The stack formed in 6.1.1 is clamped with a specified total force. For a selected specimen length of 153 mm or less, the force is applied through a force gage in a line centered on the outer faces of the steel bars. For greater lengths, the force should be distributed through force gages at two or more positions not further than 153 mm apart along the length to get uniformity of force per unit length along the specimen length with minimal deflection of the steel bars. Thus, for a 304.8 mm length, apply equal forces at the 76.2 mm and 228.6 mm positions. If a 381 mm was used, apply force at the 63.5 mm, 190.5 mm, and 317.5 mm positions.

6.1.3 Remove the alignment jig used in 6.1.1.

6.1.4 For type A specimens, the center copper strip will still be extending beyond the plane formed by the surfaces of the copper plates, ground foil, and specimen end. This is clipped off cleanly flush with that plane. One preferred method for doing this is to use a lever-action toe nail clipper with a convex shaped cutting pattern modified by grinding so that the metal extending beyond the cutting edges is removed so that the cutting edges are able to reach to the specimen edge for cutting the copper strip.
An alternate method for trimming the copper strip is to use a sharp scalpel. However, this can smear the copper across that the specimen end surface, especially with thin specimens, and may introduce end fringing errors on short L values.

6.1.5 Fasten the probe assemblies to the clamped stack at both ends so that the coaxial cable probe end is centered on the stripline resonator center line. Adjust the assembly so the contact areas on the soldered copper fitting make firm electrical contact by the wires to both top and bottom copper plates. Figure 9 shows by vertical and horizontal sectional views through the stripline resonator centerline this relationship among:

- the copper ground plates (see 5.1.2).
- the specimen with conductors (see 3.0).
- the coaxial cable with extended center conductor end (see 5.2.1).
- the copper fitting (see 5.2.2) soldered to the coaxial cable.
- the wire connection (see 5.2.3).

For the purpose of this method horizontal orientation is parallel to the plane of the specimen surface in the fixture. See three requirements under 5.2.4.

6.1.6 Adjust the position of the coaxial cable probe ends so the air gaps they form with the stripline resonator element are equal. This may be done with the help of a network analyzer set for lowest frequency by adjusting the gaps smaller until each causes a sudden shift in reflected or transmitted power, then adjusting them back to a small gap value, equal on both ends.

6.1.7 With the probe’s longitudinal position set to a small air gap such as 0.05 mm, use an appropriate means with the electronic instrumentation to identify the approximate location of the lowest resonant frequency (the fundamental where the resonator length is half the wavelength in the material being tested) and a series of resonances (harmonics) up to the highest frequency of interest. Ideally harmonic resonances occur at each integer multiple of the fundamental resonance. The integer multiples are the values of n in formula 1 of section 7.1. Select which of these resonances will be measured as discussed in section 6.3, 6.4, or 6.5.

6.2 Adjustment of Air Gap for Each Resonance Before the measurement at each resonance, adjust the air gaps at each probe an equal amount to get the dB insertion loss at the maximum transmission to a recommended value between 49.5 and 51.5 dB. As resonant frequency is increased from resonance to resonance for a given specimen, the gap required for a nominal 50 dB insertion loss at resonance tends to increase. A high value dB minimizes the correction for unloaded Q and makes this correction less sensitive to poor data on the baseline dB of the instrumentation. Too high a dB value will put the measurements down in the noise region of the instrumentation, making results less certain and less reproducible.

6.3 Manual Measurement of the Specimen The following procedure is most applicable where only equipment as described in 4.1 is available. The equipment of 4.2 could also be operated manually.

6.3.1 The resonant frequency shall be found by scanning frequency over the expected transmission range of the test resonator. The frequency shall be precisely adjusted to get a maximum reading of power in dB.

6.3.2 Determine half power points by adjusting frequency to give three dB readings both above and below the maximum transmission frequency. Measure each frequency with the frequency meter and record the results:

- f1 - 3 dB down, below the maximum transmission frequency.
- f2 - 3 dB down, above the maximum transmission frequency.

6.4 Automated Measurement of the Specimen For an automated system to be used in performing the measurement, computer software is needed that will collect paired values of frequency and transmitted power. From this data, the frequency for maximum power transmission and the frequencies of the half power points are determined. The computer program may optionally include computation of permittivity and loss tangent as described in section 7.0. Results and collected data may be displayed on the screen, stored in a disk file, sent to a printer, or any combination of these.

In one possible mode of operation, with the equipment described in 4.2, the sequence of steps described in 6.4.1 through 6.4.4 is performed as many times as necessary to get enough data to complete the test procedure. The computer is designated as the controller on the GPIB.
6.4.1 The computer sets the sweeper to a selected carrier wave frequency without an AM or FM audio signal and to a desired output power level, such as 10 dBm.

6.4.2 The same frequency is given to the synchronizer with instructions to lock the frequency of the sweeper to the specified value.

6.4.3 The computer checks the synchronizer for status until the status value indicates the frequency is locked.

6.4.4 The power meter reading is obtained by the computer. Since it takes a finite amount of time for the power sensor to stabilize, either a delay is used or the reading may be taken repeatedly until consecutive readings meet a given requirement for stability.

6.5 Use of the Network Analyzer for Measurement of the Specimen An automated network analyzer may be used either by operating the front panel controls manually or under computer control with suitable specialized software. The fixture with the specimen is connected by test cables and adapters as a device under test. Set up the instrument so the Cartesian screen display shows the S21 parameter, the transmission/incident power ratio, in negative dB vertical scale units versus frequency on the horizontal scale. Select the start and stop frequency range to sweep across the resonance peak and at least 3 dB below the peak. Adjust the start and stop frequency values as narrowly as possible, but still include the resonant peak and the portions of the response curve on both sides of it that extend 3 dB downward.

6.5.1 The first option is to get the three points (f_r, f_1 and f_2) as described in 6.3 or 6.4. Determine the resonant dB_r and frequency f_r values for the highest point (maximum) on the response curve. With manual operation, instrument program features may be available to do this very quickly. On the response curve to the left and right of f_r, locate the f_1, dB_1 and f_2, dB_2 points as near as possible to 3 dB below dB_r. These may then be used in the calculations shown in 7.2.

6.5.2 A second option requires a computer external to the instrument. Collect from the network analyzer all of the f, dB data points represented by the response curve between f_1, dB_1 and f_2, dB_2 and apply non-linear regression analysis techniques to determine statistically values for Q_loaded, f_r and dB_r that best fit the f_r, dB_r paired data points to the formula.

$$dB_r = dB, - 10 \log_{10}(10) \log_{10} \left(1 + 4 \frac{Q_{\text{loaded}}}{Q_c} (f_r / f_i - 1)^2\right)$$  \[1\]  

where 10 log_{10}(10) is the constant for converting from log_{10} to dB. This formula may be derived from formula 5 with the reasonable assumption that f_r - f_1 equals f_2 - f_r. The statistically derived values for f_r and Q would then be used in formulas 2 of section 7.1, formula 3 of section 7.2, and formula 6 of section 7.3 respectively.

This has been found to fit the collected data points very well at all regions across the entire f_1 to f_2 range. It is a simplified version of the non-linear regression method for complex S21 parameters described by Vanzura^4.

7.0 Calculations

7.1 Stripline Permittivity Use special care to assign the correct n value for each resonance measured. At resonance, the electrical length of the resonator circuit is an integral number of half wavelengths. The effective stripline permittivity, ε_r, can be calculated from the frequency of maximum transmission as follows:

$$\varepsilon_r = \left[n \frac{C}{2(f_r(L + \Delta L))}\right]^2$$  \[2\]

where n is the number of half wavelengths along the resonant strip of length L in mm, ΔL is the total effective increase in length of the resonant strip due to the fringing field at the ends of the resonant strip, C (the speed of light) is 2.9978 \times 10^{11} mm/s, and f_r in Hz (or cycles/s) is the measured resonant (maximum transmission) frequency.

The resonator ends coincide with the end edges of both the dielectric and the ground planes. The relative fringing field at the ends becomes extremely small. It has been the practice with this method to ignore this fringing field and consider the ΔL value to be zero in the calculation of stripline permittivity.

7.2 Calculation of Effective Dielectric Loss Tangent

$$\tan \delta = 1/Q_{\text{unloaded}} - 1/Q_c$$  \[3\]

where:

1/Q_c is the loss factor of the conductor

1/Q_{\text{unloaded}} is the total loss factor of the unloaded resonator due only to the dielectric, copper, and copper-dielectric interface, and does not include loss due to coupling of the probes.

7.2.1 The resonator loss factor The measurement of the resonance gives a value for the loss factor of the resonator with loading due to probe coupling (1/Q_{\text{loaded}}).
For the three point measurement described in 6.5.1, the calculation is

\[ 1/Q_{\text{loaded}} = \left( \frac{f_2 - f_1}{f_r} \right) \left( 10^{\Delta_1/10} - 1 \right)^{-0.5} + \left( \frac{f_2}{f_r} - 1 \right) \left( 10^{\Delta_2/10} - 1 \right)^{-0.5} \]

where:
\[ \Delta_1 \text{ is the positive dB difference in power level from } f_r \text{ to } f_1, \]
and
\[ \Delta_2 \text{ is the positive dB difference in power level from } f_r \text{ to } f_2. \]

For the many point measurements of the resonance described in 6.5.2, the non-linear regression to fit the formula 1 derives the \( Q_{\text{loaded}} \) value.

### 7.2.2 Correcting the Resonator Loss Factor for Loading

The probe gap set for about 50 dB insertion loss at resonance is intended to make \( Q_{\text{loaded}} \) approximately equivalent to \( Q_{\text{unloaded}} \). Nevertheless, corrections in the measured total loss value, \( 1/Q_{\text{loaded}} \), are desirable. With the assumption that the \( S21 \) parameter with straight through connection without the test fixture is at 0 dB, dBr, the insertion loss or \( S21 \) parameter in dB units at the resonant peak, is related to the power ratio by

\[ \frac{P_2}{P_1} = 10^{\text{dBr} / 10} \]

where the dBr value at resonance is taken as positive. Then the correction is

\[ Q_{\text{unloaded}} = Q_{\text{loaded}} \left( 10^\text{dBr} / 10 \right)^{0.5} \]

or

\[ Q_{\text{unloaded}} = Q_{\text{loaded}} \left( 1 - 10^{\text{dBr} / 20} \right) \]

As can be seen from the following tabulation at high degrees of insertion loss such as 50 dB errors in the straight through connection assumption are not as important as they would be at lower values such as 20 or 15.

<table>
<thead>
<tr>
<th>dB</th>
<th>60</th>
<th>50</th>
<th>40</th>
<th>30</th>
<th>20</th>
<th>15</th>
<th>10</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Q_{\text{unloaded}} / Q_L )</td>
<td>1.00</td>
<td>1.00</td>
<td>1.01</td>
<td>1.03</td>
<td>1.11</td>
<td>1.22</td>
<td>1.46</td>
<td>2.28</td>
</tr>
</tbody>
</table>

### 7.3 Calculation of \( 1/Q_c \)

The following calculation scheme is used to estimate the conductor loss needed for formula 3:

\[ 1/Q_c = \frac{\alpha_c}{\pi f_l (\varepsilon_r)^{0.5}} \]

where:
\[ \alpha_c = 4 R_s \varepsilon_r Z_0 Y / (377^2 B) \]
\[ R_s = 0.00825 f_r^{0.5} \]
\[ Z_0 = 377/(4 \varepsilon_r^{0.5} (C_f + (W/(B - T)))) \]
\[ Y = 2 X \log_e(X+1)-(X-1) \log_e \left( X^2 - 1 \right) / \pi \]
\[ X = 1/(1 - T/B) \]
\[ \varepsilon_r = \text{relative permittivity} \]
B = ground plane spacing, mm
W = resonator width, mm
T = resonator conductor thickness, mm

Proven data is not currently available for correcting this calculated value to account for increased conductor loss associated with roughness of the copper foil or surface treatments for adhesion. When smooth rolled copper foil is used in Type A specimens the estimate seems quite reliable in the 0.4 to 15 GHz range based on work done with neat (PTFE) poly(tetrafluoroethylene) sheet specimens. 

### 8.0 Report

The report shall contain the following:

#### 8.1 The type of specimen: A, B, C, or D.

#### 8.2 For specimen type A, if not copper foil type W (wrought), grade 5 (as rolled-wrought), bond enhancement N (none, no stain proof), or for specimen types B, C, or D, state at least:
metal, type, grade, and bond.

#### 8.3 The measured length of the resonator and specimen dielectric.

#### 8.4 The measured thickness of specimen cards or, if applicable, of stacks.

#### 8.5 The center conductor width.

#### 8.6 The center conductor total thickness (for type C, this is twice the cladding thickness).
8.7 The temperature of the test fixture, if not in the 21°C to 23°C range.

8.8 Any conditioning prior to measurement.

8.9 The orientation of the resonator with respect to X or Y axis of the specimen.

8.10 For each resonance, show 8.10.1 through 8.10.9.

8.10.1 The node number n.

8.10.2 The calculated effective stripline permittivity.

8.10.3 The calculated effective dielectric loss tangent.

8.10.4 The resonant frequency, $f_r$, at maximum transmission.

8.10.5 The insertion loss at resonance, $dB_r$, at maximum transmission.

8.10.6 The $Q_{\text{loaded}}$ (optional).

8.10.7 The calculated $Q_{\text{unloaded}}$ (optional).

8.10.8 If the three point method of 6.3, 6.4, or 6.5.1 is used, report the frequency and dB value of the two points either side of the peak (optional).

8.10.9 If the non-linear regression (NLR) method of 6.5.2 is used, report the number of data points used, NLR uncertainty values (for $f_r$, $Q_{\text{loaded}}$, $dB_r$) and the standard deviation of the fit in dB units (optional).

9.0 Notes

9.1 Permittivity The dielectric of a stripline circuit affects the electrical response of all the circuits printed on it. Velocity of propagation, wavelength, and characteristic impedance all vary with permittivity. If the permittivity varies from the design value, the performance of such circuits is degraded.

Throughout this document, the term “permittivity” refers to relative permittivity of the dielectric material, a dimensionless ratio of the absolute permittivity of the material to that of a vacuum.

9.2 Loss Tangent The attenuation and Q (figure of merit) of stripline circuits are a function of combined copper and dielectric loss. An excessively high loss tangent leads to loss in signal strength and to degraded performance of frequency selective circuits such as filters.

9.3 Dielectrics Clad with Thick Metal on One Side This method can be used for measurements of dielectric substrates with thin foil on one side and thick cladding such as aluminum sheet on the other by using the Type C specimen configuration. In some cases, with very thick metal cladding it may be necessary to use a modified part 5.1.2 (Figure 4) with a reduced thickness dimension.

9.4 Anisotropic Materials For anisotropic materials, test methods in which the electric field is not imposed on the dielectric in a stripline configuration can give misleading values of effective stripline permittivity and loss tangent. This test method measures an effective stripline permittivity when the specimen configuration is close to that of the application.

10.0 References


2. The Complex Permittivity of RF Circuit Board Materials by Resonances of a Stripline Section in the 0.2 to 15 GHZ Range, Traut, G. Robert, Preprints of the Measurement Science Conference 1997 January 23 & 24, Pasadena Convention Center, Pasadena, CA


1 Scope  The full sheet resonance (FSR) method is a means for non-destructive measurement of relative permittivity (K’) of clad laminates at microwave frequencies.

1.1 Applicability  The FSR method is applicable to rectangular laminates consisting of dielectric substrate clad with metal foil on both sides, or clad with thick metal on one side and metal foil on the other. Unlike methods using stripline or microstrip resonator elements, the FSR method is sensitive to specimen permittivity only in the Z direction of the material under test.

It is useful for comparing the permittivity of clad panels of essentially the same dimensions. No means is provided in this method to account for error caused by fringing capacitance at the open edges of the parallel plate waveguide formed by the metal cladding. For a series of panels of the same length, width, dielectric thickness, and nominal permittivity and measured by the same selection of resonant modes, the fringing errors will be essentially constant and the permittivity values obtained should correlate with performance in stripline or microstrip circuit boards fabricated from the laminates tested.

The method may be applied to full size clad laminates as manufactured and trimmed to nominal size or to smaller panels cut from such laminates.

1.2 Limitations  While it is convenient to estimate the 1/Q or total D value for the specimen under test, this value will be a sum of dissipative losses in the dielectric, resistive losses in the conductors, and radiation losses from the open edges of the resonant cavity. The radiation losses are a large portion of the D value, so the FSR method is not very sensitive to the dissipation factor of the specimen. The FSR is not recommended for dissipation factor measurements.

The method is not capable of providing useful information on the variation of K’ within a panel.

2 Applicable Documents

2.5.5.6 Stripline Test for Permittivity and Loss Tangent (Dielectric Constant an Dissipation Factor) at X-Band

3 Test Specimen  Test specimens are clad laminate panels trimmed accurately to a rectangular shape. Specimens should be uniform thickness with clad metal over the entire surface on both sides. Edges must be straight with 90° corners and free of conductive bridges across the edges.

Measure the length and width as the distance between centers of opposite edges with precision to the nearest 0.4 mm or better. The length direction is usually taken to be in the X (grain) direction of the cladding and dielectric, which is not necessarily the longest dimension.

4 Equipment/Apparatus  The test method requires a controllable and stable microwave signal source, an accurate means to determine the signal frequency, and an accurate means to measure the microwave power transmitted through the test configuration. The equipment required is the same as that specified in IPC-TM-650, Method 2.5.5.5.

The following equipment in the connection scheme shown in IPC-TM-650, Method 2.5.5.5, or equivalent may be used:

- Sweep Oscillator H.P. 835OB-Option 908
- RF Plug-in 0.01 to 20 GHz H.P. 83592A-Option 002
- Microwave Frequency Counter H.P. 5343A
- Source Synchronizer H.P 5344S-Options 043, 908
- Power Meter H.R 436A
- Power Sensor H.P. 848A
- Power Splitter H.P. 11667A

Although not required, a computer-automated test setup is recommended and the following additional equipment will be required:

- Controlling computer with GPIB interlace
- Appropriate specialized CAT software
- IEEE 488 GPIB cables

4.1 Test Fixture  It is recommended that a test fixture be constructed as shown in the Appendix. This design provides the features given in 4.1.1 through 4.1.5.

4.1.1 The probe gap for control of RF coupling is precisely adjustable.
4.1.2 The test specimen is supported to minimize both movement during the test and distortion of the fringing field by proximity of parts of the fixture or the work surface.

4.1.3 Loading and unloading of specimens is easy and fast.

4.1.4 Heavy metal backed laminates may be tested as is.

4.1.5 Very thin laminates may be tested without tending to bend them in the probe region.

5 Procedure

5.1 Preparation for Testing  Unless otherwise specified, the specimens shall be stored before testing at 23°C, -1°C, +50°C/50% ± 5% RH. The referee minimum storage time is 16 hours. Shorter storage times may be used if they can be shown to yield equivalent test results.

The temperature for the test is to be in the range of 22°C to 24°C, unless otherwise specified. Control of this temperature may be accomplished by performing the test in a laboratory having ambient temperature in the same range.

The two probe assemblies of the test fixture are placed on a level work surface close to the microwave test equipment. Each part has a type N jack fitting to be connected to a type N plug from the microwave equipment.

Make sure the ends of the jack and plug are free of dirt or metallic particles. Align the axes of the jack and plug and push them together with care to avoid twisting, while turning the knurled retaining nut on the plug to firmly tighten the joint. Misalignment or twisting causes excessive wear of contacting metal surfaces and increases the risk of permanent damage to delicate and critical connector parts. Tighten the retaining nut as tightly as is comfortable with the thumb and forefinger.

5.2 Zero Gap Setting  The zero gap setting for each probe assembly on the fixture should be determined. Use the micrometer screw to raise the pusher dock so the surface for supporting the specimen is above the probe block. Mount a flat metal plate or clad board specimen in the fixture as described in 5.3. Lower the pusher by turning the micrometer screw until there is a slight change in torque. To detect it electrically, connect a low voltage battery powered portable Ohmmeter across the center pin of the type N jack fitting and a clip on the mounted specimen. A sudden drop in resistance reading indicates the point at which the probe has made contact with the surface. Record this micrometer setting as the zero gap point on a label on the fixture for convenience.

5.3 Positioning the Specimen for K' Measurement  Use the bead chains and notches to lift and hold the grounding assemblies in a raised position. Place the specimen on the support surfaces of the dielectric pusher blocks with the thin foil clad side down toward the probe. The specimen should rest flat on the top 0.25 mm long flat surface and push against the 1.27 mm vertical surface as a stop as illustrated in Figure 1. Set the probe gap either at the zero setting or a predetermined value. Gaps on both probe assemblies should be set at the same value.

Release the bead chain from the notch so the springs pull the copper bar down against both the top cladding on the specimen and the vertical ground plate. It is important to have good ground contact of the top metal cladding of the specimen at both probes.

5.4 Selection of Unambiguous Resonant Modes  In a conventional waveguide cavity, reflections at the metal bounded sides show a current maximum, while in the parallel plate waveguide, reflections at open edges or corners show a voltage maximum. When the waveguide is a rectangle, as for clad panels, each resonance mode is a grid array pattern of maxima and may be designated (M:N), where M is the integer number of times (nodes) the pattern repeats along the length and N along the width. For a rectangular waveguide with either closed or open edges having length L and width W, the resonant frequency \( f_{r[M:N]} \) for a given mode is predicted by

\[
 f_{r[M:N]} = \left(\frac{C}{2}\right) \left[\left(\frac{M}{L}\right)^2 + \left(\frac{N}{W}\right)^2\right]/\varepsilon_r 0.5
\]

Where,

- \( C = \) speed of light = 299.792 mm/ns
- \( \varepsilon_r = \) dielectric constant of the dielectric filling the waveguide
- \( f_{r[M:N]} = \) resonant frequency in GHz (cycles/ns)

Equation 1 can be used to predict a series of expected resonances for a given panel size. Rearranged in order of frequency, they become proportionately more closely spaced as the frequency increases. In many cases, different modes have very nearly the same frequency.

It is possible to select a resonant mode and predict a frequency that falls in a region of the spectrum where there are so many frequencies for different modes that one is bound to find a resonance close to where it was expected, even though it could be a different mode for a considerably different actual dielectric constant value.

The resonance for a given dielectric constant at different modes will differ somewhat from the prediction of Equation 1.
Part of this is due to variability of thickness or dielectric constant of the panel. Part of it is due to the effect of fringing effects on the edge of the panel.

For a given aspect ratio (length/width) panel, there should be a certain pattern of resonances versus frequency. This pattern will change somewhat as individual panels differ slightly from the nominal dimensions, as well as differing as mentioned before.

These cases of uncertainty about the test can be largely avoided by selecting, for a given nominal aspect ratio with its tolerance, a series of resonances that are well separated from their nearest neighbors and that, when actually found in a test, are certain to be the mode expected, even though deviating from expected frequency for the above several reasons.

If the probes are positioned at opposite corners of the specimen, then the mode selection process must take into account modes with all combinations of all integer values from 0 upward for both M and N, excluding the [0:0] mode and any combinations predicting a resonance exceeding the frequency range to be used.

If the probes are positioned at the centers of opposite edges, then the modes with an odd node number in the transverse direction are excluded from consideration in the selection process.

If the specimen has length and width equal within close tolerance, making it a square, and the probes are positioned at corners, the only truly unambiguous modes will be those where M and N are equal. For a given nominal panel size, selection of a series of three or more resonant modes with differing widthwise node numbers is advised. To obtain equivalent data on a series of panels of the same size and nominal permittivity, all should be measured at the same series of resonant modes.

5.5 Measure the Resonant Frequency for Each Mode Selected The following steps are followed for each selected mode. If the test is performed correctly, one (and only one) distinct resonance should be found for each selected mode. This procedure is greatly aided by computer automation.

5.5.1 Use Equation 1 with measured specimen length and width, the selected mode’s M and N values, and the range of possible K’ values to calculate a frequency range where the resonance should appear.

5.5.2 By taking transmitted power readings across the frequency range, determine the resonant frequency where the transmitted power is maximum. If the transmitted power reading exceeds the sensor capacity, the source power should be reduced by about 3 dB and the procedure restarted.

5.5.3 Record the resonant frequency and resonant mode.

5.6 Calculations The effective permittivity for each resonant mode measured is calculated by the formula:

\[ e_r = \left(\frac{C}{2f_{(M:N)}}\right)^2 (\frac{M}{L})^2 + (\frac{N}{W})^2 \]

Normally, the permittivity values for the selected modes are averaged to give an agreed upon K’ value for the test as applied to a specific specimen size and type.

5.7 Report The report should contain the everything given in 5.7.1 through 5.7.4.

5.7.1 Measured length, width and dielectric thickness of the specimen.

5.7.2 For each selected mode, the (M:N) node numbers, the resonant frequency observed, and the calculated effective permittivity value. If computer-automated testing and calculation of permittivity is used, the resonant frequency may optionally be omitted from the report.

5.7.3 The conditioning of the specimen and ambient temperature at the time of measurement, if either of these differs from the standard values given in 5.1.

5.7.4 A mean permittivity value calculated from the values obtained for each of the selected modes.

6 Notes

6.1 Comments on Precision and Accuracy Precision has been found to be excellent, based on repeated measurements on a series of specimens among a series of three laboratories with ambient temperature identified as the major cause of variation.

Where measurements on specimens over a range of permittivity values have been compared to measurements by IPC-TM-650, Method 2.5.5.5, there was good correlation in that both methods ranked the specimens in the same order; however, the FSR method showed greater differences between the extremes. Unlike the stripline test, in which the dielectric of the pattern card is a part of the material measured, the FSR measurement does not involve any dielectric material other than the specimen.
The permittivity value observed is not necessarily an accurate measure, since the open edges allow fringing field error. For a ceramic filled composite at $K'$ of about 10, specimens of the same length and width have been observed to vary in effective $K'$ as the thickness of the specimen is varied.

### 6.2 Reference


### APPENDIX

List of drawings for the FSR test fixture.

- Figure 1 Side and Face Views of One of Two Fixture Assemblies
- Figure 2 Side and Face Views of Frame, Base, and Brace
- Figure 3 Detail of Flange Mount Coaxial Fittings and of Probe Block in Position with Flange Plug and Ground Planes
- Figure 4 Details of Vertical Ground Plane and Dielectric Pusher
- Figure 5 Detail of Ground Contact Assembly
- Figure 6 Detail of Parts for Ground Contact Assembly
- Figure 7 Details of Bracket for Mounting the Flange Mount Adapter

*Note: All dimensions and sizes are in inches.*
## Parts List for FSR Fixture

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Figure No.</th>
<th>Required No.</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Frame</td>
<td>2</td>
<td>2</td>
<td>Aluminum</td>
</tr>
<tr>
<td>B</td>
<td>Base</td>
<td>2</td>
<td>2</td>
<td>Aluminum</td>
</tr>
<tr>
<td>C</td>
<td>Brace</td>
<td>2</td>
<td>2</td>
<td>Aluminum</td>
</tr>
<tr>
<td>D</td>
<td>3.2 mm x 12.7 mm Machine Screw For Joining A, B &amp; C</td>
<td>2</td>
<td>10</td>
<td>steel</td>
</tr>
<tr>
<td>E</td>
<td>Flange mount OSM plug receptacle</td>
<td>1,3</td>
<td>2</td>
<td>as supplied</td>
</tr>
<tr>
<td>F</td>
<td>Flange mount N jack to OSM plug adapter</td>
<td>1,3,7</td>
<td>2</td>
<td>stainless steel</td>
</tr>
<tr>
<td>G</td>
<td>Block mounted on pin of E</td>
<td>3</td>
<td>2</td>
<td>brass</td>
</tr>
<tr>
<td>H</td>
<td>Vertical ground plate</td>
<td>4</td>
<td>2</td>
<td>brass</td>
</tr>
<tr>
<td>I</td>
<td>2.4 mm x 5 mm machine screw for attaching E to H</td>
<td>3</td>
<td>8</td>
<td>brass</td>
</tr>
<tr>
<td>J</td>
<td>1.6 mm x 6.4 mm machine screw for attaching H to A</td>
<td>none</td>
<td>4</td>
<td>steel</td>
</tr>
<tr>
<td>K</td>
<td>Contact bar connects specimen to H</td>
<td>1,4,5</td>
<td>2</td>
<td>copper</td>
</tr>
<tr>
<td>L</td>
<td>Body piece holds K</td>
<td>1,4,5</td>
<td>2</td>
<td>steel</td>
</tr>
<tr>
<td>M</td>
<td>#0 x 6.4 mm cap screw for attaching K to L</td>
<td>1,5</td>
<td>4</td>
<td>steel</td>
</tr>
<tr>
<td>N</td>
<td>Top plate slides and pivots on H</td>
<td>1,4,5</td>
<td>2</td>
<td>steel</td>
</tr>
<tr>
<td>O</td>
<td>#2 x 6.4 mm flat head screw for attaching N to L</td>
<td>5</td>
<td>4</td>
<td>steel</td>
</tr>
<tr>
<td>P</td>
<td>Tension spring to N pulls K against specimen and H</td>
<td>1</td>
<td>4</td>
<td>steel</td>
</tr>
<tr>
<td>Q</td>
<td>Pin for attaching P to A</td>
<td>1,2</td>
<td>4</td>
<td>steel</td>
</tr>
<tr>
<td>R</td>
<td>Bead chain to N for lifting K,L,N assembly when changing specimens</td>
<td>1</td>
<td>2</td>
<td>steel</td>
</tr>
<tr>
<td>S</td>
<td>Notched plate for retaining R as lifted for specimen change steel</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>1.6 mm x 6.4 mm machine screws for attaching S to A</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>Dielectric pusher lifts specimen for gap to G</td>
<td>4</td>
<td>2</td>
<td>molded PTFE</td>
</tr>
<tr>
<td>V</td>
<td>Micrometer screw unit for lifting U</td>
<td>1</td>
<td>2</td>
<td>as supplied</td>
</tr>
<tr>
<td>W</td>
<td>Bracket Mounts on A and supports E</td>
<td>1,7</td>
<td>2</td>
<td>as supplied</td>
</tr>
<tr>
<td>X</td>
<td>#4-40 x 6.4 mm cap screw fastens E to W</td>
<td>1,7</td>
<td>8</td>
<td>steel</td>
</tr>
<tr>
<td>Y</td>
<td>3 mm semirigid coaxial cable with jack fitting on both ends is bent to connect E to F</td>
<td>none</td>
<td>2</td>
<td>as supplied</td>
</tr>
</tbody>
</table>
Figure 1  Side and Face Views of One of Two Fixture Assemblies
Figure 2  Side and Face Views of Frame, Base, and Brace
Figure 3  Detail of Flange Mount Coaxial Fittings and of Probe Block in Position with Flange Plug and Ground Plate

IPC-TM-650

Number 2.5.5.6  Subject Non-Destructive Full Sheet Resonance Test for Permittivity of Clad Laminates

Revision  Date 5/89

FLANGE MOUNT N JACK TO OSM PLUG
ADAPTER OMNI SPECTRA PART NUMBER 3082-2243-00
MODEL NUMBER 21031 STAINLESS STEEL

OSM FLANGE MOUNT PLUG RECEPTACLE

BRASS BLOCK HAS A 1.27 mm HOLE AND IS PLACED ON THE CENTER PIN AGAINST THE INSULATOR AND SOLDERED IN PLACE, THEN FINISHED TO A 2.5 mm CUBE INCLUDING REMOVAL OF EXTRA PIN LENGTH

PTFE INSULATOR, CUT AWAY ON TOP TO LEVEL OF PROBE BLOCK

VERTICAL PLATE 7

FACE VIEW

SIDE VIEW

IPC-2-5-5-6-3a, 3b and 3c
Figure 4  Details of Vertical Ground Plate and Dielectric Pusher
Figure 5 Detail of Ground Contact Assembly

- NOTCH FOR BEAD CHAIN
- #2-48 X 6.4 mm FH SCREW, 2 PLACES
- STEEL TOP PLATE
- #0-80 X 6.4 mm CAP SCREW, 2 PLACES
- COPPER CONTACT BAR
- STEEL BODY PIECE
Figure 6  Detail of Parts for Ground Contact Assembly
Figure 7  Details of Bracket for Mounting the Flange Mount Adapter
1.0 Scope  Time domain reflectometry, TDR, is used to measure reflections and time delays of pulses injected into a transmission line. Discontinuities in characteristic impedance, \( Z_0 \), along the line under test, reflect portions of incident pulses back toward the source where they combine with the injected pulse to produce a voltage-time waveform.

1.1 Applicability  If the rate of pulse propagation (distance/time delay) along the line is uniform, then the distance to changes in the line’s \( Z_0 \) will be proportional to observable times for voltage changes in the waveform. The observed voltage changes are related in magnitude and direction to the \( Z_0 \) change at the related discontinuity. Thus the TDR method is useful for measuring \( Z_0 \) and locating changes in \( Z_0 \) of a transmission line and is capable of detecting and characterizing defects or the influence of various features along the length of a line.

Conversely, if the locations and types of discontinuity in a line are known, the observed times for corresponding voltage changes in the waveform are useful for determining the time delay of pulses. The time delay is related to the effective permittivity of the dielectric and the transmission structure.

TDR measurements of \( Z_0 \) are used for both engineering development and manufacturing control.

Engineering development requires detailed information on the electrical performance of prototype units to assure the design yields the desired result. Analysis of the effect of variations in design features expected in actual manufacture can be done to assure the proposed article can be manufactured at a useful quality level.

Measurements for manufacturing control are performed to identify and correct process or materials problems occurring during a manufacturing run as well as to assure that a product will perform electrically as designed. Examples of parameter variations detectable by TDR, and that are evidence of process or materials problems, include the following:

- Over/under etching (line width problems)
- Over/under plating (line width and thickness problems)
- Permittivity of the dielectric
- Thickness of the dielectric
- Residues from process steps including cleaning
- Degradation from excessive heating and humidity
- Damage from excessive pressure during the multi-layer process.

Increased performance requirements for computers and other electronic products often demand even greater signal fidelity, time precision, and noise immunity than can be easily obtained with a single ended transmission line. That is, a line geometry consisting of a signal trace over ground plane in microstrip or between ground planes in stripline. Differential lines are employed to increase signal fidelity with improved time precision and increased noise immunity. Single ended lines may be called unbalanced transmission lines. Differential lines may be called either balanced or coupled transmission lines. The required TDR method is different for differential lines.

1.2 Limitations  Measurements of \( Z_0 \) often vary greatly depending on equipment used and how the tests were performed. Following a specified method helps assure accurate and consistent results. Both “single-ended” and differential line measurements have limitations in common including the following:

- The \( Z_0 \) measured units are derived and not directly measured.
- These units are for ideal transmission lines where the electrical characteristics do not vary along the length. The measured \( Z_0 \) is only a value that approximates the characteristic impedance of an ideal line that is representative of the line under test.

Lines on a PWB only approximate uniformity. Microstrip lines longer than 6 inches on plated through hole boards often have trace width variations of 40% along the length of the line.

The accuracy of measurements can not be directly traced to a referee standard at NIST (National Institute of Standards and Technology.)

A variety of methods for TDR measurements each have associated accuracies and repeatabilities.

If the nominal impedance of the line(s) being measured is significantly different from the nominal impedance of the measurement system (typically 50 ohms), the accuracy and repeatability of the measured numerical valued will be degraded. The greater the difference between the nominal
impedance of the line being measured and 50 ohms, the less reliable will be the numerical value of the measured impedance.

2.0 Applicable Documents

3.0 Test Specimens

3.1 Specimen Types The test specimen can take one of several forms, depending on the application. Four types are enumerated here. The lines to be measured may be of either stripline or microstrip construction, and configured as either single-ended or differential.

3.1.1. Representative samples of the actual PWB being manufactured are selected. In some cases this sample may be all of the boards. Agreed-upon functional or non-functional transmission lines within the sample are used for the measurement. Criteria for selection of such lines includes: inclusion of the PWB’s critical features, accessibility of terminations for the line, absence of branching, and representation of controlled $Z_0$ signal layers in a multi-layer board.

3.1.2. As in 3.1.1, except that the test lines are non-functional lines designed into the board for easy termination for TDR measurements. Such test lines should be planned to include critical features typical of functional lines and should lie in controlled $Z_0$ signal levels.

3.1.3 Test coupons are cut from the master board at the time the individual PWBs are separated. Such test coupons will have one or more sample transmission lines with termination suited for testing.

3.1.4 A sample of the substrate laminate to be characterized before use in manufacturing PWBs is fabricated with test transmission lines. The fabrication may involve laminating several board layers together in the same manner anticipated for PWB manufacture.

3.2 Identification For specimens of types 3.1.1, 3.1.2 or 3.1.3, a board serial number should be adequate. Type 3.1.4 specimens should include whatever lot or panel identification is available for the substrate laminate being evaluated.

3.3 Conditioning Unless otherwise specified, specimens shall be stored before testing at 23 $\pm 1/–5$ degrees C and 50 $\pm 1/–5$% relative humidity. The referee minimum storage time is 16 hours. Shorter times may be used if they can be shown to yield equivalent results. Special conditioning in elevated humidity and/or temperature may be used prior to stabilization. Typically measurements are performed under standard laboratory conditions. Special cases may exist where measurements are performed while the specimen is maintained at a higher or lower temperature and relative humidity.

In some cases it will be normal to test the specimens in the manufacturing situation without conditioning.

4.0 Apparatus The apparatus, as depicted in Figures 1 and 2, consists of the TDR instrumentation, the optional but recommended protection switches, cables used for connecting and calibrating the instrument, a coaxial air line as a referee standard for calibration, and a probe for conveniently connecting the instrument to the specimen being measured.

4.1 Instrumentation

4.1.1 TDR instrumentation that contains a pulse (step) generator and an oscilloscope with the following features is required:

Pulse generator with a step that has:
- 35 ps maximum reflected into the open instrument port.
- Step aberrations:
  - Less than 3% from 10ns to 35ps before step.
  - Within the range +10% and –5% from step edge to 500ps after the step.
  - Less than 3% between 500 ps and 5 ns after the step.
- Step amplitude of greater than 400 mv into an open or 200 mv into a 50 ohm load.
- Offset drift and amplitude drift of the step less than 0.25% of the step amplitude over 1 calibration period of time.
- Horizontal time base accuracy of at least 10 ps $\pm 0.1\%$ of the time interval. Horizontal resolution of at least 250 fs.
- Vertical voltage repeatability of the rho = 1 step voltage over the TDR calibration interval:
  - Stored Reference Method $= \pm 0.1\%$
  - In Situ Method $= \pm 2\%$

Mainframe oscilloscope bandwidth of at least 10 Ghz.

4.1.2 The following instruments or their equivalent can be used:
Hewlett-Packard’s HP 54120 series.
Tektronix TEK CSA series or TEK 11800 series
with a SD-24 plug-in.
Tektronix TEK 7854.

4.2 Accessories  The following or equivalent are recommended:

4.2.1 Reference Impedance Standard  Use a 7 mm coaxial air line at least 10 cm long such as Maury Microwave 50 ohm air line #2603D. If the line under test is less than 30 ohms or greater than 85 ohms, a 7 mm air line at least 10 cm long that is close to the Z₀ of the line under test will improve accuracy.

4.2.2 Connectors for Air Lines  Each end of the 7 mm air line should be terminated with high quality connector adapters such as M/A-Com Omni-Spectra connectors #7482-2700-00 (OSM jack to 7 mm adapter) and #7481-2700-00 (OSM plug to 7 mm adapter).

4.2.3 Test Cable  Cables, such as Gore cable, part #T2R010139.4, may be used as a test cable. The 039.4 in the part number is the length in inches of the cable. This cable has male connectors on each end.

4.2.4 Extension Cable  Cables, such as Gore cable, part #T2R02R01018.0, may be used as an extension cable. The 018.0 in the part number is the length in inches of the cable. This cable has a male connector on one end and a female on the other. This cable is only used during the calibration process.

4.2.5 Torque Wrench  Use a torque wrench calibrated for 5 inch-pound torque for APC-3.5 connections. This may be HP model #8710-1582 or equivalent.

4.2.6 Static Protection Switch  Static build up on specimens prior to test can damage the sampling heads in the TDR equipment. It is recommended that a protection switch be used between the line under test and the TDR Instrumentation. The switch should have a VSWR (voltage standing wave ratio) of less than 1.4 at 18 Ghz. The Tektronix SIU-800 is acceptable for this purpose. A maximum of 12 inches of high quality, high frequency cable is required to connect the TDR instruments to the protection switch.

4.2.7 Protection Switch Cable  If the protection switch is to be used, use Gore cable, part #T2R01R01012.0 or equivalent, as the protection switch cable. The 012.0 in the part number is the length in inches of the cable. This cable has male connectors on each end.
4.3 Probes

4.3.1 For large numbers of routine measurements a contact connection to the specimen may be effected by use of a microstrip probe such as that shown in Figure 3. The 50 ohm $Z_0$ microstrip line with ground plane is transformed into two contacts spaced to match grounded and signal line features on the board being tested. This probe is suitable for use with automated x-y probing systems.

4.3.2 A probe mouse is a simple fixture for manual probing and is suited to large numbers of routine measurements. The probe mouse illustrated in Figure 4 rests on the board as a tripod with one foot being the center conductor of the semi-rigid cable. Its weight applies force to this foot and also compresses the spring pressing the grounding pin against its board connection. Constant force and angle is maintained between the probe tip and the board connection.

4.3.3 For less frequent measurements the probe fixture may consist of an SMA PC mount as illustrated in Figure 5. The SMA PC mount connector will plug into a hole pattern in the board under test. Be sure to use a connector that properly interfaces into these holes. Also do not let the under side of the SMA hole pattern make contact to any surface. Supporting the perimeter of the board will accomplish this.

SMA PC mount straight jacks are available as part number 2062-0000-00 from M/A-Com Omni Spectra, Merrimack, New Hampshire. This fitting has a 1.3 mm center pin surrounded by four 1 mm square ground pins with centers in a 5.1 mm square pattern. All extend 4 mm from the face. A convenient probe with unimpaired measurement accuracy may be made by cutting away three of the four ground pins.

The TDR probing scheme of SMA probes with board hole patterns is most commonly used because of its simplicity of implementation.

5.0 Procedure The process of measurement of $Z_0$ of PWB specimens consists of two activities—calibration and specimen test measurements. Normally, calibration is performed once before test measurements are made.
Two similar methods for measuring the $Z_0$ of PWB specimens as shown in Figures 1 and 2 are:

Stored Reference Method (Figure 1)—The voltage corresponding to the reference coaxial air line standard is measured during the calibration process and used during the test process. The reference air line standard is not used during testing. The advantage of this method is that 1) it prolongs the life time of the reference air line standard and, 2) it can be used in connection schemes where it is not practical to leave the reference air line connected.

In Situ Reference Method (Figure 2)—The voltage corresponding to the reference coaxial air line standard is measured each time a test measurement is performed. The reference air line standard is part of the test fixturing. The advantage of this method is that it is less sensitive to voltage offset drifts within the TDR instrumentation.

In Situ Reference Method (Figure 2)—The voltage corresponding to the reference coaxial air line standard is measured each time a test measurement is performed. The reference air line standard is part of the test fixturing. The advantage of this method is that it is less sensitive to voltage offset drifts within the TDR instrumentation.

The two methods use the same equation. The two methods are identical if there is no voltage offset drift for the TDR instruments. Use the In Situ Reference Method if the voltage offset drift plus the uncertainty of measurement is greater than 0.1% of the measured incident step amplitude.

5.1 Calibration—Stored Reference Method

The following calibration steps are required to support accuracy and repeatability specified in the test measurement process defined in the stored reference test section.

5.1.1 Zero reflection reference voltage is obtained by first connecting the test cable to a coaxial air line of known characteristic impedance, $Z_{ref}$. The other end of the air line is connected to a cable of similar characteristic impedance whose other end is left open. The waveform is obtained and the average voltage of the waveform section corresponding to the air line’s undisturbed interval is obtained as $V_{ref}$ as shown in Figure 6. The characteristic impedance of the air line used for this purpose should correspond to the instrument’s characteristic impedance, normally 50 ohms if the $Z_0$ of the line under test is greater than 30 ohms or less than 85 ohms. An air line that has a characteristic impedance corresponding to the $Z_0$ of the line under test should be used in other cases.

5.1.2 Incident wave voltage is obtained by disconnecting the open cable from the other end of the air line and replacing it with the probe as shown in Figure 7. From the waveform
obtained, measure the voltage amplitude of the step between the reference coaxial air line standard and the pulse height corresponding to the open probe. The time range for this measurement, as depicted in highlighted region of Figure 7, starts at the air line and extends for 2 times the air line’s delay. The voltage amplitude can be measured by subtracting the voltage mode of the waveform corresponding to the air line and the voltage mode of the waveform corresponding to the open. The IEEE STD 181-1977 “Pulse Measurements and Analysis by Objective Techniques” can also be used to calculate this voltage. This is referred to as $V_{inc}$.

5.1.3 Time at probe’s end is determined by disconnecting the air line from the instrument cable and connecting the probe to be used for measurements. The probe is left open and the waveform is obtained as shown in Figure 8. Measure and record as $T_{40\%,\text{probe}}$, the time at the end of the probe where the waveform reaches 40% of the step amplitude define by the voltage mode (base) corresponding to the test cable and the voltage mode (top) corresponding to the open termination. Also record as $T_{40\%-60\%,\text{probe}}$, the time interval from 40% to 60% of the rise time between the cable voltage (base) and the open voltage (top).

5.1.4 A voltage to check for re-calibration is determined
from the same waveform as in 5.1.3. Obtain the voltage average along the cable as shown in Figure 8 and record this as $V_{\text{cal,check}}$ to be used in the test process to determine when recalibration may be necessary. Too frequent calibration has often been a problem with TDR testing. Most air lines are only rated for about 100 connect/disconnect cycles.

5.1.5 Some coaxial cables exhibit small changes in impedance and loss with flexing. The addition of a short (roughly 6 in) length of semi-rigid coax just prior to the probe tip can reduce these changes by limiting flexing. While adding this semi-rigid coax may induce minor aberrations at the interconnect between the flexible and rigid coax, the semi-rigid coax will tend to have a more stable impedance with handling. The semi-rigid coax also provides a convenient rigid “handle” for SMA connector probes like the one shown in Figure 5.

5.2 Test measurements—Stored Reference Method

The following steps are to be performed after the calibration process of 5.1. After the initial calibration process, is only required if the calibration check step of 5.2.1 fails.

The probe is connected or contacted to the transmission line and associated ground to be measured. The other end of this
line is to be left open. The waveform is obtained and used for determination of test values by the following steps.

5.2.1 Check for need for recalibration. Compare the mean voltage \( V_{\text{check}} \) on the cable as shown in Figure 9 with \( V_{\text{cal,check}} \) measured during calibration step 5.1.4. If the absolute difference is equal or less than 0.2% of the pulse voltage, \( V_{\text{inc}} \), no recalibration is required. It is suggested that this step be performed every few minutes during the test. It doesn’t need to be performed before each test for each line.

Each time a line is probed, care should be taken to make a good probe tip to line connection. If there is a large transient reflection that is greater than 5% of the pulse height, \( V_{\text{inc}} \), or excess ringing lasts for longer than 250 picoseconds after the probe tip to line transition point, forthcoming measurements will be suspect. This would usually indicate a bad connection. Often retightening connections and reprobing will remedy the situation.

5.2.2 Measure the time on the waveform as \( T_{40\%\text{line}} \) where the waveform reaches 40% of the voltage change from base to top. Also measure \( T_{40\%\text{line}} \) as the time difference for the rise from 40% to 60% of top-base. This is illustrated in Figure 9.

5.2.3 As shown in Figure 9, measure the waveform voltage, \( V_{\text{line}} \), as the mean voltage value along the undisturbed region of the test line.

5.3 Calibration—in Situ Reference Method The following calibration steps are required to support accuracy and repeatability specified in the test measurement process defined in the In Situ Reference Test Method sections 5.1 and 5.2.

5.3.1 Incident wave voltage is obtained by connecting the test cable to one end of the coaxial air line reference standard and connecting the probe to the other end as shown in Figure 10. From the waveform obtained, measure the voltage amplitude of the step between the reference air line standard and the pulse height corresponding to the open probe. The time range for this measurement, as depicted in highlighted region of Figure 10, starts at the air line and extends for 2 times the air line’s delay. The voltage amplitude can be measured by subtracting the voltage mode of the waveform corresponding to the air line (base) and the voltage mode of the waveform corresponding to the open (top). The IEEE STD 181-1977 “Pulse Measurements and Analysis by Objective Techniques”
can also be used to calculate this voltage. This is referred to as $V_{\text{inc}}$.

5.3.2 Time at probe’s end is determined as shown in Figure 10. Measure and record as $T_{40\%\text{probe}}$, the time at the end of the probe where the waveform reaches 40% of the step amplitude defined by the voltage mode (base) corresponding to the test cable and the voltage mode B corresponding to the open termination. Also record as $T_{40\%\text{to}60\%\text{probe}}$ the time interval from 40% to 60% of the rise time between the cable voltage (base) and the open voltage (top).

5.4 Test measurements - In Situ Reference Method The following steps are to be performed after the calibration process of 5.3.

The reference coaxial air line standard is left connected to the end of the test cable. The probe is connected to the other end of the air line as shown in Figure 11.

The probe is connected or contacted to the transmission line and the associated ground to be measured. The other end of this line is to be left open. The waveform is obtained and used for determination of test values by the following steps.

Each time the line is probed, care should be taken to make a good probe tip to line connection. If there is a large transient reflection that is greater than 5% of the pulse height, $V_{\text{inc}}$, or excess ringing lasts for longer than 250 picoseconds beyond the probe tip to line transition point, forthcoming measurements will be suspect. This would usually indicate a bad connection. Often retightening connections and reprobing will remedy the situation.

5.4.1 Measure the time on the waveform as $T_{40\%\text{line}}$, where the waveform reaches 40% of the voltage change from base to top. Also measure $T_{40\%\text{to}60\%\text{line}}$, the time difference for the rise from 40% to 60% of base-top. This is illustrated in Figure 11.

5.4.2 As shown in Figure 11, measure the waveform voltage, $V_{\text{line}}$, as the mean voltage value along the undisturbed
5.5 Calculation

The data collected in 5.1 and 5.2 or 5.3 and 5.4 is used for characterizing the transmission line.

5.5.1 Delay, velocity of propagation, and effective relative permittivity, \( K_{\text{eff}} \) \((\varepsilon_{\text{eff}})\) may be calculated from the time difference between end of line and the end of the probe.

\[
T_{\text{end}} = T_{40\%\text{line}} - 3.2[(T_{40\%-60\%\text{line}})^2 - (T_{40\%-60\%\text{probe}})^2]^{0.5} \tag{1}
\]

where:

\( T_{\text{end}} = \) time at the end of the line.

\( T_{40\%\text{line}} = \) time where the waveform reaches 40\% of the voltage from base to top from 5.2.2 or 5.4.1.

\( T_{40\%-60\%\text{line}} = \) time difference for rise from 40\% to 60\% of base to top in measurement step 5.2.2 or 5.4.1.

\( T_{40\%-60\%\text{probe}} = \) probe’s time difference for rise from 40\% to 60\% of base to top in step 5.1.3 or 5.3.2.

From the preceding, the delay time, \( T_{\text{delay}} \), for the line in test is given by

\[
T_{\text{delay}} = (T_{\text{end}} - T_{40\%\text{probe}}) / 2 \tag{2}
\]

where

\( T_{40\%\text{probe}} = \) time where the waveform reaches 40\% of the voltage from base to top at the probe’s open end in calibration step 5.1.3 or 5.3.2.

If the length of the line, \( L \), being measured is known, then the velocity of pulse propagation, \( v \), is determined by

\[
v = L / T_{\text{delay}} \tag{3}
\]

The effective permittivity \( K_{\text{eff}} \) of the line is given by the relationship

\[
K_{\text{eff}} = (\varepsilon / v)^2 \tag{4}
\]

where
5.5.2 The $Z_0$ value for the line being measured is based on the measured mean voltage value in the test waveform along the undisturbed interval of the test line as shown in Figure 9 or Figure 11. This mean value and the calibration parameters are used in the formula:

$$Z_0 = Z_{ref} \frac{V_{inc} + V_{line} - V_{ref}}{V_{inc} - V_{line} + V_{ref}}$$  \[5\]

where $Z_{ref} = \text{characteristic impedance of the coaxial air line reference as described in 5.1.1.}$ This is normally 50 ohms.

$V_{inc} = \text{measured mean voltage value along the undisturbed region of the test line from 5.2.3 or 5.4.2.}$

$V_{ref} = \text{voltage of the coaxial air line reference recorded in calibration step 5.1.1 or 5.3.1.}$

5.6 Report The test report should include a description of the instrument and accessories used plus the calibration data, test data and calculated results.

Calibration data:

- $Z_{ref}$ from 5.1.1.
- $V_{ref}$ from 5.1.1 or 5.4.2.
- $V_{inc}$ from 5.1.2 or 5.3.1.
- $T_{40\%probe}$ from 5.1.3 or 5.3.2.
- $T_{40\%to60\%probe}$ from 5.1.3 or 5.3.2.
- $V_{cal\_check}$ from 5.1.4 (stored reference method only)

Test data:

- $V_{check}$ from 5.2.1 (stored reference method only)
- $T_{40\%line}$ from 5.2.2 or 5.4.1.
- $T_{40\%to60\%line}$ from 5.2.2 or 5.4.1.
- $V_{line}$ from 5.2.3 or 5.4.2.
Calculated results:

- $T_{\text{delay}}$ calculated delay time from 5.5.1
- $L$, line length, if known
- $v$, pulse propagation rate, if known
- $K_{\text{eff}}$, if known from 5.5.1
- $Z_0$ from 5.5.2

6.0 Notes

6.1 Comments on accuracy of $Z_0$  Accuracy is the difference between the most likely measurement and the defined standard. The most likely measurement is also called the mode of all measurements within a sample set. Three times the standard deviation around each side of the mode is the repeatability. Accuracy and repeatability depend on the impedance of the line being measured.

The single-ended method of 5.2 can be expected to yield +/-0.5 ohm accuracy with 0.1 ohm repeatability for lines around 50 ohms and +/-0.8 ohm with 0.2 ohm repeatability for lines around 100 ohms on the most stable of instruments used by careful operators. More typical instrumentation and operators will only yield 0.5 ohm repeatability at 50 ohms and 0.8 ohms of repeatability at 100 ohms. However there are sources of inaccuracy that need to be considered. Many of the problems of measurement quality are related to excess "ringing" in the TDR waveform or inconsistent waveform measurement intervals. Ringing is the appearance of multiple reflections from the same features in the line being tested.

6.1.1 Cable and probe defects can reduce accuracy. Only low loss, high frequency, rugged cable should be used. Faulty cables can contribute up to 1 ohm error. Disturbances caused by the physical design of the probe or connector and the test target signal launch site can contribute up to 0.5 ohm error. Inconsistent probe force and placement is most common and can cause up to 5 ohms error. Starting the "undisturbed interval" at 25% of the way into the test line helps to avoid the effects of this.

6.1.2 Coaxial air line calibration standards must be of high quality. Air line standards should be checked for mechanical tolerances or replaced at regular intervals. They should be handled with care. Worn out standards can contribute over 2 ohms of error.

6.1.3 Environmental factors such as temperature and humidity should be monitored during the test. Long exposures to conditions such as 85°C and 85% relative humidity can change the impedance by as much as 5 ohms, in some materials.

6.1.4 Instrument anomalies can contribute error. Many instruments perform differently under different loads. If a test is performed with open lines, the calibration of the reference should also be done using an open circuit termination as advised in the procedure section. Many instruments change accuracy when their scales are changed that can contribute up to 3.0 ohms error. Many instruments have self calibration features that should be exercised prior to performing the TDR calibration of this standard method. For the HP54120T, this is called "Channel Vertical Cal" in the "Utility" menu. For the TEK CSA 803 and TEK 11802, they are called "Calibrate All," "TDR Amplitude," and "Offset Null" in the "Enhanced Accuracy" menu.

6.1.5 Poor uniformity and wrong selection of the "undisturbed region" of the line under test can contribute large errors. If the standard deviation of a line’s impedance as calculated for voltages along the waveform region to be averaged is greater than 0.5 ohms, then the line is not uniform enough for determination of a value for $Z_0$.

Inconsistency in the definition of where the undisturbed region is may contribute up to 5.0 ohms of error. The recommended region starts at 25% of the line’s length away from the signal launch point and ends 15% away from the end of the line.

6.1.6 Subtle static damage to the TDR instrumentation can cause up to 5 ohms error. Static damage to TDR instrumentation is often not easily detected. All cables should have terminator attached to one end when not in use and while being connected to the TDR instrumentation. The use of a static protection switch helps eliminate this problem. Use the test procedure of 5.2 to verify a test line on a "golden" correlation board after each calibration operation to detect this type of problem. The impedance for the line should read with within 0.3 ohms of the mean of previous readings. A "golden" board is one board that is put aside for measurement correlation only. The "golden" board must be stored in environmental conditions conforming to the requirements of section 3.3 of this test method.

6.2 Quality Acceptance Test Limits  Quality acceptance
test limits are based on the accuracy and repeatability of the measurement and the variability of the product. If the calibration and test processes of 5.2, 7.1 and 7.2 are employed with the best of TDR equipment and operators, acceptance limits of +/- 5% for 50 ohm lines and +/- 9% for 100 ohm lines can be achieved. For more typical instrumentation and operators, acceptance limits of +/- 7.5% for 50 ohm lines and +/- 14% for 100 ohm lines is more reasonable.

The acceptance test limits for surface lines on plated-through-hole PWBs are greater than the limits for inner layers. Surface lines on plated through hole boards have greater variability than inner layers.

7.0 TDR Applied to Differential Lines

As mentioned in 1.1 there is interest in TDR measurements of differential lines, also referred to as balanced lines. Many of the practices developed for single ended measurements can be used to insure the quality of differential measurements.

Two methods of measuring differential lines can be used depending on the equipment available. Each has its advantages and disadvantages. Both are subject to the same shortcomings, and are 2–3 times less accurate than the single-ended method. Both may use the in situ reference or stored reference method.

7.1 Test Method for a Differential TDR Instrument

Differential TDR instrumentation injects two equal pulses of opposite polarity into the coupled transmission lines to get two waveforms A and B, shown schematically in Figure 12. The resultant voltage waveform between the two paths is C. Differential Impedance \(Z_{0,\text{diff}}\) is an average that is the ratio of the voltage between and the current through the pair of lines. Odd mode impedance \(Z_{0,\text{odd}}\) is half the differential impedance.

7.1.1 The calibration method is the same as described in 5.1 or 5.3. Differential waveforms are used and each step uses two coaxial air line reference standards, two sets of cables, two protection switch, and (two) probes. For the \(V_{\text{ref}}\) voltage in 5.1.1 or 5.4.2 two air lines are used, one on each channel, with an open extension cable added to each. For incident wave voltage, \(V_{\text{Inc}}\), in 5.1.2 or 5.3.1 two air lines are used. For time at probe’s end and voltage to check for recalibration of 5.1.3, 5.3.2 and 5.1.4 (stored reference method only) use two test probes connected to the cables.

7.1.2 The test method is the same as described in 5.2 or 5.4, but the waveforms used are differential (as in C of Figure 12) Identical performance cables and probes are used. This method can yield the same accuracy and twice the repeatability as compared to the single-ended method. Figure 13 shows a fitting and hole pattern being advocated at Digital Equipment Corporation.

7.1.3 Calculate results and report as in 5.5 and 5.6.

7.2 Differential TDR by Waveform Super-Position

This method is recommended if differential TDR instrumentation is not available. It can be expected to yield the same accuracy and repeatability as the method of 7.1 that uses two sources. See Figure 14. This method is for balanced symmetrical transmission lines. Permittivity derivations from time delay measurements are inaccurate for differential measurements. This method assumes that both channels are precisely de-skewed (i.e., signals arriving at the input at precisely the same time will be displayed as coincident). The channels must be
Figure 13  A suggested fitting and hole pattern for applying TDR to differential lines

Note:
For each modified SMA PC pattern:
- 3 references to an adjacent reference plane
- signal line adjacent to the reference plane

The lines from +/- are coupled and Symmetrical

Finished diameter .055 ± .002
de-skewed to within 10 ps before the measurement is made and the interconnect cables must be precisely matched in length.

7.2.1 Single-ended instrumentation must have the following capabilities:

- 2 channel measurements.
- Waveform math (waveform addition and subtraction)
- Waveform storage sourced from the waveform math function for at least 2 waveforms.

7.2.2 The procedures for calibration and test are the same as in 7.1 except that a different technique must be used for acquiring each waveform required in calibration and measurement. The method for acquiring the differential waveform to use for measurement is:

7.2.2.1 For the required connections in the calibration or measurement step connect the appropriate accessories to channels 1 and 2 and record a waveform consisting of channel 1 minus channel 2.

7.2.2.2 Swap the probes and record a waveform consisting of channel 1 - channel 2 again.

7.2.2.3 Add the waveforms of 7.2.2.1 and 7.2.2.2. Use the resulting waveform for test and calibration procedures as required in 5.1 and 5.2 or 5.3 and 5.4.

7.2.3 Calculate results and report as in 5.5 and 5.6. incident wave voltage.

Figure 14 Waveform super-position applying TDR to differential lines
1.0 Scope

1.1 This test method establishes a procedure for determining the low frequency out of plane dielectric constant and loss tangent of organic free films using a two-fluid method. (Low frequency is defined as less than or equal to 1 MHz in this method.)

1.2 The two-fluid method uses a three-terminal guarded electrode cell and allows for capacitance measurements which are independent of sample dimensions, electrode size, and electrode spacing. The two fluids to be used in this procedure are air and 1.0 centistoke silicone fluid.

1.3 The change in dielectric constant is the key indicator of moisture uptake and can be used to estimate the mass uptake of water by an organic film. For this reason, the dielectric constant is to be measured on films conditioned at two relative humidity levels and the difference used to estimate a value defined as “electrical water” for the sample.

2.0 Applicable Documents

ASTM D 150 Standard Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials

ASTM D 1531 Standard Test Method for Relative Permittivity (Dielectric Constant) and Dissipation Factor by Fluid Displacement Procedure

ASTM E 104 Standard Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

3.0 Test Specimen

3.1 Free films should have a minimum thickness of approximately 25 µm for ease of handling. Films may be stacked to achieve a total test specimen thickness of approximately 50 µm (minimum) or greater for the test.

3.2 Note that sample handling becomes more difficult as the number of film layers used in a test specimen increases, especially when trying to keep air bubbles from between the layers when immersed in the silicone fluid. However, greater accuracy is achieved with thicker test specimens.

3.3 Process the organic coating according to the manufacturer’s recommended procedures. Specify the film preparation method, including coating method, substrate type, and release method as follows.

3.3.1 Particulate Control Many test methods for determining the physical properties of polymers are sensitive to defects or particulates in the test specimens (e.g., measurement of tensile properties). The preparation of organic coatings should be conducted in a particulate free environment (e.g., laminar flow hood or clean room) to minimize particulate defects in the films.

3.3.2 Preparation of Uniform Coatings

3.3.2.1 Apply the test material using one of the coating methods listed in Column A of Table I to one of the substrates listed in Column B of Table I following the manufacturer’s recommended procedure.

3.3.2.2 Process the coating according to the manufacturer’s recommended procedures.

3.3.3 Patterning Techniques
3.3.3.1 The organic or metal coating can be patterned using one of the following techniques.

Wet Etch  
Plasma Etch  
RIE Etch  
Laser Ablation  
Photosensitive Material

3.3.3.2 Patterning may involve the use of organic photoresists or metal hard masks. Descriptions of how these materials were processed must be provided.

3.3.4 Release Methods

3.3.4.1 Buffered HF Solution

3.3.4.1.1 This release method can be used to remove films that have been coated on silicon wafers containing an oxide layer.

3.3.4.1.2 Score completely around the outside of the coated substrates approximately 3 mm (⅛ inch) in from the edge. A template (e.g., inverted funnel) can be used as a cutting aid.

3.3.4.1.3 Place several rubber bands around the coated substrate to prevent the film from floating away.

3.3.4.1.4 Place the coated substrates in a *Teflon® boat, leaving a space between each coated substrate. Be sure to write down the order of the coated substrates since the HF will remove any ink labeling on the backs of the coated substrates.

3.3.4.1.5 Place the boat of coated substrates into a plastic container filled with a buffered (6:1) HF solution.

3.3.4.1.6 Remove the boat of coated substrates from the bath once the films have lifted from the coated substrates (15 min to 2 hrs.). Place the boat in a clean empty container and rinse with water for 1 hour or until all traces of HF have been removed (the water will turn from cloudy to clear).

3.3.4.1.7 Carefully remove the films from the substrates while still wet and place between two absorbent sheets to dry. Label the absorbent sheets, put in a safe place, and allow the films to dry overnight.

3.3.4.2 Buffered HCL Solution

3.3.4.2.1 This release method can be used to remove films coated on aluminum disks or panels.

3.3.4.2.2 Secure the test specimen to a glass plate with several rubber bands to prevent the film from floating away.

3.3.4.2.3 Place the coated substrate in a bath of buffered HCL solution. Stir the bath to keep a fresh supply of HCL flowing past the substrate and to remove any oxide that has formed.

3.3.4.2.4 After the substrate has been completely removed, carefully pick up an end of the free film with tweezers, and place the film in a clean empty container and rinse with water for 1 hour or until all traces of HCL have been removed.

3.3.4.2.5 Remove the films while still wet and place between two absorbent sheets to dry. Label the absorbent sheets, put in a safe place, and allow the films to dry overnight.

3.3.4.3 Mercury Amalgam

3.3.4.3.1 This release method can be used to remove films that are coated onto substrates coated with a layer of tin.

3.3.4.3.2 Place the tin coated substrate film side up in a pool of mercury to remove the tin by amalgamation.

3.3.4.3.3 After amalgamation is completed, carefully pick up an end of the free film with tweezers, and carefully brush the film free of mercury and amalgam with a soft camel hair brush.

3.3.4.4 Boiling Water

3.3.4.4.1 This release method can be used to remove films coated on any of the recommended substrates. This release method generally can not be used if the material contains an adhesion promoter (coupling agent) or if the manufacturer recommends that the material be tested along with the use of an adhesion promoter.

3.3.4.4.2 Place the coated substrate in a bath of boiling water.

3.3.4.4.3 Once the film has lifted from the substrate (or can be easily peeled from the substrate without tearing) carefully remove the films while still wet and place between two absorbent sheets to dry. Label the absorbent sheets, put in a safe place, and allow the films to dry overnight.
3.4 Reporting of Specimen Processing History

3.4.1 Specify the thermal processing history of the film as follows.

3.4.2 The properties of polymers are highly dependent on the thermal history of the polymer. When performing cross laboratory comparisons of properties, identical processing conditions must be used. The test results must list in specific detail how the polymer was processed. The description should include the following information:

- Coating method and conditions
- Substrate
- Processing conditions (time, temperature, etc.)
- Patterning technique and conditions
- Release method

For example:

The solution was deposited onto 125 mm silicon wafers containing 1500 Å of thermally grown oxide by spin coating at 3000 RPM for 30 sec. The coatings were processed as follows:

Dry: 135°C for 30 min. in air in an oven
Cure: Ramp from ambient to 200°C at 2°C/min in nitrogen
Hold at 200°C for 30 min
Ramp from 200°C to 350°C at 2°C/min
Hold at 350°C for 60 min
Ramp from 350°C to ambient at 5°C/min

The cured coatings were patterned using an aluminum mask and oxygen plasma. The aluminum mask was deposited by sputtering and wet etched. The cured films were released from the silicon wafers by dissolving the oxide in a buffered HF bath.

3.4.3 The physical and electrical properties of polymers are affected by temperature and relative humidity in a manner that may significantly affect test results. In order to make quantitative comparisons of different materials and between different laboratories, the temperature and relative humidity conditions that the test specimen are exposed to both prior to and during testing must be standardized.

3.5 Test samples should be cut into square or rectangular shapes at least 2 cm greater than the electrode diameter.

3.6 Clean the samples with a suitable solvent (e.g., acetone) or other means and allow to dry. Wipe the samples free of dust and lint particles with Masterwipe cleaning wand and follow with static removal using the Zerostat device prior to relative humidity conditioning.

4.0 Apparatus or Material

- HP 4275 LCR meter or equivalent
- Two-fluid cell reference ASTM D 1531, Figure 1 and ASTM D 150
- High quality coaxial test leads (kept as short as possible)
- 1.0 centistoke silicone fluid, Dow Corning No. 200, or equivalent
- 3M Masterwipe cleaning wand, or equivalent
- Zerostat antistatic instrument, or equivalent
- Nitrogen purged dry box
- Quality paper filter, Whatman No. 1 Qualitative, or equivalent
- Humidity chamber prepared in accordance with ASTM E 104 for conditioning samples at an elevated humidity level

5.0 Procedure

5.1 Sample Preparation For Low Humidity Test (films conditioned at less than 5% R.H.)

5.1.1 Dry the clean prepared films in a nitrogen purged forced air oven overnight at 120°C.

5.1.2 Place the dried films into a nitrogen purged dry box @ 22°C for storage until tested.

5.2 Sample Preparation For Elevated Humidity Test (films conditioned at approximately 53% R.H.)

5.2.1 Place the dry films that were used in the low humidity test into a 53% R.H. chamber for conditioning prior to testing. (Use a chamber prepared with magnesium nitrate (Mg(NO₃)₂·6H₂O) to achieve 53% R.H. at 22°C.)

5.2.2 Films should be conditioned for 3 to 7 days prior to testing, or until a quasi-steady state weight gain has been achieved. Tests have shown that most of the water uptake occurs very rapidly (within 24 hours) in thin organic films. (See 6.1.1)

5.3 Test Cell Preparation

5.3.1 Connect the high potential leads from the LCR meter to the movable electrode. Connect the low potential leads from LCR meter to the stationary electrode. Connect the guard ring to ground.
5.3.2 Zero the LCR meter according to manufacturer’s instructions.

5.3.3 Clean the inside of the cell with filtered air to remove lint and dust particles.

5.3.4 Set the cell electrode spacing so that the sample occupies at least 80% of the gap. Once set, it is very important that the gap is not changed between any of the measurements.

5.4 Measurement

5.4.1 All measurements should be performed at 22 ± 1°C.

5.4.2 Measure capacitance (C₁) of the cell in air at 10 KHz and 1 MHz.

5.4.3 Transfer test specimen from conditioning environment to test cell and measure capacitance (C₂) of the cell plus sample in air at 10 KHz and 1 MHz.

5.4.4 Remove sample from test cell and return to conditioning environment.

5.4.5 Carefully pour the silicone fluid into the cell to avoid formation of air bubbles.

5.4.6 Measure capacitance (C₃) and loss factor (D₃) of the cell in silicone fluid at 10 KHz and 1 MHz.

5.4.7 Transfer test specimen from conditioning environment to test cell and measure capacitance (C₄) and loss factor (D₄) of the cell plus sample in silicone fluid at 10 KHz and 1 MHz. There must not be any air bubbles trapped between multiple film layers when the sample is immersed in the silicone fluid.

5.4.8 Measurement Considerations

5.4.8.1 Keep test specimens in the conditioning environment as much as possible between measurements.

5.4.8.2 Avoid over-handling of films to prevent contamination with lint or other particles.

5.4.8.3 Thin films tend to pick up static charge during the process of sliding into and out of the electrode gap, therefore, it is necessary to perform static removal periodically during the test procedure to keep the sample moving freely in and out of the gap.

5.4.8.4 It is important that both measurements are made on the same area of the specimen because the thickness may not be the same at all points on the films. To ensure that the same area is measured each time, a specimen holder may be used. Specimen holders also facilitate handling thin samples that have little stiffness and are difficult to slide down between the electrodes. The specimen holder can be a U-shaped piece of thin plastic sheeting which secures 3 edges of the test specimen.

5.5 Post-Measurement Clean-up

5.5.1 Remove the silicone fluid from the test specimens by wiping with an appropriate solvent (e.g., acetone). Use low linting wipes to minimize particle accumulation on the films.

5.5.2 Wipe the samples free of dust and lint particles with Masterwipe cleaning wand and follow with static removal using the Zerostat device.

5.5.3 Return test specimens to conditioning environment.

5.5.4 Remove the silicone fluid from the test cell by wiping with an appropriate solvent (e.g., acetone). Use low linting wipes to minimize particle accumulation on the interior surface of the cell.

5.5.5 Clean the inside of the cell with filtered air to remove lint and dust particles.

5.5.6 Filter the silicone fluid through a quality filter paper after each use before it is returned to its storage container.

5.6 Duplicate Measurement

5.6.1 Allow the test specimen to remain in the conditioning environment for 3 to 7 days after the initial test.

5.6.2 Repeat steps 5.3 through 5.5.

5.6.3 Perform duplicate measurements for samples conditioned at both the low and elevated humidity levels.

5.7 Calculations – (See 6.1.2)
5.7.1 Definition of Symbols:

$C_1, C_2, C_3, C_4 =$ capacitance measurements as specified in 5.4.2, 5.4.3, 5.4.6, 5.4.7

$D_3, D_4 =$ loss tangent measurements as specified in 5.4.6, 5.4.7

$k' =$ dielectric constant of sample

$C_0 =$ cell vacuum capacitance = $C_1/k_a$

$k_a =$ dielectric constant of air = 1.00059

$D =$ loss tangent of sample

$\text{EW} =$ ''electrical water''

5.7.2 Formula for dielectric constant of sample:

$$k' = \frac{1}{C_0} \left[ C_1 + \frac{C_4(C_2-C_1)(C_5-C_1)}{C_2(C_2-C_1)C_2(C_4-C_3)} \right]$$

Report values at 10 KHz and 1 MHz.

5.7.3 Formula for loss tangent of sample:

$$D = D_4 + \frac{(k'C_0-C_2)(D_4-D_3)}{(C_4-C_3)}$$

Report values at 10 KHz and 1 MHz.

5.7.4 The formula used to estimate the moisture uptake of the organic film is shown below. This calculated value for moisture uptake defined as “electrical water” is based on the difference between the dielectric constants measured dry and at an elevated humidity level and normalized to 100% R.H.

$$\text{EW} = \frac{2[k'(@ 53\% \text{ RH}, 1 \text{ MHz}) - k'(@ \text{ dry, 1 MHz})]}{53} \times 100\%$$

6.0 Notes

6.1 Additional Reference


1 Scope
This procedure outlines a test method to determine the permittivity (dielectric constant or E’r) and loss tangent (dissipation factor or Tanδ) of printed wiring materials at various frequencies (from 1 MHz to 1.5 GHz) using a single test fixture for the measurement.

The permittivity and loss tangent are measured using a narrow sweep of frequency around the target or desired frequency. The test method is built around the capability of currently available materials analyzers, which use a capacitance method to determine permittivity.

This test method is not intended for low loss materials, such materials may be tested at fixed frequencies using other IPC test methods.

2 Applicable Documents
HP 4291A-5 Product Note “Dielectric Constant Evaluation of Rough Surface Materials,” which describes how to make accurate measurements using the HP 4291A and HP 16453A.

HP Application Note 380-1 “Dielectric Constant Measurements of Solid Materials,” which contains a technical background, suitable for this subject.

3 Test Specimen
3.1 Each specimen shall be 50 mm x 50 mm by the thickness of the substrate material. Within the limits of the test fixture, the thicker the sample the less error in the measurements. Multilayer samples can be used to increase the thickness of the sample, but these cannot be simple stacked layers; they must be physically bonded with no air gaps between the layers. A target thickness would be 1.0 mm, but both thinner and thicker samples will work.

3.2 Three specimens are required for this test.

3.3 All materials are affected by moisture, including all reinforced laminates and most films. Therefore, all samples shall be conditioned at 23°C ± 2°C and 50% RH ± 5% RH for a minimum of 24 hours prior to testing. However, if a sample has recently been etched or exposed to excessive moisture, it should be dried in an air-circulating oven for two hours at 105°C +5°C, -2°C prior to testing and conditioned at room temperature as mentioned above.

3.4 Sample Surface Preparation
3.4.1 It is preferred that the sample be patterned with a conductive material in the shape and size of the test electrode. This conductive material is preferably 100 angstroms of vapor deposited copper. Other metals may be used. In all cases, the conductor on the sample must make good electrical contact with the fixture electrode. Such a conductive pattern eliminates air gaps and other potential sample mounting errors.

3.4.2 Bare dielectric materials may be tested with this test method. The fixture electrodes must be applied with some level of force to ensure a gap-free contact area. Determining the correct force setting may require some trial and error testing for each type of sample (see 6.4).

4 Equipment/Apparatus
4.1 The Hewlett-Packard Impedance Material Analyzer, model 4291A, or equivalent is recommended.

4.2 Hewlett-Packard model number 16453A test fixture, or equivalent

4.3 An appropriate calibration-verification kit and a fixture-correction kit as recommended in the instrument’s manual (i.e., HP4291A Calibration kit). Such a kit usually includes the following devices:

- OPEN and SHORT for fixture correction
- 50 Ohms impedance
- Dielectric (PTFE) of known characteristic for the purpose of the calibration verification

4.4 Micrometer, capable of 0.001 mm resolution

4.5 Circulating oven capable of 105°C +5°C, -2°C

5 Procedure
5.1 Calibrate the instrument using the calibration kit according to the recommendations of the instrument manufacturer.
5.2 Set up the unit to sweep the target frequency ± 0.5% of the target.

5.3 Measure the sample thickness with the micrometer and insert into the test fixture. The sample must make good contact with the fixture electrodes (see 6.1 concerning the proper force to be applied). The sample must not touch the back wall of the fixture. The sample electrode placement and thickness measurement shall be obtained from the same area of the sample.

5.4 Run the test and record the average permittivity and loss over the narrow frequency range sweep. The scanned data may also be saved on disk. See 6.2 for comments on expected behavior for permittivity as a function of frequency.

5.5 Repeat 5.1 through 5.4 for all desired frequencies.

5.6 Report the average permittivity and loss at the frequencies requested.

6 Notes

6.1 Correct calibration and operation of the test equipment is required to obtain accurate measurement of permittivity and loss. Proper sample preparation is also very important for obtaining useful data from this test. Calibrate the materials analyzer in accordance with manufacturer’s instructions. An automatic program has been developed for the HP 4291A, which will ease calibration and setup (see 6.6).

6.2 The permittivity should decrease slightly with increasing frequency. If it increases greatly or decreases more than 0.2 units from approximately 20 MHz to 1.2 GHZ, reposition (reset) the sample in the fixture and measure again (check for debris between the electrodes; blow out with air).

6.3 Testing at temperatures and humidities other than room temperature may be performed with this instrument, as a specialized fixture can be placed in a temperature chamber. A temperature chamber must be used when testing with this fixture under conditions where condensation might contaminate the electrodes, as such contamination gives spurious results.

6.4 The pressure of the test fixture on the specimen affects the measured permittivity and loss values, in particular for un-metallized test specimens. Too light of pressure reduces the area of electrode/sample contact, thus leaving air gaps, which result in erroneous measurements. If the pressure is too high, the sample can be reduced in thickness and the measured values would be incorrect because the thickness is unknown. Making measurements while adjusting the force should lead the operator to a force setting where the measured value is independent of the force applied.

6.5 The HP 4291 Materials Analyzer and related fixtures and calibration kits are available from Hewlett Packard, (800) 452-4844.

6.6 Reference Program for Automatic Calibration and Operation This automatic calibration and operation program was developed for the HP 4291A and is published in this method as a reference. Although the program listed in this section has been tested and used, it is given here for “reference only.”

6.6.1 Procedure Using Automatic Program Turn on the analyzer with the program/calibration disk in the drive and follow the user friendly calibration instructions, which appear on the monitor. The calibration on the HP4291 lasts about 24 hours; after that, it begins to drift and provides slightly higher values as a function of time. The calibration procedure in 6.6.1.1 through 6.6.1.10 should therefore be performed, at a minimum, on a daily basis. During the calibration procedure, the line traces on the monitor should be observed during each step. Noisy or erratic traces are an indication of external interference. If noise is observed, the calibration procedure should be aborted and rerun. Clean the electrode on the test head, standards, and fixture connections and electrodes on a regular (weekly) basis. Blow dry.

6.6.1.1 Allow at least 30 minutes for the unit to warm up and stabilize.

6.6.1.2 As the unit is a frequency sweeping unit, enter the start and stop frequency (in megahertz) of the test (single frequency tests use close start/stop frequencies, which should be ± 0.5% of the target frequency).

6.6.1.3 Place the OS (open) calibration standard on the test head as prompted on the unit’s monitor and press Return on the unit’s keyboard or “x1” on the unit.
6.6.1.4 Place the 0Ω (short) calibration standard on the test head as prompted on the unit’s monitor and press Return on the unit’s keyboard or “x1” on the unit.

6.6.1.5 Place the 50Ω calibration standard on the test head as prompted on the unit’s monitor and press Return on the unit’s keyboard or “x1” on the unit.

6.6.1.6 Place the HP 16453A test fixture or equivalent on the test head as specified in accordance with the manufacturer’s instructions as prompted on the unit’s monitor.

6.6.1.7 Open the fixture gap and lock it open as prompted on the monitor and press Return on the unit’s keyboard or “x1” on the unit.

6.6.1.8 Short the fixture gap as prompted on the monitor and press Return on the unit’s keyboard or “x1” on the unit.

6.6.1.9 Place the pure PTFE specimen in the fixture in close contact with electrodes and with the PTFE specimen not touching the back wall of the fixture, then press Return on the unit’s keyboard or “x1” on the unit. Pull out the PTFE and recheck. Permittivity should be within ± 0.01 or ± 0.02 units. If not, recalibrate starting at “Fixture.” If it is still off, redo the calibration from beginning.

6.6.1.10 Test the sample in accordance with Section 5.

6.6.2 The following calibration/test program is the latest version of what was developed for the P H4291A. Using a text editor (no embedded coding), enter this program on a DOS-formatted disk and name it “AUTOST.” Place the disk in the unit and turn it on (If you have any improvements PLEASE forward them to the IPC): The program disk will calibrate and configure the instrument’s screen. Two windows will appear. The top window should be permittivity (E'r) and the bottom window should be loss tangent (δ). Both windows should be set to the frequency range entered in 6.3.1.2. If they are not, return to 6.3.1 and repeat the process.

100 !**** PLEASE SET PTFE THICKNESS ON LINE 1610 AND 2600 ****
110 !**** PLEASE SET PTFE PERMITTIVITY ON LINE 2580 ****
120 !**** PLEASE SET PTFE LOSS TANGENT ON LINE 2590 ****
130 !****
200 !**** SAVE THIS PROGRAM ON A DOS FORMATTED DISK USING A TEXT EDITOR (LINES 100-5000
1530 !
1600 !***** SET PTFE STANDARD THICKNESS IN METERS ON LINE 1610****
1610 OUTPUT @Hp4291;:"CALC:MATH1:DIM1 0.00075"
1620 !
1700 !***** MEASUREMENT TYPE er' AND tan delta ****
1710 OUTPUT @Hp4291;:"DUAM DRLT"
1720 !
1800 !***** FORMAT LINES LIN Y-AXIS ****
1810 OUTPUT @Hp4291;:"DISP:TRAC:Y:SPAC LIN"
1820 !
1900 !***** SWEEP SETTINGS ****
1910 OUTPUT @Hp4291;:"SENS:SWE:SPAC LOG"
1920 OUTPUT @Hp4291;:"SENS:SWE:TIME:AUTO ON"
1930 OUTPUT @Hp4291;:"SENS:SWE:POIN 256"
1940 OUTPUT @Hp4291;:"SENS:SWE:DWEL1:AUTO ON"
1950 !
2000 !***** CHANNEL 1 SETUP ****
2010 OUTPUT @Hp4291;:"INST CH1"
2020 OUTPUT @Hp4291;:"CALC:FORM REAL"
2030 OUTPUT @Hp4291;:"DISP:TRAC1:STAT ON"
2040 OUTPUT @Hp4291;:"DISP:TRAC1:Y:BOTT 1"
2050 OUTPUT @Hp4291;:"DISP:TRAC1:Y:TOP 12"
2060 OUTPUT @Hp4291;:"CALC:CALC:ON""""TR1"""
2070 OUTPUT @Hp4291;:"CALC:CALC:Y:XPOS 1MHZ"
2080 OUTPUT @Hp4291;:"CALC:CALC:Y:MST ON"
2090 !
2200 !***** CHANNEL 2 SETUP ****
2210 OUTPUT @Hp4291;:"INST CH2"
2220 OUTPUT @Hp4291;:"CALC:FORM LTAN"
2230 OUTPUT @Hp4291;:"DISP:TRAC1:STAT ON"
2240 OUTPUT @Hp4291;:"DISP:TRAC1:Y:BOTT -0.5"
2250 OUTPUT @Hp4291;:"DISP:TRAC1:Y:TOP 15"
2260 OUTPUT @Hp4291;:"CALC:CALC:ON""""TR1"
2270 OUTPUT @Hp4291;:"CALC:CALC:Y:XPOS 1MHZ"
2280 OUTPUT @Hp4291;:"CALC:CALC:Y:MST ON"
2290 OUTPUT @Hp4291;:"INST CH1"
2300 !
2400 !***** SETUP AVERAGING ****
2410 OUTPUT @Hp4291;:"SENS:AVER1 ON"
2420 OUTPUT @Hp4291;:"SENS:AVER1:COUN 10;STAT ON"
2430 !
2500 !***** SELECT 16453A FIXTURE AND COMPENSATE ****
2510 !***** PLEASE SET PTFE STANDARD PERMITTIVITY ON LINE 2580 ****
2520 !***** PLEASE SET PTFE STANDARD LOSS TANGENT ON LINE 2590 ****
2530 !***** PLEASE SET PTFE STANDARD THICKNESS IN METERS ON LINE 2600 ****
2540 OUTPUT @Hp4291;:"DISP:FORM ULOW"
2550 OUTPUT @Hp4291;:"DISP:ALL BST"
2560 OUTPUT @Hp4291;:"SYST:FIXT HP16453"
2570 OUTPUT @Hp4291;:"SENS:CORR2:CKIT2 TEFL"
2580 OUTPUT @Hp4291;:"SENS:CORR2:CKIT2:STAN6:PRE 2.1"
2590 OUTPUT @Hp4291;:"SENS:CORR2:CKIT2:STAN6:PLF 0.0001"
2600 OUTPUT @Hp4291;:"SENS:CORR2:CKIT2:STAN6:THIC 0.00075"
2610 OUTPUT @Hp4291;:"SENS:CORR2:CKIT2:SAVE"
2620 !
2700 !***** OPEN STANDARD MEASUREMENT ****
2710 ON INTR Scode GOTO Open_end
2720 OUTPUT @Hp4291;:"CLS;"Opc"
2730 ENTER @Hp4291;Opc
2740 INPUT "CONNECT OPEN (OS) STANDARD, THEN PRESS [RETURN OR x1]",A$
2750 ENABLE INTR Scode;2
2760 OUTPUT @Hp4291;:"SENS:CORR1:COLL STAN1"
2770 Wait_open:GOTO Wait_open
2780 Open_end:!
2790 !
3100 !***** 50 OHM LOAD STANDARD MEASUREMENT ****
3110 ON INTR Scode GOTO Load_end
3120 OUTPUT @Hp4291;:"CLS;"Opc"
3130 ENTER @Hp4291;Opc
3140 INPUT "CONNECT 50 OHM STANDARD, THEN PRESS [RETURN OR x1]",A$
3150 ENABLE INTR Scode;2
3160 OUTPUT @Hp4291;:"SENS:CORR1:COLL STAN2"
3170 Wait_load:GOTO Wait_load
3180 Load_end:!
3190 !
3300 !***** SAVE UNIT CALIBRATION ****
3310 OUTPUT @Hp4291;:"SENS:CORR1:COLL:SAVE"
3320 !
3330 !**** END CALIBRATION OF UNIT ****
3340 !
3400 ! **** OPEN 16453A FIXTURE MEASUREMENT ****
3410 ON INTR Scode GOTO Open_end1
3420 OUTPUT @Hp4291;"*CLS;*OPC?"
3430 ENTER @Hp4291;Op
3440 INPUT "CONNECT FIXTURE AND LOCK GAP OPEN, THEN PRESS [RETURN OR x1]",A$
3460 ENABLE INTR Scode;2
3470 OUTPUT @Hp4291;"SENS:CORR2:COLL STAN4"
3480 Wait_open1:GOTO Wait_open1
3490 Open_end1:!
3500 !
3600 ! **** 16453A FIXTURE SHORT MEASUREMENT ****
3610 ON INTR Scode GOTO Short_end1
3620 OUTPUT @Hp4291;"*CLS;*OPC?"
3630 ENTER @Hp4291;Op
3640 INPUT "CLOSE AND SHORT FIXTURE GAP, THEN PRESS [RETURN OR x1]",A$
3650 ENABLE INTR Scode;2
3660 OUTPUT @Hp4291;"SENS:CORR2:COLL STAN5"
3670 Wait_short1:GOTO Wait_short1
3680 Short_end1:!
3690 !
3800 ! **** TEFOLON LOAD IN 16453A MEASUREMENT ****
3810 ON INTR Scode GOTO Load_end1
3820 OUTPUT @Hp4291;"*CLS;*OPC?"
3830 ENTER @Hp4291;Op
3840 INPUT "PLACE TEFOLON STANDARD INTO FIXTURE, THEN PRESS [RETURN OR x1]",A$
3850 ENABLE INTR Scode;2
3860 OUTPUT @Hp4291;"SENS:CORR2:COLL STAN6"
3870 Wait_load1:GOTO Wait_load1
3880 Load_end1:!
3890 !
4000 ! **** SAVE FIXTURE COMPENSATION SETTINGS ****
4010 OUTPUT @Hp4291;"CALC;MATH1:DIM1 ";B
4160 OUTPUT @Hp4291;"CALC;MATH1:DIM1 ";B
4170 ON INTR Scode GOTO Sweep1_end
4180 OUTPUT @Hp4291;"STAT:INST:ENAB 1"
4190 OUTPUT @Hp4291;"SRE 4"
4300 OUTPUT @Hp4291;"CLS;*OPC?"
4310 ENTER @Hp4291;Op
4320 OUTPUT @Hp4291;"ABOR"
4330 ENABLE INTR Scode;2
4340 OUTPUT @Hp4291;"INIT"
4350 GOTO Wait:GOTO Waiting
4360 Sweep1_end:!
4370 !
4400 ! **** SAVE DATA ROUTINE ****
4410 INPUT "SAVE DATA? [1] Yes; [0] No [RETURN OR x1]",Ans$
4420 IF Ans$<>"1" THEN GOTO Sweep1_Begin
4430 INPUT "Input Job Number [RETURN OR x1]",Job$
4440 OUTPUT @Hp4291;"MMEM:STOR:DINT:TRAC SEL,";Job$;""""DISK"""
4450 GOTO Sweep1_Begin
4460 ! **** END MEASUREMENT LOOP ****
4470 !
5000 END
1.0 **Scope**

This method describes a procedure for determining the ability of rigid insulating materials to resist breakdown parallel to laminations (or in the plane of the material) when subjected to extremely high voltages at standard AC power frequencies of 50-60Hz.

As for most electrical properties, values obtained on most materials are highly dependent on the moisture content and tests using different conditioning cannot be compared. Tests in other mediums, e.g., air are generally impractical due to its relatively low breakdown.

This method is based on the test technique described as ASTM D229.

2.0 **Applicable documents**

- ASTM D229 Standard Method of Testing Rigid Sheet and Plate Materials Used for Electrical Insulation
- ASTM D149 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

3.0 **Test Specimens**

3.1 **Number**

Four specimens shall be tested. When specified, two shall be in the machine direction and two in the transverse direction for reinforced materials.

3.2 **Form**

Specimens shall be approximately 3.0 inch X 2.0 inch X thickness and shall be prepared by shearing or sawing the specimen from the test sample. Two holes 0.188 inch in diameter are to be drilled along the center line of the 3.0 inch dimension and midway between the edges in the 2.0 inch dimension, with a spacing of 1.0 inch ± .01 inch center to center.

3.3 **Location**

The specimens may be cut from any location in the sheet (except from the outer 1.0 inch of full size sheets).

3.4 **Foil Clad Material**

Foil clad material shall have all metal cladding removed by etching and shall be thoroughly cleaned prior to conditioning or testing.

4.0 **Apparatus/Materials**

4.1 High voltage breakdown tester (generally 50KV minimum) with current rating of .5KVA up to 10KV and 5KVA above 10KV and a motorized control capable of a 500 volts/second rate of rise.

4.2 Oil tank filled with insulating oil\(^1\) capable of exceeding the requirements of the specification.

4.3 Tapered pin electrode fixture utilizing two American Standard #3 pins. (Note spherical ends on the pins are permitted and recommended to reduce likelihood of breakdown in the oil.)

4.4 High voltage test leads (leads rated in excess of machine capacity are recommended).

4.5 Constant temperature water bath, capable of 50°C ± 2°C, filled with distilled water.

4.6 Beaker or pan filled with ambient temperature distilled water.

4.7 Racks for supporting specimens in the 50°C water bath (with all specimen surfaces exposed).

4.8 Timer 0-60 seconds.

4.9 Lint free paper towels.

5.0 **Procedure**

5.1 **Preconditioning**

Unless otherwise specified the specimen shall be conditioned for 48 hours (+2 hours −0 hours) in distilled water maintained at 50°C ± 2°C.

Following this step the specimen shall be immersed in ambient temperature distilled water for 30 minutes minimum, 4 hours maximum, to allow the specimens to achieve temperature equilibrium without a substantial change in moisture content.

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\(^1\) Insulating Oil: Transfer oil such as Shell Dial Ax may be used. Use of dibutyl phthalate is acceptable but it may cause failure of the adhesives used for plastic tanks.
5.2 Test Condition  The test shall be performed at ambient temperature (23°C ± 5°C). Relative humidity is not significant as the tests are performed under oil.

5.3 Equipment Set Up

5.3.1 Adjust the transformer on the high voltage tester (manually for most models) to the position which will allow for the necessary voltage to be achieved with adequate current capacity for breakdown.

5.3.2 Set the machine for testing using a 500 volt per second rate of rise.

5.4 Test

5.4.1 Remove a preconditioned specimen from the ambient temperature water and wipe dry with a lint free paper towel.

5.4.2 Insert the first specimen into the fixture (inserting the tapered pins from opposite sides) and immerse in the oil bath.

5.4.3 Attach leads (if not permanently wired) so that one high voltage lead is connected to one tapered pin electrode and the ground lead is connected to the other tapered pin electrode.

5.4.4 Operate the tester such that the voltage is applied with a 500 volts per second rate of rise and observe the specimen until an electrical breakdown occurs.

5.4.5 Record the voltage at which breakdown occurs, using the meter memory device if available. Note: If the breakdown appears to be in the oil and no specimen damage is obvious it is recommended that the same sample be retested. If the specimen still will not breakdown due to breakdown of the oil, the oil should be filtered or replaced.

5.4.6 Determine the starting voltage and steps for the remaining specimens from the same sample from Table 1.

5.4.7 Change the high voltage tester to manual (or programmed stepped) operation, remove a specimen from the water bath, wipe dry, and insert the second specimen.

5.4.8 Set the voltage to the 50% value (plus or minus the value of one step) and apply the voltage for 60 seconds.

5.4.9 If no breakdown occurs increase the voltage in steps per Table 1 until the material breaks down or the breakdown capacity of the machine or oil is reached. Record the breakdown voltage to the nearest kilovolt or record “N. B.” if there is no breakdown of the material. Note: If the minimum value required by the material specification is not exceeded, but material breakdown does not occur, it is necessary to replace or filter the oil.

5.4.10 Repeat steps 5.4.7-5.4.9 for the remaining specimens from the sample.

5.5 Calculation

5.5.1 Average the values for the three specimens tested using the stepped technique and round to the nearest kilovolt. Even if some specimens do not break down, the maximum individual voltages will be used to calculate an average. Note: If the accuracy of the meter on the machine is not within 5% for all values in the range, apply a correction obtained from the last machine calibration to each reading to determine the actual value for the dielectric breakdown.

5.6 Report

5.6.1 Report the average value of the dielectric breakdown (if all specimens actually breakdown), e.g., 85KV average.

5.6.2 Report the average with a plus after the value if one or two specimens do not break down, e.g., 82 + KV average 2NB.

5.6.3 Report the minimum value at which the oil broke down, if no actual specimen breakdowns are obtained, e.g., 75 + KV N.B.

5.6.4 Report any anomalies in the test or any variations from prescribed procedures or tolerances.

6.0 Notes

<table>
<thead>
<tr>
<th>Breakdown Voltage (KV)</th>
<th>Increment KV</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 12.5</td>
<td>0.5</td>
</tr>
<tr>
<td>over 12.5 to 25</td>
<td>1.0</td>
</tr>
<tr>
<td>over 25 to 50</td>
<td>2.5</td>
</tr>
<tr>
<td>over 50 to 100</td>
<td>5</td>
</tr>
<tr>
<td>over 100</td>
<td>10</td>
</tr>
</tbody>
</table>
6.1 The dielectric breakdown of the material may be adversely affected if the drilling process used to produce the holes is inadequate. Use of a sharp high speed drill is recommended to prevent burning the material or producing rough holes.

6.2 This test requires voltages which are life threatening. The High Voltage Tester must be installed and operated in accordance with the manufacturer's instructions. If the test chamber is not totally enclosed, with a safety interlock, extreme care must be exercised in performance of the test.
1.0 Scope  The dielectric strength test (also called high-potential [Hi-Pot], over potential, or voltage breakdown) consists of the application of a test voltage for a specific time between mutually insulated portions of a component or between insulated portions and ground. This is used to prove that the component part can operate safely at its rated voltage and withstand momentary overpotentials due to switching, surges, and other similar phenomena.

2.0 Applicable Documents  None

3.0 Test Specimen  Three 102 mm x 102 mm [4 in x 4 in] squares of glass epoxy laminate materials having 1 ounce (0.035 mm [0.0014 in] nominal) copper foil laminates on one side, and having the test specimen polymer film applied to the copper surface (see specimen preparation).

4.0 Apparatus

4.1 A high voltage potential test equipment capable of achieving 500 volts dc per second, up to at least 10,000 volts dc (see paragraph 6).

4.2 Standard ASTM 2 inch diameter electrode having 6.4 mm [1/4 in] radius cover the test surface.

5.0 Procedure

5.1 Preparation of Test Specimen

5.1.1 Cut laminate specimen to 102 mm x 102 mm [4 in x 4 in] and sand edges lightly.

5.1.2 If double clad material is used, etch off all copper foil on one side.

5.1.3 Clean copper foil surface thoroughly, per polymer manufacturer’s recommendations, prior to applying polymer coating.

5.1.4 Apply a film of the polymer test material on an area of 76.2 mm x 76.2 mm [3 in x 3 in] at the center of the copper clad surface. A pinhole-free film is essential.

5.1.5 Cure polymer coating per manufacturer’s recommendations.

5.2 Test

5.2.1 Clip ground terminal of tester over the thickness of the copper foil and substrate, being careful not to let clip extend inward to the polymer coating.

5.2.2 Place positive electrode on top of test panel at the center. Make certain electrode and clip are electrically isolated by the test polymer film.

5.2.3 Set up potential voltage tester. Raise voltage in 500 volt increments per second, until specimen exceeds requirement or failure occurs.

5.3 Evaluation  Determine the dielectric strength by dividing the breakdown voltage by the thickness of the test polymer film to the nearest 0.03 mm [0.001 in]. Record results as “Volts per mil”.

6.0 Notes

6.1 Suggested source for tester: Hipotronics Model HD-140 from Hipotronics, Inc. Brewster, NY 10509, or equivalent.

6.2 Safety must be exercised because of the potential danger of electrical shock.
1.0 Scope
This method describes a technique for evaluating the ability of an insulating material to resist electrical breakdown perpendicular to the plane of the material when subjected to short term, high voltages at standard AC power frequencies of 50-60 Hz.

1.1 Applicability and Use of Data
This method may be used on material of any thickness up to approximately 0.125 inch, however, for material over 0.020 inch, other methods such as dielectric breakdown are normally used to characterize a material’s electrical integrity. Results of this test may be drastically affected by moisture content, and results obtained using different preconditioning may not be comparable.

This method uses an oil medium to prevent flashover on a small specimen and results may not be comparable to tests run in air. Values obtained using this method should not be used for predicting the insulating ability of ultra thin metal clad laminates.

The values determined by this method generally decrease with increasing specimen thickness for otherwise identical material. This method is based on the techniques described in ASTM D149.

2.0 Applicable Document
ASTM D149 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

3.0 Test Specimens
3.1 Number
Three specimens shall be prepared unless otherwise specified.

3.2 Form
Specimens should be 4.0 inch ± 1.0 inch X 4.0 ± 1.0 inch; however, size is not critical as long as no flashover occurs around the edges.

3.3 Location
Specimens shall be cut by any convenient means from both edges and the center of the laminate (except no specimen shall be taken closer than 1 inch from the edge of full size sheets).

3.4 Foil Clad Material
Foil clad materials shall have all metal cladding removed by etching and should be thoroughly cleaned prior to conditioning or testing.

3.5 Uncured Material
Uncured material must be fully cured. Under normal conditions, two ply lamination is recommended for comparison of prepreg material. Single ply laminates are recommended for cover lams and similar products designed for single ply usage.

4.0 Apparatus/Materials
4.1 High voltage breakdown tester, 25 KV, minimum with an adequate current rating, a motorized control capable of 500 volts per second rate of rise and a meter capable of indicating breakdown voltage within 5% over the entire range of actual breakdown voltages (generally 1 KV to 20 KV).

4.2 Oil tank filled with insulating oil.

4.3 Electrode test set 2 inch diameter electrodes with 1/4 inch radius on the edge of the electrodes and 50 g. ± 2 g. load applied by the weight of upper electrode (in air).

4.4 Two high voltage test leads (leads rated in excess of the tester voltage capability are recommended).

4.5 Micrometer capable of resolving at least 0.0001 inch. Note: For accurate measurement of material under 0.005 inch test accuracy may be severely limited by the ability to measure the specimen accurately.

4.6 Constant temperature water bath, capable of maintaining 50°C ± 2°C, filled with distilled water.

---

1. Edges: For a reinforced laminate the specimens shall be from opposite edges of the reinforcement.
2. Current capacity: 40 milliamps is normally satisfactory.
3. Insulating oil: Shell Dial AX Insulating Oil has been found suitable for breakdowns up to 100 KV.
4.7 Large beaker or pan filled with ambient temperature distilled water.

4.8 Rack for supporting and separating specimens in the 50°C water bath.

4.9 Lint free paper towels.

5.0 Procedure

5.1 Preconditioning Unless otherwise specified, the specimen shall be conditioned for 48 hours (+2 hours –0 hours) in distilled water maintained at 50°C ± 2°C. Following this the specimen shall be immersed in the ambient temperature distilled water for 30 minutes minimum, 4 hours maximum, to achieve temperature equilibrium without significant changes in moisture content.

5.2 Test Conditions The test should be performed at ambient temperature, 23°C ± 5°C. Relative humidity is not significant as the tests are performed under oil.

5.3 Equipment Set Up

5.3.1 Set the high voltage tester in accordance with the manufacturer’s instructions so that the voltage range will be adequate for the material being tested.

5.3.2 Set up the control for testing using a 500 volt per second rate of rise.

5.3.3 Attach the leads (if not permanently wired) such that the high lead is connected to one electrode and the ground lead is connected to the other electrode.

5.4 Test

5.4.1 Remove a preconditioned specimen from the ambient temperature water and wipe dry with a lint free paper towel.

5.4.2 Determine and record the thickness of the specimen at four locations 1 inch from the edge at the midpoint of each side.

5.4.3 Insert the specimen into the test fixture centering it to reduce chances of flashover.

5.4.4 Operate the tester such that the voltage is applied with a 500 volts per second increase and observe the point at which the tester indicates a breakdown.

5.4.5 Record the breakdown voltage to the nearest .1 KV for values over 10 KV and to at least the nearest 5% for all lower values.

5.4.6 Remove the specimen from the oil medium and verify that a breakdown has occurred. If none is apparent reinsert the specimen, carefully centering it, and retest as in 5.4.4 and 5.4.5. Note: If flashover occurs, either a larger specimen or new oil must be used.

4.7 Test the remaining two specimens as in 5.4.1 through 5.4.6.

6.0 Calculations

6.1 Calculate the average thickness for each specimen from the four individual values measured.

6.2 Determine the electric strength in volts per mil for each specimen by dividing the breakdown voltage expressed in kilovolts by the thickness expressed in inches.

\[
ES = \frac{6.8\text{ KV}}{0.005\text{ inch}} \times \frac{1000\text{ V}}{\text{KV}} \times \frac{1\text{ inch}}{1000\text{ mils}} = 1360\text{ v/mil}
\]

6.3 Determine the average electric strength by averaging the individual values for each specimen. Round the average to the nearest 10 volts/mil.

6.4 If any specimen falls below the specification minimum, calculate the percentage of the requirement:

\[
ES_{\text{min}} = \frac{\text{Lowest Value}}{\text{Spec Value}} \times 100\%
\]

e.g. Value = 670 volts per mil
 Specification = 750 volts per mil

\[
ES_{\text{min}} = \frac{670}{750} \times 100\% = .893 \times 100\% = .89 \times 100\% = 89\%
\]

7.0 Report

7.1 Report the average value for electric strength in volts per mil to the nearest 10 volts per mil.
7.2 Report the minimum value in percent of requirement if it is below the requirement for average electric strength.

7.3 Report the actual thickness range of the material tested including the minimum and maximum individual thickness measurements.

7.4 Report any anomalies in the test or any variations from the prescribed procedures or tolerances.

8.0 Notes

8.1 This test method may be modified to an air medium to predict performance in normal environments more accurately, however, unless the electrode is effectively guarded, the breakdown will generally occur in air.

8.2 For testing the effect of copper foil on clad laminate under 0.005 inch it is suggested that two inch circular electrodes be left on the 4 inch X 4 inch specimen by etching. The ground electrode may be slightly larger to assure registration.

8.3 For materials which are compressible, a standard pressure of 25 PSI is to be used for determining specimen thickness.
1 Scope  These methods are designed for use in determining the dielectric strength of solid electrical insulating materials.

2 Applicable Documents  None

3 Test Specimens

3.1 Dimensions  The specimens shall be of such a diameter that flashover will not occur. This usually means that the diameter should be 76 mm or more.

3.2 Thick Solid Materials  The breakdown voltage of thick solid materials may be so high that special test specimens cut or molded in reduced thickness may be required.

3.3 At Various Thicknesses  When it is desired to determine the dielectric strength for different thicknesses of a material, it is necessary to test each different thickness, unless the variation due to thickness is already known.

3.4 Exceptional Conditions  The special sizes of specimens required for determining dielectric strength under exceptional conditions shall be as specified in the material specification.

4 Equipment/Apparatus

4.1 Transformer  The desired test voltage may be most readily obtained by a step-up transformer energized from a variable low-voltage source. The transformer and its controlling equipment shall be of such size and design that the test specimen in circuit, the crest factor (ratio of maximum to mean effective) of the test voltage shall not differ by more than ± 5% from that of a sinusoidal wave over the upper half of the range of test voltage. The crest factor may be checked by means of a sphere gap or peak-reading voltmeter in conjunction with a r.m.s. voltmeter. For test specimens of small capacitance, a testing transformer as small as 500-volt-ampere rating must be used. Where the wave-form cannot be determined conveniently, a transformer having a rating of not less than 2 kilovolt amperes shall be used for voltages not exceeding 50,000 volts. Tests shall be made at commercial power frequencies. When a transformer is used at voltages lower than its full rating, the current drawn from the high-voltage winding should not exceed the full-load full-voltage current rating.

4.2 Circuit Breaker  The test transformer circuit shall be protected by an automatic circuit-breaking device designed to open instantaneously on the current produced by breakdown of the test specimen. Excessive flow of current at the time of breakdown causes pitting and heating of the electrodes and thereby increases the work of electrode maintenance and time of testing.

4.3 Voltage Control  The rate of voltage rise shall not, for short time tests, vary more than ± 25% from the specified rate. Control of voltage may be secured in one of several ways:
   a. Variable-ratio autotransformer
   b. Resistance-potential divider
   c. Generator-field regulation
   d. Induction regulator
   Preference should be given to equipment having an approximately straight-line voltage-time curve over the desired operating range. Motor drive with variable speed control should be preferred to manual drive because of the difficulty in maintaining reasonable uniform rate of voltage rise with the latter.

4.4 Voltmeter  The voltage shall be measured by an approved method, which gives root-mean-square values, preferably by means of
   a. A voltmeter connected to the secondary of a separate potential transformer
   b. An electrostatic voltmeter in the secondary circuit
   c. A voltmeter connected to a well-designed tertiary coil in the test transformer. A voltmeter connected to the primary side of the testing transformer may be used only if the ratio of transformer does not change appreciably with load.

4.5 Electrodes  The electrodes used for thin solid materials (sheets and plates) shall be metal disks 5 mm in diameter and 25 mm in length, with the edges rounded to a radius of 6.4 mm. The electrodes used for thick solid materials shall be metal disks 25 mm in diameter and 25 mm in length, with edges rounded to a radius of 3.2 mm. The electrodes for tapes and sheet materials to be compared with tapes shall be
opposing cylindrical rods 6.4 mm in diameter, with edges rounded to a radius of 0.75 mm. The upper movable electrodes shall weigh 45.35g ± 2g. When 6.4 mm electrodes are used, it is advisable that they be surrounded by guard electrodes or shrouds.

4.5.1 The dielectric strength of an insulating material varies with the thickness of the material and the area and geometry of the test electrodes, and these should be specified in the specification. Tests made with different electrodes are not comparable. Where materials are made up into forms of uniform thickness, such as sheets and plates, tests shall be made upon that thickness of material. In other cases, a thickness of the test specimen and diameter and shape of the electrode have been selected, which are compatible with convenience of testing.

4.6 Equipment Testing Apparatus

4.6.1 For Tests Made in Air Use may be made of any well designed oven of sufficient size to hold the test equipment. It should be provided with some means of circulating air so that approximately constant temperature is maintained around the test specimen and with a thermometer or thermocouple for measuring the temperature as near the point of test as practicable to the nearest 1°C.

4.6.2 For Test Under Oil Use may be made of an oil bath, provided with some means for circulating the oil so that the temperature is substantially uniform around the test specimens and with a thermometer or thermocouple for measuring the temperature as near the point of test as practicable to the nearest 1°C.

5 Procedure

5.1 Test Medium The medium to be used in the tests should be specified in the specification. In general, it is preferable to test materials in the medium, whether air or oil, in which they are to be used. Where conditions of use are not well defined, materials should be tested in air up to the point where the breakdown is so high that an excessive amount of material is required to prevent flashover to excessive burning of the surface. For specimens having a high breakdown, such as the thicker and highgrade materials, it is usually necessary to make dielectric strength tests under oil; however it should be understood that breakdown values obtained under oil are not comparable with those obtained in air.

5.2 Preparing Specimens

5.2.1 In the preparation of test specimens, care shall be taken to have the surfaces adjacent to the electrodes parallel and as plane and smooth as the material permits. The dielectric strength of an insulating material varies with the thickness of the test specimen. Therefore, tests on specimens of different thicknesses are not comparable. The thickness used shall be the average thickness of the sample measured as specified in the specification involved.

5.2.2 The dielectric strength of most insulating materials varies with temperature and humidity. The test conditions to be used should be specified in the specification. Usually it is desirable to determine the dielectric behavior of a material over the range of temperature and humidity to which it is likely to be subjected in use. When required, materials may be conditioned in a suitably controlled chamber. The test specimen shall be kept in the chamber long enough to reach a uniform temperature and humidity prior to testing. When required, the dielectric strength tests shall be made on the specimen while still in the conditioning chamber. For purpose of tests, a high-voltage conductor may be conveniently carried into the chamber through an insulating bushing.

5.3 Positioning and Care of Electrodes Electrodes shall be held truly coaxial. Where electrodes have flat test faces, the latter shall be parallel to each other. The test faces shall be kept smooth and polished and free from pitting.

5.4 Application of Voltage

5.4.1 Test for Specified Minimum Requirement The voltage shall be applied and increased at a uniform rate from zero to the value specified in the material specification and shall be held at the value for the specified time. Unless otherwise specified, the rate of rise per second shall be 5% of the specified voltage. Note that this test is to check for ability to withstand a specified voltage and not to determine the breakdown value.

5.4.2 Test to Breakdown, Short-time Test The voltage shall be increased from zero to breakdown at a uniform rate. The rate of rise shall be 0.5 or 1.0 kilovolts per second. Depending on the total test time required and the voltage-time characteristic of the material. The rate of rise of voltage should be specified in the material specification.
5.4.3 **Test to Breakdown, Step-by-Step Test** An initial voltage shall be applied equal to 50% of the breakdown voltage in the short-time test, adjusted as shown in Table 1.

<table>
<thead>
<tr>
<th>Breakdown voltage by short-time method</th>
<th>Adjust 50% of breakdown voltage to nearest</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 kilovolts or less</td>
<td>1.0 kilovolt (unless otherwise specified)</td>
</tr>
<tr>
<td>Over 25 to 50 kilovolts, inclusive</td>
<td>2.0 kilovolts</td>
</tr>
<tr>
<td>Over 50 to 100 kilovolts, inclusive</td>
<td>5.0 kilovolts</td>
</tr>
<tr>
<td>Over 100 kilovolts</td>
<td>10.0 kilovolts</td>
</tr>
</tbody>
</table>

The voltage shall then be increased in equal increments as stated in the various material specifications, the voltage being held at each step for a definite time as stated in the specifications. The change from each step to the next higher shall be made as rapidly as possible and the time of change included in the succeeding test interval.

5.4.4 **Test to Breakdown, Slow-Rate-of-Test** An initial voltage shall be applied equal to approximately 50% of the breakdown voltage in the short time test, unless otherwise specified. The voltage shall then be increased at a uniform rate up to the point of breakdown. Unless otherwise specified, the rate should be chosen to give approximately the same voltage-time exposure of the test specimen, as provided in the step-by-step test.

5.4.5 **Determining Rate of Rise of Voltage** The rate of voltage rise may be calculated from measurements of time required to raise the voltage between two prescribed values. When motordriven regulating equipment is used, the speed-control rheostat may be calibrated in terms of voltage rise for any particular test transformer.

5.5 **Number of Tests** Unless otherwise specified, five tests shall be made. If the average deviation from the mean exceeds 10% or if any individual test deviates more than 15% from the mean, five additional tests shall be made.

5.6 **Report** The report shall include the following data:

1. The average thickness of the sample
2. Breakdown voltage at each puncture
3. Volts per mil for each puncture
4. The average, maximum, and minimum volts per 0.0075 mm for each sample
5. The temperature of the surrounding medium should be recorded
6. The RH% of the surrounding air
7. The conditioning treatment
8. The duration of the test
9. In the step-by-step test, the value of the initially applied voltage and the voltage increment
10. In the slow rate of rise test, the value of the initially applied voltage and the rate of rise of the voltage
11. The size and type of electrodes
12. The test medium (air or type of oil)

**Notes** Due to the high voltage used in this test method, extreme caution should be exercised.
1.0 Scope  The dielectric withstanding voltage test (also called high-potential, over potential, voltage breakdown, or dielectric strength test) consists of the application of a voltage higher than rated voltage for a specific time between mutually isolated portions of a PWB or between isolated portions and ground. This is used to prove that the PWB can operate safely at its rated voltage and withstand momentary over potentials due to switching, surges, and other similar phenomena. Although this test is often called a voltage breakdown or dielectric strength test, it is not intended that this test cause insulation breakdown or that it be used for detecting corona, rather it serves to determine whether insulating materials and/or conductor spacings are adequate.

2.0 Applicable Documents  None

3.0 Test Specimen  The test specimen shall be comprised of a minimum of two conductor lines per conductive layer, sufficient to allow a voltage to be applied between adjacent conductor patterns both between conductive layers and on the same conductive layer (see note 6.1).

4.0 Apparatus or Material

4.1 A high voltage source capable of supplying the specified voltage with a tolerance of ± 5% (see note 6.2).

4.2 A voltage measuring device with an accuracy of 5%. If leakage current measuring capability is required, the device shall be capable of detecting the leakage current to within 5% of the requirement.

4.3 Soft bristle brush

4.4 Deionized or distilled water (2 megohm-cm minimum resistivity recommended)

4.5 Isopropyl alcohol

4.6 Drying oven

5.0 Procedure

5.1 Specimen Preparation  (see note 6.3)

5.1.1 Positive, permanent, and non-contaminating identification of test specimen is of paramount importance.

5.1.2 Visually inspect the test specimens for any obvious defects, as described in the applicable performance specification. If there is any doubt about the overall quality of any test specimen, the test specimen should be replaced and this replacement noted.

5.1.3 Solder single stranded (to simulate discrete component axial leads) polytetrafluroethylene (PTFE) insulated wires in each of the connection points of the test specimens. These wires will be used to connect the test patterns of the test specimens to the high voltage source.

5.1.4 Wet test lead terminals with deionized or distilled water and scrub with a soft bristle brush for a minimum of 30 seconds. During the remainder of the test specimen preparation, handle test specimens by the edges only (see note 6.4).

5.1.5 Spray rinse thoroughly with deionized or distilled water. Hold test specimen at an approximate 30° angle and spray from top to bottom.

5.1.6 Wet test lead terminals with clean isopropyl alcohol and agitate for a minimum of 30 seconds. Scrub with a soft bristle brush to remove flux residue.

5.1.7 Rinse cleaned area thoroughly with fresh isopropyl alcohol.

5.1.8 Dry test specimens in a drying oven for a minimum of three hours at an oven temperature of between 49 to 60°C (120 to 140°F).

5.1.9 Allow the test specimens to cool to room temperature. (see note 6.5)

5.2 Test  (see note 6.6)
5.2.1 Raise the test voltage from zero to one of the following specified test condition values (see note 6.2) as uniformly as possible, at a rate of approximately 100 volts DC per second. If the test condition is not specified Condition A shall be the default.

Condition A: 500+15/-0 volts DC
Condition B: 1000+25/-0 volts DC

5.2.2 Maintain the test voltage at the specified value for a period of 30+3/-0 seconds.

5.2.3 Upon completion of the test, the test voltage shall be gradually reduced to avoid surges.

5.3 Evaluation Examine the test specimens and note any evidence of inadequate insulating materials and/or conductor spacing (i.e., visually inspect for flashover, sparkover or breakdown between conductor patterns or between conductor patterns and mounting hardware).

6.0 Notes

6.1 Recommended test specimens include “Y” test patterns (also referred to as “E” test coupons) or “comb patterns.” Production printed boards may also be used as test specimens.

6.2 Performance specifications should specify the high voltage test condition and any deviations to this test method. If no test condition is specified, use test condition A.

6.3 This test method may be performed on test specimens which have previously been prepared and tested for moisture and insulation resistance.

6.4 Alternative cleaning procedures may be implemented if there is a concern that scrubbing will adversely affect test results, i.e., when the test specimens have very fine spacing and/or are plated with soft metals (tin/lead, gold, etc.).

6.5 Insulating compound (conformal coating) may be applied to the test specimens following soldering and cleaning. Any coating application and cure shall be as specified by the coating supplier.

6.6 The testing process outlined in section 5.2 should be used for qualification testing. For in-plant quality conformance testing, the following testing modifications may be chosen:

6.6.1 At the option of the customer, reduced time with a possible correlated higher test voltage may be used.

6.6.2 At the option of the customer, an AC test voltage may applied.

6.6.3 At the option of the customer, the test voltage may be applied instantaneously.
1 Scope  The dielectric withstanding voltage test (also called high-potential, over potential or voltage breakdown test) consists of the application of a voltage higher than rated voltage for a specific time between mutually isolated portions of a PWB or between isolated portions and ground. This is used to prove that the PWB can operate safely at its rated voltage and withstand momentary over potentials due to switching, surges, and other similar phenomena. Although this test is often called a voltage breakdown test, it is not intended that this test cause insulation breakdown or to be used for detecting corona. Rather, it serves to determine whether insulating materials and/or conductor spacings are adequate.

2 Applicable Documents

IPC-CC-830  Qualification and Performance of Electrical Insulating Compound for Printed Board Assemblies
IPC-A-600  Acceptability of Printed Wiring Boards
MIL-STD-202  Method 301
J-STD-004  Requirements for Soldering Fluxes

3 Test Specimens

3.1 Qualification Testing, Classes 1-3  Five IPC-B-25A boards (see Figure 1) using the D comb pattern (one uncoated and four coated) with conformal coating according to the coating suppliers recommendations.

3.2 Conformance Testing  Five IPC-B-25A Boards (See Figure 1) containing the C pattern (“Y” shape pattern) with 0.635 mm lines/0.635 mm spacing [25.00 mil lines/25.00 mil spacing] or minimum spacing on the production board, whichever is smaller, coated with conformal coating according to the coating supplier’s recommendations.

4 Apparatus

4.1 Soldering Iron

4.2 Flux  Water white rosin (R or RMA) with halide content less than 0.5%, i.e., type Symbol A and B or ROL0 and ROL1 according to J-STD-004.

Figure 1  IPC-B-25A Test Board (Leads on D Pattern Are Identified)

4.3 Hi-Pot Tester  Capable of supplying a test voltage of 1,500 VAC at 50-60 hertz (Hz) and able to record a leakage rate.

4.4 Timer

4.5 Oven  Capable of maintaining 60°C [140°F].

4.6 Desiccator

5 Test Specimens Preparation Prior to Testing

5.1 Solder wires to the finger tabs on the “D” comb pattern using R or RMA flux.

5.1.1 Clean the specimens using a soft bristle brush while rinsing with deionized water for 30 seconds.
5.1.2 Immerse and agitate the test specimens in 2-propanol for 30 seconds. Scrub with a soft bristle brush and spray with clean 2-propanol.

5.1.3 Place the cleaned specimens in an oven maintained at 50°C [122°F] for three to five hours to dry.

5.1.4 Remove the specimens from the oven and place in a desiccator to cool.

5.1.5 Conformal coat the test specimens and cure in accordance with the suppliers recommendations. If the specimens are not used immediately, seal the specimens in Kapac® bags.

5.2 Procedure

5.2.1 For each individual specimen, secure all the positive leads (1, 3 and 5) together and the negative (2 and 4) together.

5.2.2 Attach the leads of the Hi-Pot Tester to the wires of the test specimen.

5.2.3 Raise the test voltage from zero to 1,500 VAC at 100 VAC per second.

5.2.4 Apply the test voltage of 1,500 VAC at 50-60 Hz for one minute and record any leakage rate.

5.2.5 After the one-minute duration, turn off the voltage and disconnect the test specimen from the Hi-Pot Tester.

6.0 Evaluate

6.1 Record if the specimen exhibits flashover, sparkover or breakdown.

6.1.1 Record the leakage current of each specimen.
1 Scope  This test method provides a standard procedure to determine the dissipation factor of printed circuit materials.

2 Applicable Documents  None

3 Test Specimen

3.1 At least three specimens; each shall be 10 cm x 10 cm x the thickness of the laminate or substrate.

4 Equipment/Apparatus

4.1 Standard capacitance bridge and accessories

5 Procedure

5.1 Preparation

5.1.1 Remove foil from both sides of the specimens using standard copper etching practices.

5.1.2 Rinse in tap water until clean.

5.1.3 Condition specimens in distilled water for 24 hours at 23°C, then air dry.

5.1.4 Coat both sides of the specimens with silver conductive paint, dry, and file all edges to prevent a conductive path.

5.1.5 Calibrate the capacitance bridge assembly.

5.1.6 Set the Method dial on “Substitute” and connect the balancing capacitor to the unknown direct terminals.

5.1.7 The balancing capacitor must be 100 picofarads greater than the test specimen.

5.1.8 Turn the Method switch to the “Substitute” position.

5.2 Test

5.2.1 Set the Voltage dial for maximum output and obtain a null on the detector by balancing the Capacitance and Dissipation dials, then take the reading of the capacitance of the dissipation.

5.2.2 Proceed by connecting the test specimen to the unknown substitute terminals.

5.2.3 Obtain a null on the detector by balancing the capacitance bridge, then read the capacitance and the dissipation factor as before.

5.3 Calculation  Calculate the dissipation factor from the following equation:

\[ DX = (6.01) \frac{C_1}{C_1 - C} (D - D_1) \]

\( DX = \text{dissipation factor} \)
\( C_1 = \text{capacitance of balancing capacitor} \)
\( C = \text{capacitance of test specimen} \)
\( D_1 = \text{dissipation of balancing capacitor} \)
\( D = \text{dissipation of test specimen} \)

5.4 Report  The results should be recorded in a written report, which contains the following as a minimum:

- Certification that the test was performed in accordance with this test method
- Identification of specimens tested
- Dissipation factor for each specimen tested and the average of all specimens for each material tested

6 Notes  The dissipation factor of a dielectric material is the relationship between the permittivity (capacitance of material) and conductivity (ability to conduct or the reciprocal of the electrical resistivity) measured at a given frequency.
1.0 **Scope**  This method is to determine the electrical resistance of the dielectric material between layers, during and after cycling.

2.0 **Applicable Documents**

- IPC-ML-950  Multilayer Printed Wiring Boards
- IPC-TM-650  Section 5.8.3

3.0 **Test Specimen**  Test coupon “A” from test pattern described in section 5.8.4 of this publication.

4.0 **Apparatus**

4.1 **Test Chamber**  Test chamber capable of maintaining 65°C (145°F) to -10°C (+14°F) and 95% relative humidity.

4.2 **Meter**  Megohm meter capable of delivering 100 volts DC (polarized) and of reading from 1 ohm to 30,000 megohms.

4.3 **Vibration System**  A machine capable of 0 to 25.4 mm [0 to 1 in] displacement. The frequency shall be variable from 5 to 60 Hz.

5.0 **Procedure**

5.1 **Preparation**

5.1.1 Mount specimens by normal mounting means in the normal mounting position of the production boards being represented by the test coupons.

5.1.2 Prior to cycling, perform and record initial resistance measurements at room ambient conditions.

5.1.3 Subject each specimen to 10 cycles as shown in Fig. 1.

5.2 **Test**

5.2.1 Take measurements after the fifth and tenth cycles. Electrification must be 100 volts ± 10% for one minute.

5.2.2 Measurement should also be taken 15 minutes after removal from the chamber.

5.2.3 Checkpoints 1 and 2, 2 and 3, and 3 and 4 of the test coupons.

6.0 **Notes**  For Class 3 requirements of IPC-ML-950 use polarized voltage; for Class 1 and 2 use non-polarized voltage.
Figure 1  Graphical representation of moisture-resistance test
1 Scope
The purpose of this test method is to quickly assess the adequacy of a given Anisotropically Conductive Adhesive Film (ACF) construction and bonding process for avoiding short circuits between adjacent traces of a flex circuit being bonded to a low profile circuit substrate.

1.1 Purpose
ACF materials are often used to interconnect fine-pitch flexible circuitry to substrates such as flat-panel displays. A center to center pitch range of 80 µm to 200 µm is not uncommon in circuits for flat panel display applications. It is critical that the particle dispersion within the ACF be of sufficient quality such that there is no inherent tendency for short circuits between adjacent traces. In addition, it is important that a bonding process is used, which doesn’t create any undue accumulation of particles, which will lead to short circuits.

2 Applicable Documents
None

3 Test Specimens
3.1 In order to perform this test, a custom-designed and fabricated flex circuit substrate will need to be produced. A suggested flex circuit construction of a design is shown in Figure 1. Flex circuit materials should be selected to be representative of what is being used in the application. The traces alternate between anodic and cathodic polarity as shown. Trace thickness, width, and pitch, should be selected in accordance with the application. Total trace count should be at least 100, and total width of the pattern should be slightly less than the thermode length. Total length of the traces should be sufficient to allow at least four bonds to be accommodated as shown in Figure 2 and Figure 3.

N is the number of circuit traces (at least 100).

I is the measured leakage current in amps after 10 seconds @ 50V.

g is the gap spacing between adjacent traces on the circuit in mm (of the order 0.04 mm to 0.1 mm).
4 Apparatus

4.1 DC power supply capable of providing voltage in the range of 10 V to 100 V, with an accuracy of at least \( \pm \) 10\%, and capable of supplying current in the range of 0 mA to 1 mA at those voltage levels.

4.2 DC ammeter capable of measuring current in the range of 0 to 1 mA, with an accuracy of \( \pm \) 0.001 mA.

4.3 Stopwatch or other timing mechanism capable of resolving \( \pm \) 1 second.

4.4 Hot-bar bonds capable of producing ACF bonds between flex circuits and flat panel displays, and outfitted with a thermode of appropriate length and width for a given application (Thermode width is generally in the range of 2 mm to 3 mm, and length is in the range of 25 mm to 50 mm.)

5 Procedure

5.1 Calculate the insulation resistivity \( (\rho_i) \) in Ohm-cm for each of three samples. Each sample must meet the specification requirement (see Figure 4).

\[
\rho_i = \frac{(A)(B)(C)(D)(E)}{(F)(G)(H)} = \Omega \cdot \text{cm}
\]

where:

A = voltage
B = number of bonds
C = width of bond (mm)
D = conductor thickness (mm)
E = total number of lines - 1
F = mm to \( \mu \)m conversion
G = current amps
H = trace to trace gap (mm)

Example A test circuit is designed with 100 total circuit traces (50 anodic and 50 cathodic) on 100 \( \mu \)m pitch. The trace thickness is 0.035 mm (1 oz Cu) and the trace to trace gap is 0.05 mm. Suppose also that four ACF bonds are prepared, with each bond being 3 mm wide. After applying a 50 VDC bias for 10 seconds, a leakage current of 0.5 mA is measured.

\[
\rho_i = \frac{(50)(4)(3)(0.035)(99)}{(10)(0.0005)(0.050)} = 8.3 \times 10^6 \Omega \cdot \text{cm}
\]
1 Scope
This test method is used to determine the electrical resistance of the dielectric material between conductors (including plated through holes (PTHs)) within a specific layer during and after cycling.

2 Applicable Documents
5.8.3 Peel Strength Test Pattern
2.5.10 Insulation Resistance, Multilayer Printed Wiring (Between Layers).

3 Test Specimen
3.1 Test coupon “H” from test pattern described in IPC-TM-650, Method 5.8.3

4 Equipment/Apparatus
4.1 Test chamber capable of maintaining 65°C to -10°C and 95% RH
4.2 Megohm meter capable of delivering 100 volts (polarized) and of reading from 1 ohm to 30,000 megohms

5 Procedure
5.1 Preparation
5.1.1 Mount the specimens by normal mounting means in the normal mounting position of the production boards being represented by the test coupons.
5.1.2 Prior to cycling, perform and record initial resistance measurements at room ambient conditions.
5.1.3 Subject each specimen to 10 cycles (see IPC-TM-650, Method 2.5.10).

5.2 Test
5.2.1 Take measurements after the fifth and tenth cycles. Electrification must be 100 volts ± 10% for one minute.
5.2.2 Measurements should also be taken 15 minutes after removal from the chamber.
5.2.3 Check points 1 & 1’, 2 & 2’, 3 & 3’, and 4 & 4’ of the test coupons.

6 Notes
6.1 For Class A requirements of IPC-TM-650, Method 2.5.10, use polarized voltage; for Class B, use non-polarized voltage.
1 Scope  This test method determines electrical resistance of multilayer PWBs.

2 Applicable Documents  None

3 Test Specimen

3.1 Test coupon “G”

4 Equipment/Apparatus

4.1 A four-terminal Kelvin Bridge or equivalent

5 Procedure

5.1 Test

5.1.1 Measure the resistance between any two adjacent holes in row A or E of Specimen G, except holes A5 & 6, E3, 4, 11, and 12 (see Figure 1).

5.1.2 Solder leads in the selected holes for proper connection to the four terminals of the test instrument according to diagram A.

5.1.3 Repeat this test for each of the five pairs of holes.

5.2 Evaluation  Record and report all electrical resistance values.

---

**Figure 1  Distance from Clips**
1 Scope  This test method is used to determine the resistivity of copper foil.

2 Applicable Documents
ASTM-B-193  Resistivity of Conductive Materials

3 Test Specimen
3.1 Three samples should be selected at equal distances across the width of the material from each lot and the width and gauge length measured to the nearest 0.025 mm.

4 Equipment/Apparatus
4.1 Tester  The resistance of the samples shall be measured with instruments of suitable sensitivity (see ASTM-B-193).

5 Procedure
5.1 Test
5.1.1 Resistance Determination  Three samples shall be selected at equal distances across the width of the material from each lot and the width and gauge length measured to the nearest 0.025 mm. The resistance of the samples shall be measured with instruments of suitable sensitivity, in accordance with ASTM-B-193.

5.1.2 For convenience, the distance between test points may be 15 cm, and the weight of the 2.5 cm wide sample being measured is determined by weighing a 2.5 cm x 15 cm strip from the test specimen.

5.2 Evaluation
5.2.1 Calculate the resistance using the formula:

$$ R_T = \frac{R_t}{1 + \alpha T (t - T)} $$

where:

- $T$ = reference temperature (20°C)
- $t$ = temperature at which measurement is made (°C)
- $\alpha T$ = temperature coefficient of resistance (0.00388)
- $R_T$ = resistance at reference temperature (20°C)
- $R_t$ = measured resistance

5.2.2 Calculate weight resistivity in ohms - gram/meter² using the formula:

$$ P_w = \frac{W}{L_1 L_2 R_T} $$

where:

- $W$ = weight of test specimen (grams)
- $L_1$ = gauge length (meters)
- $L_2$ = length of test specimen (meters)
- $R_T$ = resistance at reference temperature (20°C)

Note: If the procedure described in 5.1.2 is used, then:

$L_1 L_2$ Therefore is (0.1524 meters)² or:

$$ P_w = \frac{\text{weight of 0.040 mm x 0.235 mm specimen}}{0.02323 R_T} $$
1.0 Scope

1.1 Purpose This test method covers procedures for determining the electrical resistivity of copper foil. It provides for an accuracy of ± 0.30 percent of test specimens having a resistance of 0.00001 ohm (10 microhms) or more.

1.2 Definition Resistivity is the electrical resistance of a body of unit length and unit cross-sectional area or unit weight. Volume resistivity is commonly expressed in ohms for a theoretical conductor of unit length and cross-sectional area; in English units in ohm–circular mil/ft and in metric units in ohm–mm²/meter. It may be calculated by the following formula:

\[ p. = \frac{A}{L} R \]

where:
- \( p. \) = volume resistivity in ohm–circular mil/ft or ohm–mm²/meter,
- \( A \) = cross-sectional area in circular mils, or sq mm,
- \( L \) = gauge length, used to determine \( R \), in ft, or m, and
- \( R \) = measured resistance in ohms.

Weight resistivity is commonly expressed in ohms for a theoretical conductor of unit length and weight. The method for calculating weight resistivity, based on resistance, length, and weight measurements, of a test specimen is given in Note 2.

2.0 Applicable Documents None

3.0 Test Specimen The test specimen must have the following characteristics:
1. A resistance of at least 0.00001 ohm (10 microhms) in the test length between potential contacts,
2. A test length of at least 1 ft or 30 cm,
3. A thickness, width or other dimension suitable to the limitations of the resistance measuring instrument,
4. No surface cracks or defects visible to the unaided normal eye, and substantially free from surface oxide, dirt and grease,
5. No joints or splices.

4.0 Apparatus

4.1 Tester

4.1.1 A Kelvin-type double bridge or a potentiometer, if the resistance of the specimen is below 1 ohm,

4.1.2 If 1 ohm or more, a Wheatstone bridge may be used.

4.1.3 Where applicable, a Hoopes conductivity bridge may be used.

4.2 Conditions When the measurement is made at any other than a reference temperature, the resistance may be corrected for moderate temperature differences to what it would be at the reference temperatures as follows:

\[ R_T = \frac{R_t}{1 + \gamma T (t - T)} \]

where:
- \( R_T \) = resistance at reference temperature \( T \),
- \( R_t \) = resistance as measured at temperature \( t \),
- \( \gamma T \) = known or given temperature coefficient of resistance of the specimen being measured at reference temperature \( T \),
- \( T \) = reference temperature, and
- \( t \) = temperature at which measurement is made.

NOTE: The parameter \( T \) in the above equation, varies with conductivity and temperature. For copper of 100 percent conductivity and a reference temperature of 20°C, its value is 0.00393. Table 2 lists temperature coefficients for copper.

5.0 Procedure

5.1 Preparation

5.1.1 All determinations of the dimensions and weight of the test specimen must be accurate within 0.05%.
5.1.2 The cross-sectional dimensions of the specimen may be determined by micrometer measurements, and a sufficient number of measurements shall be made to obtain the mean cross section to within ± 0.10 percent.

5.1.3 In case any dimension of the specimen is less than 0.100 in. and cannot be measured to the required accuracy, the cross section shall be determined from the weight, density, and length of the specimen.

5.1.4 When the density is unknown, it shall be determined by weighing a specimen first in air and then in a liquid of known density at the test temperature, which shall be at room temperature to avoid errors due to convection currents.

5.1.5 Calculate the density from the following formula:

\[ \delta = \frac{W_a \times d}{W_a - W_l} \]

where:
\( \delta \) = density of the specimen, grams per cu cm,
\( W_a \) = weight of the specimen in air, grams,
\( W_l \) = weight of the specimen in the liquid, grams, and
\( d \) = density of the liquid at the test temperature, grams per cu cm.

5.2 Test

5.2.1 When potential leads are used, the distance between each potential contact and the corresponding current contact shall be at least equal to 1-1/2 times the cross-sectional perimeter of the specimen.

5.2.2 The yoke resistance (between reference standard and test specimen) shall be appreciably smaller than that of either the reference standard or the test specimen unless a suitable lead compensation method is used, or it is known that the coil and lead ratios are sufficiently balanced so that variation in yoke resistance will not decrease the bridge accuracy below stated requirements.

5.2.3 Make resistance measurements to an accuracy of ± 0.15 percent.

5.2.4 In all resistance measurements, the measuring current raises the temperature of the specimen above that of the surrounding medium. Therefore, care shall be taken to keep the magnitude of the current low, and the time of its use short enough so that the change in resistance cannot be detected with the galvanometers.

5.2.5 To eliminate errors due to contact potential, two readings, one direct and one with current reversed, must be taken in direct succession.

5.2.6 Check tests are recommended whereby the specimen is turned end for end, and the test repeated.

5.2.7 Surface cleaning of the specimen at current and potential contact points may be necessary to obtain good electrical contact.

5.3 Evaluation

5.3.1 Reference Tests For reference tests, the report should include the following:
1. Identification of test specimen,
2. Kind of material,
3. Test temperature,
4. Test length of specimen,
5. Method of obtaining cross-sectional area: the average values of micrometer readings, or, if by weighing a record of length, weight, and density determinations that may be made, and calculated cross-sectional area.
6. Weight, if used,
7. Method of measuring resistance,
8. Value of resistance,
9. Reference temperature,
10. Calculated value of resistivity at the reference temperature, and
11. Previous mechanical and thermal treatments. (Since the resistivity of a material usually depends upon them, these shall be stated whenever the information is available.)

5.3.2 Routing Tests For routine tests, only such of the items in paragraph 5.3.1 as apply to the particular case, or are significant, shall be reported.
6.0 Notes

6.1 Volume Resistivity Volume resistivity is used in place of “weight resistivity” and “percent conductivity.” The value of 10.381 ohm–circular mil/ft at 20°C (68°F) is the volume resistivity equivalent to the International Annealed Copper Standard (IACS) for 100 percent conductivity. This term means that a wire 1 ft in length and 1 cir mil in cross-sectional area would have a resistance of a wire 1 m in length, and 1 sq mm in cross-sectional area.

6.2 Weight Resistivity Weight resistivity is expressed in English units in ohm-pound/mile² and in metric units in ohm–gram/meter². It may be calculated as follows:

\[
\rho_w = \frac{W}{L_1 L_2 R}
\]

where:

\( \rho_w = \) weight resistivity in ohm-pound/mile², or ohm-gram/meter²,
\( W = \) weight of the test specimen in lb, or gm,
\( L_2 = \) length of the test specimen in miles, or m, and
\( L_1 = \) gauge length, used to determine R, in. miles or m, and
\( R = \) measured resistance in ohms.

Table 1 Equivalent Resistivity Values For Copper
Conductivity at 20°C (68°F), percent IACS..................100.00

<table>
<thead>
<tr>
<th>VOLUME RESISTIVITY</th>
<th>Density at 20°C, gm per cu cm</th>
<th>Temperature Coefficient of Resistance at 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohm–Circular mil/ft</td>
<td>10.371000</td>
<td></td>
</tr>
<tr>
<td>Ohm-mm²/meter</td>
<td>0.017241</td>
<td></td>
</tr>
<tr>
<td>Microhm-inch</td>
<td>0.678790</td>
<td></td>
</tr>
<tr>
<td>Microhm-cm</td>
<td>1.724100</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WEIGHT RESISTIVITY</th>
<th>Density at 20°C, gm per cu cm</th>
<th>Temperature Coefficient of Resistance at 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohm–pound/mile²</td>
<td>875.20</td>
<td></td>
</tr>
<tr>
<td>Ohm–gram/meter²</td>
<td>0.15328</td>
<td></td>
</tr>
</tbody>
</table>

6.3 Conversion Resistivity and Conductivity Conversion – Conversion of the various units of volume resistivity, weight resistivity, and conductivity, may be facilitated by employing formulas and factors. Table 2 lists values of density, for the common electrical conductor materials.

6.4 Density For the purpose of resistivity and conductivity conversion, the density of copper materials may be taken as shown in Table 2, based on a temperature of 20°C (68°F).

Table 2 Density and Temperature Coefficient of Resistance for Electrical Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Density at 20°C, gm per cu cm</th>
<th>Temperature Coefficient of Resistance at 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper, % IACS:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>8.89</td>
<td>0.00393</td>
</tr>
<tr>
<td>98.40</td>
<td>8.89</td>
<td>0.00387</td>
</tr>
<tr>
<td>98.16</td>
<td>8.89</td>
<td>0.00386</td>
</tr>
<tr>
<td>97.80</td>
<td>8.89</td>
<td>0.00384</td>
</tr>
<tr>
<td>97.66</td>
<td>8.89</td>
<td>0.00384</td>
</tr>
<tr>
<td>97.40</td>
<td>8.89</td>
<td>0.00383</td>
</tr>
<tr>
<td>97.16</td>
<td>8.89</td>
<td>0.00382</td>
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<td>96.66</td>
<td>8.89</td>
<td>0.00380</td>
</tr>
<tr>
<td>96.61</td>
<td>8.89</td>
<td>0.00380</td>
</tr>
<tr>
<td>96.16</td>
<td>8.89</td>
<td>0.00378</td>
</tr>
<tr>
<td>94.16</td>
<td>8.89</td>
<td>0.00370</td>
</tr>
<tr>
<td>93.15</td>
<td>8.89</td>
<td>0.00366</td>
</tr>
</tbody>
</table>

 IPC-TM-650
Number 2.5.14 Subject Resistivity of Copper Foil Date 8/76
Revision A
1 Scope  It is the intent of these guidelines to describe the material properties and test procedures required to ensure effective RFI and EMI shielding of flat cable.

1.2 Definitions

1.2.1 Relative Shielding Effectiveness  The attenuation difference in the electromagnetic field strength between an unprotected cable and a shielded cable system, which is expressed, S = R_x + A + B, where:

R_x = the losses caused by reflection in db
A = the losses caused by absorption in db
B = the secondary reflection losses of the shields in db.

The reflection losses are a function of the material, frequency, and type of field. Generally, the field within one wave length from a generating source will either be predominantly electric or magnetic, and at greater distance will propagate as a plane wave made up equally of electric and magnetic components. Thus, the reflection losses for each of these fields may be designated by:

R_E = electric or “E” field
R_H = magnetic or “H” field
R_p = plane wave field

The absorption losses are a function of the material and frequency but are independent of field type. If these losses (A) are greater than 10 db, the secondary reflection losses are negligible, and the expression for shielding effectiveness reduces to S = R + A.

The following are standard equations that may be used to obtain a rough approximation of a shield’s effectiveness.

Absorption Losses:
A = 3.38 X 10^-4 t (uGf)^1/2

Reflection losses:
1. Plane wave
   \[ R_p = 108.2 + 10 \log \frac{G \times 10^6}{u f} \]

2. Magnetic fields
   \[ R_H = 20 \log \frac{0.462}{r} \frac{U}{Gf}^{1/2} + 0.136 r \left( \frac{Gf}{u} \right)^{1/2} + 0.354 (r < \lambda) \]

3. Electric fields
   \[ R_E = 353.6 + 10 \log \frac{G}{u f^2} \quad (r < \lambda) \]

where:
G = conductivity relative to copper
u = magnetic permeability relative to free space
f = frequency in Hertz
r = distance from source to shield in 2.5 cm
t = thickness of metal shield in 0.0025 mm
\lambda = wavelength

A field surrounds every source of electric energy. The simple situation of an electric current flowing through a wire causes a field to exist around the wire, whose magnitude and direction follow well-known principles. Part of the energy in any field is propagated through space and eventually damps to zero. The remaining part of the energy of a field either returns to its origin or is absorbed by some receiving source. A dipole antenna behaves in this manner; part of its energy becomes a radiation field, while another portion (that periodically returns to the antenna) becomes the induction field. The general mathematical expression that describes an electromagnetic field is rather complex and is usually discussed in texts on field theory. It is easier to discuss this expression in terms of its electric vector E and its magnetic vector B, where E has the dimension of V/1 and units of volt/meter and B has the dimensions of VT/12 and units of volt-second/meter^2. E and B can then be written as the sum of two components:

E = E_i + E_R
B = B_i + B_R

The components of the induction field are E_i and B_i, while the components of the radiation field are given as E_R and B_R, and B_R are proportional to B_o/R (B_o = w/voR, where w is the angular frequency of the field in radians and v_o is the velocity of propagation in meters per second.) E_i and B_i are proportional to 1/R^2, where R is the distance from the source in meters. The ratio of the two is B_o/R or wR/v_o. It can be concluded from this that for very small values of R and any given values for w and v_o, the induction field will be so much greater than the radiation field, that the latter may be neglected. However, if R is very large, the radiation field is important and the induction field can be discarded.
Induction fields are either high- or low-impedance fields. A high-impedance field is defined as a field whose impedance is higher than the impedance of the dielectric in which it exists. A low-impedance field has an impedance lower than the impedance of the dielectric. High-impedance fields are associated with a voltage source and most of their energy is contained in their electric component, while low-impedance fields are associated with a current source and most of their energy is contained in the magnetic component.

1.2.2 Shield Impedance An important parameter associated with these radiating fields is the characteristic impedance, which is the ratio of the electric to magnetic field components. For a plane wave in free space, the characteristic impedance is 377 ohms, and correspondingly for intense electric or high impedance fields, it is greater than 377 ohms, and for strong magnetic or low impedance fields, it is less than 377 ohms. The difference in characteristic impedance between an incident field and a shield is directly proportional to the reflection losses. The characteristic impedance of a shield varies with the material’s permeability, conductivity, and frequency. Shield impedances are generally low at low frequencies and increase directly with frequency. Since at all frequencies, electric (E) fields are high impedance and magnetic (H) fields are low impedance, the corresponding reflection losses are high for electric fields at low test frequency and low or poor for magnetic fields at the same test frequency. As test frequencies increase, the impedance mismatches decrease for electric fields (decrease in R_E) and increase for magnetic fields (increase in R_H). The absorption losses for both electric and magnetic fields increase with frequency. It can be concluded from this that good shielding effectiveness against predominantly electric fields can be obtained with most high conductivity shielding materials. At low frequencies, R_E losses are so high that small absorption losses may be neglected and, at high frequencies, even though most of the transmitted energy is coupled to the shield, absorption losses are high enough for adequate shielding if all nonconductive openings in the shield are eliminated. Shielding against magnetic fields presents a different situation at low frequencies, where absorption and reflection (R_H) losses are small. Here, uniform 100% shielding is essential and in most cases ferromagnetic, highly permeable materials are employed to increase absorption losses. At high frequencies, both reflection and absorption losses are high, and shielding effectiveness is good for magnetic fields.

Table 1 shows properties of various metals at 150 KHz and 400 MHz and the corresponding absorption loss in db. The significance of this table is to show the necessity for highly permeable materials to shield against low frequency magnetic fields.

3 Test Specimen None

4 Equipment/Apparatus None

5 Procedure None

6 Notes

6.1 Shielding effectiveness is usually determined more precisely by measurement than by calculation, especially when 100% shielding is impractical. To obtain the attenuation capability of a shielding material about a flat cable, it is more practical to test a cable system for its susceptibility to radiated energy.

Figure 1 shows a test setup designed to measure shielding effectiveness in a flat cable for electric and magnetic radiating fields. Two 1.5 m cable specimens, one shielded and one unshielded, are terminated in their characteristic impedance at the generator source end and attached through a coaxial switch to a field intensity meter (or similar device) at the other end. These two cable samples are mounted and suspended 2.5 cm above a conducting ground plane and 7.5 cm to either side of a bare unshielded copper wire (see Figure 2). This radiating copper wire is connected at one end to a RF signal generator and is terminated at the opposite end in either a short or non-radiating open circuit.

6.2 When the bare wire is open circuited, the majority of the radiated field is electric, and when it is short circuited, magnetic fields dominate. Since the cables are only 7.5 cm away from the radiating source, electric and magnetic shielding effectiveness can be measured separately at frequencies up to approximately 4 GHz. It is assumed that if a shield is effective under these conditions, it will be equally effective against plane wave radiation.

6.3 Four readings must be taken at each test frequency. First the voltage pick-up in the unshielded specimen is observed and is used as the reference level for the voltage measurement on the shielded line. The shielding effectiveness in decibels is given by:

\[ S = 20 \log \frac{V_u}{V_s} \]

where:

\( V_u \) = voltage induced into unshielded cable

\( V_s \) = voltage induced into shielded cable
These readings are taken with both open and short circuits on the radiating bare wire.

6.4 It should be noted that although a shield may be quite effective in protecting a cable system, tests should be made to determine the affect the shielding materials have on the internal electrical cable properties.

In a cable system handling high-speed digital pulses, the choice of shielding materials can greatly affect important transmission characteristics. If a shield is applied to suppress strong magnetic fields and a ferromagnetic material is used, which has a low conductivity, it will create a direct capacitance coupling between adjacent signal carrying conductors. This coupling will cause an increase in the crosstalk between signals and will also distort the output rise time of the pulse.

If shielding is necessary on a sophisticated transmission line system, a few tradeoffs might be necessary to obtain the optimum operating conditions.
Figure 1  Shielding Effectiveness Test Setup
Figure 2 Connection of Copper Wire

NOTE: ALL TERMINATIONS SHOULD BE MADE AS SHORT AS POSSIBLE AND TOTAL AREA SHOULD BE SHIELDED WITH WIRE MESH OR COPPER FOIL.
1.0 **Scope**  This test method is to detect internal electrical short circuits within multilayer printed wiring boards.

2.0 **Applicable Documents**  None

3.0 **Test Specimen**  Test coupon “B” on test pattern described in section 5.8.4 of this publication, or any production boards.

4.1 **Power Supply**  Power supply capable of providing 100 volts DC.

4.2 **Meter**  Electrical ohmmeter capable of measuring resistances between conductors.

5.0 **Procedure**

5.1 **Test**

5.1.1  Perform test at ambient temperature.

5.1.2  Apply a polarized voltage of 100 volts DC between a plated through hole connected to a ground plane and an interconnection of hole not connected to this plane

5.1.3  Measure the resistance between these points and record findings.
1 Scope This test method is designed to determine both the volume (cross-sectional) and surface electrical resistance of the dielectric material under humid conditions.

2 Applicable Documents

ASTM-D-257 DC Resistance or Conductance of Insulating Materials

3 Test Specimens At least two specimens 10 cm x 10 cm x thickness.

4 Apparatus

4.1 Chamber A test chamber capable of maintaining a combination of 35°C ± 2°C and 90% -0, +5% relative humidity (RH).

4.2 Drying Chamber A chamber capable of maintaining 80°C.

4.3 Meter A Keithly model L-7 megohmmeter, or equivalent.

4.4 Miscellaneous Desiccator, silver paint, conductor composition 4817 by DuPont Co. or equivalent, distilled water source, calcium chloride desiccant, analytical balance. Fabrication of a special test fixture (such as a Balsbaugh Fixture) may be desirable if frequent testing is required.

5 Procedure

5.1 Sample Preparation for Volume Resistivity

5.1.1 Double Clad Laminate Prepare etched conductor test specimens in accordance with Figure 1 for one side and Figure 2 for other side using standard commercial practices. Immersing each specimen in distilled water for 24 hours at 23°C ± 2°C, then dry in oven for two hours at a temperature between 49°C and 60°C.

5.1.2 Single Clad Laminate Prepare test specimens by etching the foil, single clad laminate per Figure 1, then clean (if etched) by immersion in distilled water for 24 hours at 23°C ± 2°C, then dry in oven for two hours at a temperature between 49°C and 60°C.

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49°C and 60°C. Coat unclad side with silver conductive paint (per Figure 2). Sand all edges to remove any silver paint to prevent a conductive path.

5.1.3 Bare Dielectric Prepare test specimens by immersing in distilled water for 24 hours at 23°C ± 2°C, then dry in an oven for two hours at a temperature between 49°C and 60°C. Coat the unclad material with silver conductive paint (one side per Figure 1 and the other per Figure 2). Sand all edges to remove any silver paint.

5.2 Conditioning

5.2.1 Condition specimens together with the test fixture at 35°C ± 2°C and 90% -0, +5% RH for 96 hours.

5.2.2 Specimens (and test fixture) must remain in the chamber for all phases of both the volume resistivity and surface resistance tests.

5.2.3 These conditions may vary depending on the request of the material user.

5.3 Test

5.3.1 After conditioning, and without removing specimens from the chamber, connect specimen to electrodes as follows:

<table>
<thead>
<tr>
<th>Megohmmeter Leads</th>
<th>Specimen Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Guarded (5.0 cm circle)</td>
</tr>
<tr>
<td>Ground</td>
<td>Guarded (6.35 cm ring)</td>
</tr>
<tr>
<td>Test</td>
<td>Unguarded (7.6 cm circle)</td>
</tr>
</tbody>
</table>

5.3.2 Turn on the megohm meter and allow to warm up for a minimum of 15 minutes.

5.3.3 After warm up, calibrate meter and adjust internal voltage to 500 volts DC.

5.3.4 Read the meter (in megohms) after the test switch is held depressed for 60 seconds.

5.4 Evaluation

5.4.1 Calculate the volume resistivity ($r$) in megohm centimeters as derived from the following formula:

$$r = \frac{RA}{L}$$

$r$ = volume resistivity in megohm cm
$L$ = thickness of specimen in cm
$A$ = area of guarded electrodes is 25.6 cm$^2$
$R$ = volume resistance in megohms (meter reading)

5.5 Preparation for Surface Resistance Leave the same specimens in the test chamber and prepare to test surface resistance by connecting the specimens to electrodes as follows:

<table>
<thead>
<tr>
<th>Megohmmeter Leads</th>
<th>Specimen Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Guarded</td>
</tr>
<tr>
<td>Ground</td>
<td>Unguarded</td>
</tr>
<tr>
<td>Test</td>
<td>Guard</td>
</tr>
</tbody>
</table>

5.6 Test Perform the same testing procedures per 5.3.

5.7 Evaluation The surface resistance is the direct reading of the megohmmeter scale and should be recorded in megohms.

6 Notes This method may also be used for rigid dielectric materials.

6.1 For additional information see ASTM-D-257, DC Resistance or Conductance of Insulating Materials.
1.0 Scope  
This test method is designed to determine volume resistivity and surface resistivity of metallic-clad or unclad laminates under conditions of specified humidity and temperature and at elevated temperatures.

2.0 Applicable Documents

ASTM-D-257 D-C Resistance or Conductance of Insulating Materials

IPC-TM-650
Method 2.3.6, Etching, Ammonium Persulfate
Method 2.3.7 Etching, Ferric Chloride
Method 2.3.7.1, Cupric Chloride Etching
Method 2.6.3, Moisture and Insulation Resistance, Rigid, Rigid/Flex and Flex Printed Wiring Boards

3.0 Test Specimens

3.1 Laminate thickness of 0.51 mm [0.020 in] or greater. Three specimens of dimensions 101.6 ± 3.2 mm x 101.6 ± 3.2 mm [4.0 ± 0.125 in x 4.0 ± 0.125 in] by thickness shall be prepared for each test condition, unless otherwise specified.

3.2 Laminate thickness of less than 0.51 mm [0.020 in]. Three specimens of dimensions 50.8 ± 1.6 mm x 50.8 ± 1.6 mm [2.0 ± 0.062 x 2.0 ± 0.062 in] by the thickness shall be prepared for each test condition, unless otherwise specified.

4.0 Equipment Apparatus

4.1 Conditioning chamber capable of maintaining 35 ± 2°C [95 ± 3.6°F] and 90 ±5, −0% relative humidity.

4.2 Conditioning chamber capable of attaining the temperature and humidity conditions specified in IPC-TM-650, Method 2.6.3.

4.3 Air circulating oven capable of maintaining the specified test temperatures to within ± 2°C [±3.6°F].

4.4 Resistance measuring instrumentation capable of measuring to $10^{12}$ meg-ohms, minimum, with an accuracy of ±5 percent at its highest scale setting. The equipment shall have the capability of applying 500 volts dc to the test specimen.

4.5 A system/fixture for electrical connections into the temperature and humidity chambers (see 4.1, 4.2, 4.3). Three separate cables shall be provided to make connections to each specimen being conditioned/tested. The center conductor of each cable shall be connected to one of the three electrodes applied to the test specimen. The opposite ends of the cables shall be brought outside the chamber and terminated at a convenient location for connection to the measuring instrument. Shields shall be trimmed back from the ends of the center conductor insulation and interconnected to the guard post of the measuring instrument. See 6.2 for additional information.

Support the specimen parallel to the air flow through the chamber during conditioning.

Special care should be taken to ensure that materials used in the fixture are such that resistance readings are that of the material being tested and not the fixture.

4.6 A measurement device capable of measuring laminate thickness to the nearest 0.0025 mm [0.0001 in].

4.7 Material and apparatus for formation of specimen conductors.

4.7.1 Conductor silver paint; composition 4817 by Dupont Company, or equivalent.

4.7.2 A system for applying the paint to the specimen, such as silk screening.

4.7.3 A mask, fixture, photoprinting system, or equivalent, for applying the applicable electrodes/test pattern to the specimen (See Dimension Table).

4.8 Etching system in accordance with IPC-TM-650, Method 2.3.6, 2.3.7, or 2.3.7.1.

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Test patterns with the applicable dimensions shown in the Dimension Table, and in accordance with Figures 1, 2, and 3 shall be generated, as follows:
5.1.1.1 Metallic-clad materials having a thickness of less than 0.51 mm [0.020 in] shall be photoprinted with a pattern of the outline of the conductors and etched in accordance with IPC-TM-650, Methods 2.3.6, 2.3.7, or 2.3.7.1. The electrodes shall then be completed (filled in) using silver conductive paint.

5.1.1.2 Metallic-clad laminates 0.51 mm [0.020 in] or thicker shall be etched in accordance with IPC-TM-650, Method 2.3.6, 2.3.7, or 2.3.7.1. A pattern of the outline of the conductors may be photoprinted before etching. Test electrodes shall be applied using silver conductive paint and an appropriate test pattern application system.

5.1.1.3 Solid metal foil electrodes shall not be acceptable in any case, except for the outer electrode for laminates less than 0.51 mm [0.020 in]. A small pad of retained cladding may be retained within the electrode borders to facilitate soldering of leads.

5.1.2 If soldering techniques are used to attach leads, suitable cleaning procedures shall be used to remove flux and other residue.

5.2 Conditioning

5.2.1 Humidity Conditioning

5.2.1.1 Specimens of a thickness less than 0.51 mm [0.020 in] shall be subjected to 90 + 5-0% relative humidity and 35 ± 2°C [95 ± 3.6°F] for a period of 96 +2, -0 hours prior to electrical measurement.

5.2.1.2 Specimens of a thickness greater than, or equal to, 0.51 mm [0.020 in] shall be subjected to the conditioning specified in IPC-TM-650, Method 2.6.3, paragraph 5.1.3. Following the tenth cycle, the conditioning chamber shall maintain a temperature of 25 ± 2°C [77 ± 3.6°F] and 90 +5, -0% relative humidity during the interval that electrical measurements are being made.

5.2.2 At Elevated Temperature Conditioning Specimens shall be subjected to the specified temperature (based on material type and specification requirements) for a period of 24 hours -0, +2 hours. Unless otherwise specified, the temperature shall be 125 ± 2°C [257 ± 3.6°F].

5.3 Electrical Measurements All electrical measurements shall be made inside the applicable conditioning chamber and at the conditions specified in 5.2.

5.3.1 Electrical measurements taken on specimens conditioned in accordance with paragraph 5.2.1 shall be completed within the 2 hour tolerance of the conditioning.

5.3.2 Electrical measurements taken on specimens conditioned in accordance with paragraph 5.2.2 shall be made after achieving 1.5 hours steady state of 25 ± 2°C [77 ± 3.6°F] and 90 +5, -0% relative humidity. All measurements shall be completed within 2 hours.

5.3.3 Electrical measurements taken on specimens conditioned in accordance with paragraph 5.3 shall be completed within the 2 hour tolerance of the conditioning.
5.3.4 All electrical measurements shall be made using 500 volts direct current. The voltage shall be applied to the specimen for 60 +5, -0 seconds prior to taking the actual reading, for stabilization purposes.

5.3.5 Measure the volume resistance by connecting the resistance measuring device to the specimen electrodes through the fixture system as described in 4.5 in accordance with Figure 2.

5.3.6 Measure the surface resistance by interchanging the test cables connecting the solid back electrode and the outer ring to the instrument for the arrangement shown in Figure 3.

5.4 Specimen Thickness Each specimen shall be measured for its thickness without cladding. Specimens for each test condition shall have their thickness readings averaged.

Figure 1 Test pattern dimensions (See table)

Figure 2

Figure 3
5.5 Calculations

5.5.1 The volume resistivity shall be calculated as follows:

\[ r = \frac{RA}{T} \]

Where:

\( r \) = Volume resistivity in megohm-centimeters
\( R \) = Measured volume resistance in megohms
\( A \) = Effective area of the guarded electrode in square centimeters
\( T \) = Average thickness of specimen in centimeters

Note: The value of A may be obtained from the Dimension Table.

5.5.2 The surface resistivity shall be calculated as follows:

\[ r' = \frac{R'P}{D4} \]

Where:

\( r' \) = Surface resistivity in megohms
\( R' \) = Measured surface resistance in megohms
\( P \) = Effective perimeter of the guarded electrode in centimeters
\( D4 \) = Width of the test gap in centimeters

Note: The ratio of P/D4 for the electrode configuration being used may be obtained from the Dimension Table included in Figure 1.

5.6 Reporting

5.6.1 The volume resistivity of each specimen and the average shall be reported. Each condition tested shall be reported separately.

5.6.2 The surface resistivity of each specimen and the average shall be reported. Each condition shall be reported separately.

5.6.2.1 The surface resistance is the direct reading of the megohmeter scale and should be recorded in megohms.

6.0 Notes

6.1 For additional information see ASTM-D-257, D-C Resistance or Conductance of Insulating Materials.

6.2 The system of electrical connections to the specimens may benefit from a coaxial cable set-up designed to shield the measurement of volume or surface resistances from electrical interference.

6.3 Performance Specifications The following information should be reviewed within the applicable performance specification or product procurement document:

a. Specimen size, quantity, and configuration, if other than that specified in 3.0.

b. Conditioning parameters, such as temperature for Elevated Temperatures.

c. Any other changes to the specified procedures in this method.
1 Scope

This test method covers the two-wire resistance test for the determination of the volume resistivity of polymer-based conductive pastes and other conductive materials used in HDI. This test is valid for conductive materials with volume resistivity on the order of $10^{-5}$ Ω-cm or higher. For measuring resistivity on highly conductive materials or any material that cannot be patterned into a circuit pattern, a four-wire (Kelvin Probe) test method, such as IPC-TM-650, Method 2.5.14, is recommended.

1.1 Definition

Volume resistivity is a material property that can be utilized to calculate the resistance in a circuit design. For materials with high resistivity, a two-wire resistance test may be used to measure the volume resistivity.

The resistance in any sample (R in units of Ω) is related to the dimensions of the test circuit and the volume resistivity ($\rho$) inherent in the material (see Figure 1).

$$R = \rho \left( \frac{L}{W} \right)$$

L, W, and t are the length, width, and thickness respectively of the test circuit (in cm). The quantity L/W is called a square, [□]. The volume resistivity can then be expressed as:

$$\rho = \frac{Rt}{\left( \frac{L}{W} \right)}$$

with units of ohms-cm (Ω-cm).

2 Applicable Documents

2.5.14  Resistivity of Copper Foil

3 Test Specimen

The test specimen is a 0.5 mm wide serpentine circuit pattern (see Figure 2) with a length of between 200 □ and 1000 □ (length equal to 200 to 1000 times the width) prepared by screen printing or other methods. Specimens may be prepared by other methods, as long as they have measurable dimensions. If materials cannot be prepared in a circuit pattern, see 6.2.
3.1 Conductor  Any high resistance conductor used in HDI applications (polymer thick film, via fill, metal, metal composites, transient liquid phase sintering, organometallic, conductive polymer, etc.). Copper foils used in HDI should be tested according to IPC-TM-650, Method 2.5.14.

3.2 Substrate  Unless otherwise specified, the substrate shall be a PCB laminate, etched to remove all copper. Other acceptable substrates (when specified) may be plate glass, insulated metals, or flexible circuit base material.

3.3 Screen  For materials that are screen printed, unless otherwise specified, the screen shall be as outlined in 3.3.1 through 3.3.3.

3.3.1 Type  200 mesh, stainless steel, 35 µm wire

3.3.2 Emulsion  <15 µm emulsion build up

3.3.3 Wire Angle  22.5° to 45°

3.4 Typical Patterns

3.4.1 Pattern  Serpentine with 0.5 mm wide lines and spaces and 200 □ to 1000 □ long (10 cm to 50 cm). The larger the number of squares, the higher the resistance and more accurate the measurement.

3.4.2 Print  1.25 mm snapoff
0.2 Kg to 1.0 Kg squeegee pressure per cm squeegee length
2.5 cm/sec. to 12.5 cm/sec. draw speed

3.5 Cure Conditions  The conductor shall be cured according to the manufacturer’s specifications. Parts are allowed to cool to room temperature, after which they are measured for resistance.

4 Equipment/Apparatus

4.1 A digital multimeter capable of resolving 0.1 Ω resistance is required. This unit must be accurately calibrated. An example would be a Fluke 70 series digital multimeter. For improved accuracy in this measurement, a larger number of □ and/or a more sensitive multimeter can be utilized.

4.2 A screen printer capable of making 0.5 mm line/space circuitry, or any other method for preparing the desired circuit pattern

4.3 Equipment to measure the test circuit conductor length, width, and thickness. If the number of squares is accurately known (length/width of circuit) from the artwork and standard process conditions, then only the thickness needs to be measured on each specimen. Thickness can be determined by various methods: cross-section/optical microscopy, profilometer measurement, or calculation from deposition weight and material density. If the circuit thickness is very uniform, then optical sectioning is the preferred method for obtaining the thickness. If the circuit thickness is thought to be non-uniform, thickness may then be determined by averaging profilometer readings or determining average thickness from the weight of the material deposited (knowing the length, width, and density that the thickness can be determined).

5 Procedure

5.1 Samples  Prepare a minimum of five test specimens according to 3.1 through 3.5.

5.2 Conditioning  Condition the specimens at 23°C ± 5°C, 50% RH (± 5%) for 24 hours.

5.3 Measurement

5.3.1 Measure the circuit length, width, and thickness using the equipment described in 4.3.

5.3.2 Apply the digital multimeter leads to the pads at each end of the circuit. Measure and record the resistance in ohms. For a resistance less than 2 Ω, see 6.1.

5.3.3 Measure the resistance of a minimum of five specimens and average the values.

5.4 Calculation  Calculate the volume resistivity for each specimen from the equation below:

\[ \rho_i = \frac{R_t}{L/W} \]

where:

R = average resistance of a single specimen in ohms

\[ t \]

= thickness of the conductive specimen in cm

\[ L \]

= length conductive specimen in cm

\[ W \]

= width conductive specimen in cm

Note: The ratio L/W is the number of squares.
Calculate the average resistivity from the sum of the specimen volume resistivities:

\[ \rho_{\text{ave}} = \frac{\sum \rho_i}{n} \]

where:

\( n \) = number of specimens measured

Note: The units of resistivity are \( \Omega \)-cm.

5.7 Report

5.7.1 Report the volume resistivity in units of \( \Omega \)-cm.

5.7.2 Report the substrate used in the test.

5.7.3 Report the test circuit length, width (or squares), and thickness.

6 Notes

6.1 Low Resistance Measurements For test circuits with a resistance less than 2.0 \( \Omega \), the contact resistance between the probe and the pads will be significantly relative to the resistance arising from the test circuit. The 2.0 ohm lower limit, in combination with the 0.1 ohm sensitivity of the multimeter, provides for a minimum error of 5%.

One solution is to increase the length of the circuit (increase the number of squares) to increase the resistance. Another solution for measuring resistivity on a highly conductive material is to change to a four-wire (Kelvin Probe) test method, such as IPC-TM-650, Method 2.5.14.

6.2 Test Circuit Specimens It is anticipated that some materials cannot be formed into a uniform test circuit, as called out for in this test method. It is recommended that these materials be tested with a four-wire method (IPC-TM-650, Method 2.5.14) and an alternative construction.

For example, a thin film of conductive material (i.e., paste or conductive film) can be placed between two metal plates and the resistivity may be determined using the four-wire (Kelvin Probe) method. The material thickness and contact area must be known, and the material must be sufficiently compliant to completely wet (contact) the two plates.

6.3 Other References

Gilleo, Ken, Polymer Thick Films, Van Nostrand Reinhold, 1996
1 Scope  This method describes the test procedures required to measure the characteristic impedance of flat cables. To keep this test method as simple and straightforward as possible, balanced and differential signal lines are not addressed. Also, the effect of flat cable against a ground plane is not shown, because of the difficulty in determining what a lab standard ground plane should be.

1.2 General  Characteristic impedance ($Z_0$) for high-frequency pulses is defined electrically as the square root of the inductance divided by the capacitance ($C$). In equation form:

$$Z_0 = \sqrt{\frac{L}{C}}$$

Accuracy and consistency of impedance is required to match the characteristics of the other electronic circuit components. Variations and mismatches in impedance create undesirable pulse reflections and pulse distortions. These reflections and distortions increase attenuation and crosstalk. The characteristic impedance of flat cables is primarily dependent upon the dielectric properties of the insulation and the cable geometry. It is directly proportional to conductor spacing and is inversely proportional to conductor size and the effective dielectric constant of the insulation. Therefore, consistency of impedance is achieved by maintaining uniformity of the insulation dielectric constant and by maintaining accurate control over conductor dimensions and spacing of adjacent conductors.

Characteristic impedance ($Z_0$) is usually measured by time domain reflectometry (TDR). Measurement of $Z_0$ with a TDR consists of sending a pulse down a length of cable and then comparing the reflection obtained to that obtained from a laboratory standard of known impedance, $Z_0$ of a cable is fully defined when three values have been measured:

1. The average $Z_0$ for all signal lines in a length of cable when the cable is suspended in air.
2. The maximum change in impedance (or reflection coefficient) at any point on any signal line of the cable when the cable is suspended in air.
3. The maximum change in impedance when the cable is clamped against a ground plane.

Measurement of the preceding values is performed by use of the setup illustrated in Figure 1. The laboratory standard is connected to the TDR generator output, and the cable with unknown $Z_0$ is connected to the end of the laboratory standard. When a single-ended (unbalanced) cable is to be tested, connection to the laboratory standard consists of (1) the cable signal conductor to the laboratory-standard signal conductor, and (2) the ground conductors associated with the cable signal conductor to the laboratory standard ground. The far end of the cable may be left unterminated, or it may be terminated with a precision resistor to verify the laboratory standard. Balanced cable (which carries simultaneous positive and negative pulses) cannot be directly tested for impedance in this manner; however, a close approximation can be achieved by selecting an axis of symmetry between two signal conductors and then testing only one signal conductor and its associated ground conductor.

Figure 1  TDR Test Set-up for Measuring Characteristic Impedance

The typical oscilloscope trace obtained when testing a cable is illustrated in Figure 2.

3 Test Specimen

3.1 One pre-production or production sample 0.9 m to 3 m long. The number of test samples should be determined by the manufacturer and/or user.

4 Equipment/Apparatus
4.1 In this test, characteristic impedance is measured by TDR. Commercial TDRs are readily available and consist of pulse generator and sampling oscilloscopes. Rise times of the pulses are usually less than 250 picoseconds (250 \( \times \) 10\(^{-12}\) sec.), which gives a resolution sufficient to detect discontinuities smaller than 2.5 cm in length. Since the pulse rise times generally used now in electronic equipment are not this fast, a TDR is adequate for testing. Also required for this test is a lab standard air line to establish a reference impedance \( (Z_0 \text{ ref.}) \) and a standard cable connection device at the air line output (see Figure 1).

4.2 A TDR, such as a Hewlett-Packard 1415A, Hewlett-Packard 1815A, Tektronix 1S2, or equivalent

4.3 The standard air line used should be a General radio 874-L20 (20 cm), 874-L30 (30 cm), or equivalent for \( Z_0 = 50\Omega \).

4.4 Cable Holders Fixture of plexiglass or other nonmetallic material. Cable hangers to suspend the cable in air. Refer to Figure 3.

4.5 The standard cable connection device used should match Figure 4. It is made from a General radio cable connector type 874-C62A.
4.6 Coaxial Cable  Impedance: 50 - 2Ω RG-58A, RG-58C, or equivalent; Termination: GR874 connectors, both ends; Length: approximately 61 cm

4.7 Load  General Radio type GR874 or equivalent 50Ω load. This is an optional item, which is used to calibrate the TDR.

5 Procedure

5.1 Allow a minimum of one hour for TDR warm-up and calibrate the instrument per manufacturer’s instructions.

5.2 Prepare the test specimen by stripping approximately 13 mm of insulation from one end of cable. Separate the ground and signal conductors and solder a copper buss across the grounds (see Figure 5).

5.3 Adjust the TDR settings as follows:
Vertical: 0.1 e/cm
Distance/time: 20 ns/cm.
Magnifier: 50 x (For equipment other than Hewlett-Packard, use settings as close as possible to these.)

Insert the 30 cm air line into the output of the TDR. This will serve as the 50Ω reference. Attach the coaxial cable to the air line and terminate with the impedance probe. Vertically center the 50Ω reference line on the TDR graticule.

5.4 Press the probe against the conductor to be tested insuring the ground of the probe is against the cable ground (see Figure 5) and check the vertical placement of the 50Ω reference; re-center if necessary.

5.5 Adjust the distance/time magnifier to 5 or 10 and rotate the magnifier delay dial until the total length of the cable is visible on the screen. Measure the vertical reflection coefficient (e) in cm as illustrated in Figure 2.

5.7 Calculate the characteristic impedance ($Z_0$) as follows:

$$Z_0 = 50 \left( \frac{1 + e}{1 - e} \right) \text{ (Ω)}$$

Calculate $Z_0$ of the cable measuring as shown in Figure 2. Calculate $Z_0$ max., $e = e$ max; $Z_0$ min., $e = e$ min.
6 Notes

6.1 The TDR employs a pulse rise time less than 250 pico-
seconds. A pulse of this rise time is extremely rich in harmon-
ics extending well into the GHz region of the frequency spec-
trum. The impedance probe illustrated in Figure 1 is designed
to minimize the effects of impedance mismatch at the con-
nection; therefore, it is suggested that a probe of this type be
used for the impedance measurement. The importance of a
good connection between the cable under test and the TDR
can not be overemphasized.

Cables longer than 3 m in length may be tested, but care
must be exercised so as not to confuse the effect of increased
wire resistance with an apparent increase in impedance as the
magnifier delay dial is rotated to observe the longer cable
length (function of attenuation, which includes wire size).

6.2 Under no circumstances should the cable be tested
while in a coiled form due to the effect of increased induct-
tance.

6.3 Keep cable a minimum of 15 cm away from any dielec-
tric or ground plane including metal, wood, etc. (except in
step 5.5).

6.4 Measurement of $Z_0$ of unknown cable length should be
made as close as possible to the cable connection device
(after overshoot and undershoot).

6.5 The reference $Z_0$ cable may be positioned after the
RG58C cable and before the cable connection device. There-
fore, the reference $Z_0$ is adjacent to the test cable on the TDR
trace.
1 Scope This method describes the test procedures required to measure propagation delay in flat cables. Propagation delay is defined as the time required for a pulse to traverse a unit length of cable. Excessive propagation delay will result in the malfunction of critical circuits due to the late arrival of pulses. Propagation delay is directly proportional to the effective dielectric constant of the insulation.

2 Applicable Documents None

3 Test Specimen

3.1 One pre-production or production sample 1 m to 3 m long. The number of test samples should be determined by the manufacturer and/or user.

4 Apparatus

4.1 In this test, propagation delay is measured using time domain reflectometry (TDR). Commercial TDRs are readily available and consist of a pulse generator and sampling oscilloscopes. The TDR to be used should be a Hewlett-Packard 1415A, Hewlett-Packard 1815A, Tektronix 1 S2 or equal.

4.2 Two standard cable connection devices to terminate each end of the test cable, which should match Figure 1. It is made from a General Radio cable connector type 874-C62A.

4.3 A 509 load, type GR874 or equivalent, to terminate the output of the TDR.

Figure 1 Cable Connection Device
4.4 Fixture of plexiglass or other nonmetallic material. Cable hangers to suspend the cable in air (see Figure 2)

5 Procedure

5.1 Allow a minimum of one hour for TDR warmup and calibrate the instrument per manufacturer’s instructions.

5.2 Prepare the test specimen by stripping approximately 13 mm of insulation from both ends of the cable. Separate the ground and signal conductors and solder a copper buss across the grounds of each end (see Figure 3). Solder a standard cable connection device to each end of the cable (see Figure 4).

5.3 Adjust the TDR settings as follows: Vertical-0.2 p/cm; Distance-time-20 ns/cm; Magnifier-10X. (For equipment other than Hewlett-Packard, use settings as close as possible to these.)

5.4 Terminate TDR output using the 50Ω load.

5.5 Adjust the magnitude delay dial so the 50Ω termination is visible and positioned to the left on the screen. Adjust the vertical position so the pulse trace leading edge crosses the horizontal graticule center line at 10% of pulse height (see Figure 5). Mark the position of the leading edge of the pulse on the horizontal graticule (mentally or by camera). If a camera is used, don’t advance the film; a second exposure will be made in 5.8.

5.6 Remove the U section of coaxial GR connectors connecting the step out and signal in. Position each L connector (made from the U connector) in the “STEP OUT” and “SIGNAL IN” connectors.

5.7 Connect the test specimen, one end to the “Step Out” and the other end to “Signal In” (see Figure 6).

5.8 The trace on the TDR screen will have moved to the right from its original position in 5.5. Mark the position of the leading edge of the pulse on the horizontal graticule (again at 10% of pulse height). At this time, a second exposure on the same film used in 5.5 can be made. This will result in both traces on one film. The distance between this mark and the mark in 5.5 is the measured propagation delay (TD). Multiply the measured TD by 20 (distance/time set at 20 ns/cm), then
divide the result by 10 (distance/time magnifier set at 10) to get the total $T_D$ of the test specimen. Subtract $0.20 \text{ ns} \times 2 = 0.40 \text{ ns}$ delay caused by the connection device used at each end of the test cable and divide this result by the exact length of the test specimen to get the propagation delay in ns/0.3 m.
1 Scope
This test method describes the test procedures required to measure propagation delay in flat cables. This test method is an alternative to IPC-TM-650, Method 2.5.19. Propagation delay is defined as the time required for a pulse to traverse a unit length of cable. Excessive propagation delay will result in the malfunction of critical circuits due to the late arrival of pulses. Propagation delay is directly proportional to the effective dielectric constant of the insulation.

2 Applicable Documents
2.5.19 Propagation Delay of Flat Cables Using Time Domain Reflectometer (TDR)

3 Test Specimen
3.1 One pre-production or production sample 0.9 m to 3 m long. The number of test samples should be determined by the manufacturer and/or user.

4 Equipment/Apparatus

4.1 Oscilloscope: Tektronix 7623 with a 7B53A dual time base, or equivalent. The oscilloscope is dual time based, triggered by the pulse generator, and capable of accuracy to 5 ns/div.

4.2 Pulse generator: Tektronix PG501, Hewlett-Packard 8013B, or equivalent. The pulse characteristics from the pulse generator should be determined by the manufacturer and/or user.

4.3 Oscilloscope test probes, preferably high speed, with matched propagation delay

4.4 Cable holder: Fixture of plexiglass or other nonmetallic material

4.5 Cable hangers to suspend the cable in air (see Figure 1)

4.6 A termination resistor equal to the characteristic impedance of the test specimen is required to terminate the output end of the cable. When oscilloscope probes are attached to the cable, the termination resistance (RT) has to be calculated:

\[
RT = \frac{R_{PROBE} + Z_{CABLE}}{R_{PROBE} - Z_{CABLE}}
\]

4.7 An input resistor is required in series between the pulse generator and the test specimen (only) when the characteristic impedance of the cable is equal to or less than the output impedance of the pulse generator. In this case:

Input Resistance = \( Z_{OGENERATOR} - Z_{OCABLE} \)

4.8 Standard cable connection device matching Figure 2. It is made from a General Radio cable connector type 874-C62A (propagation delay 0.2 ns).

4.9 A 50Ω General Radio to BNC female adaptor is required to connect the pulse generator to the test specimen.

5 Procedure

5.1 Allow one hour for the test equipment to warm up. Connect the pulse generator Trig output to the oscilloscope main Trig in. Set the pulse generator output pulse characteristics as specified for the test. Hook up both test probes from each oscilloscope input to the single pulse generator output. Adjust the scope sweep rate to 5 ns/div and view both channels.
There should be no time delay difference between the channels caused by the probes. If there is any delay, it should be noted and added to the final TD calculation.

5.2 Prepare the test specimen by stripping approximately 13 mm of insulation from each end of the cable. Separate the ground and signal conductors and solder a copper buss across the grounds (see Figure 3). The exact length of the cable should be noted.

5.3 Solder the termination resistor from signal lead to ground buss at the output end of the cable.

5.4 Solder the input resistor in series with the signal lead on the input end of the cable (only if required).

5.5 Solder the standard cable connection device to the test specimen signal-to-signal lead and ground-to-ground buss.

5.6 Connect the pulse generator to the GR to BNC adapter via a short length of coaxial cable. Connect the input end of test specimen to the adapter.

5.7 Connect the oscilloscope input probes to the test specimen, one at the input and the other at the output termination (see Figure 4).

5.8 Set the oscilloscope sweep rate at 5ns/div and view both channels on the CRT. Measure the distance between the leading edge (at 10% pulse height) of each channel using the display graticule as a guide (see Figure 5). Divide the result by the cable length to get propagation delay in ns/0.3 m.

6 Notes

6.1 If using a small sample (0.9 m), the scope should be capable of accuracy to 1 ns/div.
Figure 3 Cable Preparation and Cable Connection

Figure 4 Test Cable Hookup
Figure 5  Dual Trace Oscilloscope Display
1 Scope  This test method gives a procedure to determine crosstalk or the magnitude of disturbance that is coupled to one conductor when another conductor in a given cable configuration is activated with a pulse.

2 Applicable Documents  None

3 Test Specimen

3.1 3.1 m ± 6.4 m length of cable

4 Equipment/Apparatus

4.1 Fast rise pulse generator

4.2 Sampling plug-in in appropriate oscilloscope (see Figure 1) with a high input impedance probe (≥152 m)

4.3 Test fixture to introduce signal, provide oscilloscope pickoff points, impedance matching and terminating potentiometers, and a means of connecting sample (see Figure 2)

4.4 Brackets to hold cable suspended in air and support fixture close to end of cable system

4.5 Styrofoam with rigid backing for “stacked” crosstalk (see Figure 3)

4.6 Ohmmeter

5 Procedure

5.1 Setup

5.1.1 Set pulse generator as follows:

- Rep Rate........................................ 1 megahertz
- Pulse Amp..................................... 2 to 5 volts
- Pulse Width................................. 1 nanosecond
- Rise Time................................. 2.5 nanosecond
5.1.2 Choose configuration and strip wires out one 2.5 cm on each end (for testing stacked configuration, prepare two identical samples).

5.2 Interlayer Crosstalk

5.2.1 Clamp the cable in brackets so that it is suspended in air away from any conductive surface.

5.2.2 Connect the wires to appropriate terminals on the test fixture, taking care to keep lead lengths as short and neatly dressed as possible without shorting.

5.2.3 Apply pulse specified and observe on the oscilloscope connected to E1 (see Figure 4).

5.2.4 Set the potentiometer R2 for minimum resistance, observed on the scope at E1 as maximum mismatch (i.e., maximum negative first reflection).

5.2.5 Adjust R1 for minimum second reflection.

5.2.6 Readjust R2 for minimum first reflection.

5.2.7 Disconnect the signal wires from the far end box (receiver) and read and record the resistance values of R1 and R2.

5.2.8 Set the potentiometers R3 and R4 to the value and read at R2.

5.2.9 Reconnect the sample to the receiver boxes and read and record voltages at E1, E2, E3, and E4. Also read and record the pulse rise time (10% to 90%) at E1 and E2.

5.3 Intralayer or Stacked Crosstalk

5.3.1 Place cables on Styrofoam base next to edge alignment block. The cables should be in close vertical alignment (see Figure 3).

5.3.2 Place the Styrofoam cover over the stack and with a thin blade, push the cables against the edge piece all along the length to assure the best possible vertical alignment. One thousand gram weights are then placed at 0.3 m intervals on top of the Styrofoam backing.

Note: The quality of the stack (vertical alignment and intimate contact) should be checked before proceeding. This is done by connecting a TDR to two grounds on the bottom layer and the center signal wire on the top layer.

O S O
G O G
(Unused wires are left open)

Any indication of discontinuities on the scope indicates poor alignment of the cables not in intimate contact.

5.3.3 Place the box holding the bracket on the raisers so that the height can be adjusted to provide a smooth transition from the cables to the test fixtures.

5.3.4 Connect the wires to the appropriate terminals on the test fixtures and proceed as in 5.2.3.

Calculations:

CROSS TALK

\[
\text{Forward } \frac{E_4}{E_1} \times 100 = \%
\]

\[
\text{Back } \frac{E_2}{E_1} \times 100 = \%
\]

ATTENUATION

\[
\text{Voltage } \frac{E_4 - E_2}{E_1} \times 100 = \%
\]

Rise time \( E_2 \) (n. sec.) – \( E_1 \) (n. sec.) = n. sec.

Report:

Crosstalk is reported in percent for a 3 m sample length. Attenuation is reported in percent voltage and nanoseconds rise time for a 3 m sample length.

The report should also include the values of R1 and R2 and rise time at E1.
1 Scope  This method describes the test procedure required to measure the conductor resistance of flexible flat cable.

2 Applicable Documents  None

3 Test Specimen

3.1 The number of production samples and length should be determined by the manufacturer and/or user and shall be a minimum of one sample with a minimum length of 3 m.

4 Apparatus

4.1 Kelvin Bridge or other suitable instrument

5 Procedure

5.1 The flat cable specimen shall be stripped at each end to expose the conductors. A minimum of three or 10% of the total number of conductors (whichever is the greater) shall be tested. The location of the conductors tested shall include some conductors at the edges and central areas of the cable.

5.2 The individual conductors shall be tested using the apparatus in 4.1 at 20°C ± 3°C. Conductors shall be tested at the minimum current value consistent with the instrument used. The attachment of the test apparatus terminals shall be such as to establish a specific cable length used for resistance calculations.

5.3 Evaluation  Using the determined specific cable length, calculate the resistance in ohms per 304 m of length and compare to values specified in the appropriate document.
1 Scope  This test method describes the test procedure required to measure the dielectric strength of flexible flat cable.

2 Applicable Documents  None

3 Test Specimen

3.1  The number of production samples and length should be determined by the manufacturer and/or user. As a minimum, one sample of at least 3 m should be tested.

4 Apparatus

4.1  A suitable container in which the specimen may be immersed in water

4.2  A power source capable of the specified potential

5 Procedure

5.1  Prepare the specimen by commoning all of the conductors together and sealing the other end in dielectric wax.

5.2  Immerse the specimen, with both ends out of the water, for a minimum of four hours.

5.3  The water is to provide one polarity of the specified potential and the commoned conductors the other polarity. Potential is to be increased at a uniform rate of 500V/sec until the test voltage is reached or until breakdown occurs.

5.4  The specimen should also be tested conductor-to-conductor at the specified potential by separating every other conductor to one side or the other and attaching the test leads.

5.5  All test voltage is to be held for one minute.

6 Notes

6.1  There shall be no failures.
1 Scope

1.1 This method describes the test procedure required to measure the insulation resistance of flexible flat cable.

2.0 Applicable Documents

2.5.25 Dielectric Withstand Voltage, Flexible Flat Cable

3 Test Specimen

3.1 The number of production samples shall be determined by the manufacturer and/or user. As a minimum one sample of at least 3 m shall be tested.

3.2 To expedite testing, use the same sample tested in IPC-TM-650, Method 2.5.25.

4 Apparatus

4.1 Megohmmeter or megohm bridge capable of 500 volts dc and 5000 megohms

4.2 A suitable container in which the specimen may be immersed in water

5 Procedure

5.1 The specimens from 3.1 and 3.2 shall be immersed, except for 5 cm at each end, in water at room temperature for four hours.

5.2 The specimen shall be tested at 500 volts dc with the conductors maintained negative to the water, and the voltage shall be applied one minute before measuring leakage current.

6 Notes

6.1 The specimen shall pass the I.R. of the applicable specifications.
1 Scope  This test method is designed to determine the surface insulation resistance of dielectric material after the prescribed conditioning cycles.

2 Applicable Documents
MIL-STD-202  Method 106, Electronic Components

3 Test Specimens
3.1 At least two specimens, modeled after the IPC-B-25 (see Figure 1) shall be made. The copper foil shall be removed by chemical etching, using standard commercial practices.

4 Apparatus
4.1 A test chamber capable of meeting MIL-STD-202, Method 106, and elevated temperature of 150°C

4.2 A meter capable of applying 500 VDC to the specimens for a period of 60 +5/-0 seconds and measuring resistance values between 1 megohm and 10 million megohms with measurement error of less than 1% — A H/P Model 4329A, High Resistance Meter, or equivalent

5 Procedure
5.1 Preparation
5.1.1 Double-clad material shall have one side completely etched. The other side and single-clad material shall be etched as specified in 3.1.

5.1.2 Specimens shall be dried for a period of 24 ± 2 hours at 50°C ± 5°C. Measurements shall be made immediately after removal from the chamber.

5.1.3 Specimens shall be subjected to the conditioning cycle of MIL-STD-202, Method 106 (except steps 7a and 7b). The measurements shall be made inside the chamber after completion of the cycle.

5.1.4 Specimens shall be subjected to elevated temperature for 24 hours at 150°C ± 5°C. Measurements shall be made within 30 minutes after the completion of this cycle.

5.2 Test
5.2.1 Measurements shall be made after each conditioning phase. The specimens shall be removed from the chamber before measurements specified in 5.1.2 and 5.1.4 are taken. Specimens shall be left inside the chamber for taking measurements specified in 5.1.3. Four readings per the comb pattern shall be taken for each specimen; readings shall be between pins 1 & 2, 1 & 3, 3 & 5, and 4 & 5 (see Figure 1).

5.2.2 Turn the megohmmeter on prior to the removal of the specimens from the chamber. Allow the meter to warm up for a minimum of 30 minutes.

5.2.3 After warm-up, calibrate the meter and set the voltage to 500 VDC.

5.2.4 Connect the leads to the appropriate pins (see Figure 1).
5.2.5 After allowing the meter to “charge” for 60 seconds, switch to “measure” and read the meter in megohms after the indicator settles down (usually within 60 seconds).

5.3 Evaluation Readings shall be recorded to two significant digits in megohms.

6 Notes

6.1 This method can be used in substitution for surface resistance. Volume resistivity cannot be replaced by this method, but other tests such as dielectric strength, dissipation factor, and dielectric constant will give a better indication of the electrical properties than volume resistivity.
1 Scope  This test method defines the procedure for determining the Q resonance of copper foil clad, rigid, and flexible dielectric material.

2 Applicable Documents
2.3.7.2  Alkaline Etching Method

3 Test Specimen
3.1 The test specimen shall consist of an etched conductor pattern in accordance with Figure 1. A minimum of three specimens shall be prepared for each frequency being tested.

4 Apparatus
4.1 Necessary equipment to produce printed wiring by the etched foil process using good commercial practices
4.2 Q meter (Hewlett Packard model #4342A or equivalent)

5 Procedure
5.1.1 Prepare the test patterns according to Figure 1 using good commercial practices or IPC-TM-650, Method 2.3.7.2.
5.1.2 Solder the tinned (22 gauge) wire leads to the land areas on the test pattern using a 25 to 40 watt soldering iron. The solder or rosin must not spread beyond the land area.
5.1.3 Thoroughly clean and dry the specimens as described in 5.1.3.1 through 5.1.3.5 and until completion of testing, handle them by the edges only.
5.1.3.1 Brush with a bristle brush under running tap water. The hardness of the tap water shall not exceed 175 ppm (expressed as calcium carbonate). Deionized water may be employed.
5.1.3.2 Dry with an oil-free, compressed air brush while submerged in isopropyl alcohol, removing all excess rosin.
5.1.3.3 Dip in fresh isopropyl alcohol and dry with an oil-free, compressed air brush.
5.1.3.4 Dry in an oven for a minimum of two hours at a temperature between 49°C and 6°C.
5.1.3.5 Remove from the oven, then condition for 24 hours prior to testing at 23°C ± 3°C and 50% ± 50% RH.
5.2 Test
5.2.1 Determine the Q of each test specimen at the required frequency (usually 1 MHz, 50 MHz, and 100 MHz) using the following procedure.
5.2.1.1 Using the resonance-rise method, resonate the Q meter without any test specimen.

5.2.1.2 Record the voltmeter reading as Q and the capacitance reading as C₁.

5.2.1.3 Resonate the Q meter with the test specimen connected in parallel to the Q circuit. It should be noted that the measurement leads should be of equal length and as short as practicable to reduce the lead inductance when performing these measurements.

5.2.1.4 Record the voltmeter reading as C₂.

5.2.1.5 Calculate the Q of the specimen as follows:

\[
Q_x = \frac{Q_1 Q_2 (C_2 - C_1)}{(Q_1 - Q_2) C_1}
\]

5.2.2 Determine the Q of each test specimen at the desired frequency using the procedure given in 5.2.1.1 through 5.2.1.5.

5.3 Evaluation

5.3.1 Report the Q value for each individual specimen at each test frequency.
1 Scope  This method is used to determine the attenuation of balanced and unbalanced cables.

2 Applicable Documents  None

3 Test Specimen
3.1 30.5 meters of completed flat cable

4 Apparatus
4.1 H.R. Model #8568A or equivalent spectrum analyzer
4.2 H.R. Model #8444A or equivalent 2 tracking generator
4.3 Two RG-223/U or equivalent 50 Ohm coaxial cables
4.4 North Hills or equivalent matching transformers

<table>
<thead>
<tr>
<th>Unbal/Bal</th>
<th>Freq. Range</th>
<th>Model No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/50</td>
<td>100 KHz to 125 MHz</td>
<td>0001 BB</td>
</tr>
<tr>
<td>50/75</td>
<td>100 KHz to 125 MHz</td>
<td>0101 BB</td>
</tr>
<tr>
<td>50/90</td>
<td>100 KHz to 125 MHz</td>
<td>0200 BB</td>
</tr>
<tr>
<td>50/100</td>
<td>100 KHz to 100 MHz</td>
<td>0300 BB</td>
</tr>
<tr>
<td>50/150</td>
<td>100 KHz to 100 MHz</td>
<td>0400 BB</td>
</tr>
</tbody>
</table>

4.5 Resistor matching network (see Figure 1)

5 Procedure

5.1 Procedure (Balanced)

5.1.1 Calibrate spectrum analyzer and adjust the tracking generator for accurate frequency tracking.

5.1.2 Select impedance matching transformers that match (as close as possible) the characteristic impedance of the cable under test.

5.1.3 Connect the outputs of the two matching transformers together. Sweep the spectrum analyzer through the required frequency range to determine the loss in the matching transformers.

5.1.4 Separate the two matching transformers and connect 30.5 m of the test cable between them; again sweep the spectrum analyzer through the required frequency range. This measurement determines the total loss, which includes the cable and matching transformers.

5.1.5 To determine the cable attenuation, based on 30.5 meters of cable, at each frequency of interest, subtract the results of 5.1.3 from the results of 5.1.4 (see Figure 2).

5.2 Procedure (Unbalanced)

5.2.1 Calculate the resistance required to match the 50 ohm system impedance to the test cable’s characteristic impedance, as shown in Figure 1.

5.2.2 Use the above resistive matching network in place of the balanced transformers as indicated in 5.1.3. Perform the unbalanced attenuation test as described in 5.1.1 through 5.1.5 (see Figure 3).
Figure 1 Resistive Matching Network for Unbalanced Cables

For Z System < Z Cable:

\[ R_1 = \sqrt{\frac{Z_C (Z_C - Z_S)}{Z_S}} \]
\[ R_2 = Z_S \sqrt{\frac{Z_S}{(Z_C - Z_S)}} \]

For Z System > Z Cable:

\[ R_1 = \sqrt{\frac{Z_S (Z_S - Z_C)}{Z_C}} \]
\[ R_2 = Z_C \sqrt{\frac{Z_S}{(Z_S - Z_C)}} \]
Figure 2  Balanced Attenuation Equipment Setup
Figure 3  Unbalanced Attenuation Equipment Setup
1.0 Scope  This test procedure is to determine the current leakage through overglaze films by application of current flow across two electrodes and measurement of the amperage developed.

2.0 Applicable Documents  None

3.0 Test Specimens  This test specimen shall consist of a thick film conductive electrode applied to the surface of a 51 mm x 51 mm [2.0 in x 2.0 in] nonporous ceramic substrate. The electrode shall be round, with a 60 mm [2.4 in] area and have a tab or contact area approximately 6 mm [0.24 in] wide extending 20 mm [0.8 in] from the perimeter of the electrode. The overglaze film shall be applied over the electrode to extend at least 5 mm [0.2 in] beyond the edge of the electrode and cover a minimum of 10 mm [0.4 in] of the electrode tab.

4.0 Apparatus

4.1 One 10-volt DC source

4.2 One normal NaCl solution made with distilled or deionized water

4.3 One glass container

4.4 One platinum foil electrode

4.5 An ammeter with a range of 0-1000 microamperes

4.6 Suitable clamps, clips, fixtures and wires for supporting samples and making electrical connections

4.7 One stirring device

4.8 The test solution shall be one normal NaCl solution made with distilled or deionized water. The solution shall be contained in a glass container of chemical laboratory quality.

5.0 Test

5.1 Procedure

5.1.1 Partially immerse the test specimen vertically into the salt solution with the electrode facing the center of the container and the tab pointing upward.

5.1.2 A minimum 5 mm [0.2 in] of the portion of the tab is to be covered by the overglaze and should extend above the solution surface.

5.1.3 Support the specimen along the top edge with a fixture or clamp. Partially immerse the platinum foil electrode into the salt solution facing the electrode on the test specimen 12 to 50 mm [0.5 to 2.0 in] apart.

5.1.4 Connect the positive terminal of a 10 volt DC source through the ammeter to the platinum electrode.

5.1.5 Connect the negative terminal of the voltage source to the exposed portion of the thick film electrode tab on the test specimen.

5.1.6 There should be no clamps, clips, fixtures or wires in contact with the salt solution.

5.1.7 The salt solution should be stirred gently during the test.

5.2 Evaluation  After the voltage has been applied between two electrodes for 5 minutes, the current flow indicated by the ammeter is recorded.
1.0 Scope  
To determine the change in resistance of plated through-holes after being subjected to repeated thermal cycling conditions.

2.0 Applicable Documents  
None

3.0 Test Specimen  
Test specimen shall be made using identical laminate as that of finished product, and shall conform to all details of Figure 1.

4.0 Apparatus

4.1 Circulating Air Chamber  
Capable of maintaining a uniform temperature of 135°C (275°F) to 149°C (300°F).

4.2 Milliohm Meter  
Incorporating use of four-point probe measurement technique, with a range of at least 2 milliohm to 300 milliohms.

4.3 Thermal Cycling Chamber  
Either an air-to-air system or a liquid to liquid system, capable of cycling between –75°C and +200°C [–103°F and 392°F] and a transfer time of one minute or less.

4.4 Desiccator

5.0 Procedure

5.1 Specimens shall be conditioned by drying in an oven for four hours at 135°C (275°F) to 149°C (300°F) and cooled to room temperature in a desiccator.

5.2 Resistance Measurement  
Using the four point milliohm meter, connect the current probes to the “l” contact pads at each end of the daisy chain pattern. Connect the voltage measurement probes to the “e” contact pads at the end of the chain. Record the total chain resistance in the appropriate “Initial Resistance” record to a chart similar to Figure 2.

5.3 Program the temperature cycling equipment for the selected test cycle.

5.3.1 Recommended Cycle: Ambient Temperature

-65°C [–85°F] ............................................................... 10 minutes  
Transfer .......................................................... 1 minute (max.)  
+125°C [257°F] ...................................................... 10 minutes  
Transfer ........................................................... 1 minute (max.)  
(Repeat)

Figure 1 Test specimen artwork

Figure 2 Resistance Values

<table>
<thead>
<tr>
<th>Entry #</th>
<th>Cycle</th>
<th>Total Chain Resistance (milliohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Initial</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cycle #10</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cycle #20</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cycle #30</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cycle #40</td>
<td></td>
</tr>
</tbody>
</table>
5.4 Load parts into chamber and allow to cycle for 10 cycles.

5.5 Remove parts from chamber at ambient temperature conditions, and repeat Resistance Measurement of Section 5.2, recording Total Chain Resistance on chart shown in Figure 2.

5.6 **Double Plated Through-Hole Resistance Measurement**

In the event it is desired that the resistance of an individual hole pair measured, use the same milliohm meter as follows:

5.6.1 Using four contact pads provided in artwork as in Figure 1, select two pads on each side of a pair of holes.

5.6.2 Apply current probes to pads furthest from the holes.

5.6.3 Apply voltage probes to pads immediately adjacent to the holes.

5.6.4 Perform resistance measurement with milliohm meter and record value.
1 Scope  EOS and electrostatic discharge (ESD) have been proven to damage and degrade electronic components and assemblies. This test method consists of a series of individual test procedures to test soldering and desoldering hand tools with grounded working surfaces for electrical grounds, transient voltages, and current leakage.

This series of test methods attempts to identify those bench-top systems, which might contribute to premature assembly failure from EOS/ESD related failure mechanisms. Test results may be erroneous or skewed if they are incorrectly performed, influenced by outside forces (e.g., air conditioning discharge over the unit under test), or if incorrect test equipment is selected.

Test equipment selected for equipment qualification must be capable of measuring the low voltages and current emitted by the unit under test (UUT). Additionally, the equipment must be capable of reading pulses and frequencies emitted by the UUT, which may be oscillator or microprocessor controlled. As faster and more capable oscillator and microprocessor controlled equipment is introduced by equipment manufacturers, it may become necessary to select test equipment with a broader bandwidth than that currently specified in this procedure. Failure to do so is likely to qualify equipment that might otherwise be disqualified.

Several of these tests can be falsely influenced by radio frequency interference and electromagnetic interference from lighting and equipment found in the workplace and testing area. To avoid these influences the leakage and transient tests should be performed in a screen room. In lieu of a screen room, a separate test procedure (see Test Method 2.5.33.4) has been provided to make a low cost shielded enclosure which should provide adequate shielding for the performance of these test procedures.

Warning:  These are laboratory test procedures that may of necessity expose terminals that carry line voltages. All standard laboratory safety procedures regarding the setup and performance of tests with line voltage equipment must be observed at all times.

Caution:  These tests are performed with soldering systems at their normal operating temperature. Test personnel must take adequate precautionary steps to protect themselves and others from potential burns.

1.1 Purpose  The purpose of the electrical overstress (EOS) test methods is to provide standardized test procedures for the qualification of equipment to Appendix A of ANSI/J-STD-001. Users may utilize Appendix A as part of an equipment qualification procedure or may be referred to Appendix A when the process has been determined to be out of control (see ANSI/J-STD-001).

2 Applicable Documents.

ANSI/J-STD-001  Requirements for Soldered Electrical and Electronic Assemblies


2.5.33.1 Measurement of Electrical Overstress of Hand Soldering Tools - Ground Measurements

2.5.33.2 Measurement of Electrical Overstress of Hand Soldering Tools - Transient Measurements

2.5.33.3 Measurement of Electrical Overstress of Hand Soldering Tools - Current Leakage Measurements

2.5.33.4 Measurement of Electrical Overstress of Hand Soldering Tools - Shielded Enclosure

3 Test Specimens  The tests that make up this test method call for the use of a locally produced sacrificial test electrode. The test electrode shall be a piece of single or double-sided 69 µm (15 mm thick) copper clad FR-4. The electrode size shall be of a uniform size 45 mm x 23 mm ± 6.4 mm. The size may be adjusted to accommodate any locally produced test fixtures.

The size of the electrode area is designed so that it is not so big that it cools the temperature of the UUT below solder melt and not so small that the temperature of the UUT causes rapid oxidation or solder sludging. This electrode is designed to be replaceable since it will deteriorate after repeated testing.

4 Equipment/Apparatus  The apparatuses utilized by the procedures that make up this test method are given in 4.1 through 4.19.

4.1 Test Electrode (see Section 3)
4.2 AC millivoltmeter capable of measuring true mvAC/rms having a resolution of 0.1 mv AC. The frequency response of the millivoltmeter shall be 20 Hz-to-20 Mhz. (MilliVac MV814A, Hewlett-Packard HP3400B, or equivalent).

4.3 DC millivoltmeter capable of measuring at least 60 mv DC and having a resolution of 1 mv DC

4.4 Ohmmeter with a digital readout unit. It shall possess scales that can measure resistances beyond 5 MΩ with an accuracy of ± 100 KΩ or better (± 10% or better of the lower limit). The ohmmeter shall have a resolution of 0.1 MΩ or better.

4.5 Storage oscilloscope, 100 Mhz bandwidth or faster, 1 MΩ input vertical amplifier

4.6 Oscilloscope probe - X10 Attenuation

4.7 Constant current Source capable of providing 10 milliamps DC

4.8 Resistor, 4.99 Ω, 1% precision ¼w or greater (any commercially available brand carbon or metal film)

4.9 Power line filter, 20 ampere @ 115 VAC, 50 dB insertion loss @ 5 Mhz/50Ω

4.10 Test box (see 5.1)

4.11 Screen room/shielded enclosure (optional) capable of accommodating the entire UUT, cord, and hand piece. A filtered AC power receptacle shall be available from within (see Method 2.5.33.4).

4.12 Resistor, 1.00 KΩ, 1% (any commercially available brand carbon or metal film)

4.13 Diodes (two), which shall be of the lowest practicable known forward bias devices. 1N34 diodes have been found satisfactory for this purpose.

4.14 AC Receptacles (two)

4.15 Line cord

4.16 Strain relief

4.17 BNC Connector

4.18 Edge card connector w/mounting hardware

4.19 Metal (bud) box

5 Procedure

All the following test procedures should be completed to ensure compliance with ANSI/J-STD-001:

Method 2.5.33.1 Measurement of Electrical Overstress from Soldering Hand Tools—Ground Measurements

Method 2.5.33.2 Measurement of Electrical Overstress from Soldering Hand Tools—Transient Measurements

Method 2.5.33.3 Measurement of Electrical Overstress from Soldering Hand Tools—Current Leakage Measurements

To construct a bench top shielded enclosure for use in lieu of a screen room, refer to:

Method 2.5.33.4 Measurement of Electrical Overstress from Soldering Hand Tools—Shielded Enclosure

5.1 Test Box

Testing has shown that for UUTs that utilize high frequency circuits, layout and cord positioning can influence the AC current leakage reading. A compact configuration such as the one shown in Figure 1 minimizes those influences (see Method 2.5.33.3).

6 Notes

6.1 Pass/Fail Limits for Transients and Steady-State Voltage

EOS/ESD papers typically discuss possible damage to electronic components coming from electrostatic discharge (ESD). The potentials discussed typically are 100’s and 1000’s of volts. This test method is also concerned with the possible damage to electronic components coming from electrical overstress (EOS). The EOS potentials of concern will be 1’s of volts down to millivolts. This test method strives to set achievable EOS limits for soldering/desoldering equipment based upon the ability to construct soldering equipment as well as resolve small potentials from background interference.

Although any electronic component can be damaged by sufficient amounts of EOS/ESD, conventional wisdom states that semiconductors are the most susceptible. Two obvious EOS/ESD caused failure modes in semiconductors are:

- Dielectric breakdown or reverse voltage breakdown due to excessive potential
• Junction overheated due to excessive forward current

6.2 Limits to Prevent Voltage Breakdown Due to Individual Transients As integrated circuit geometries shrink, dielectric breakdown voltage ratings also diminish. One semiconductor discussed here (battery operated integrated circuits) currently represents the lowest breakdown ratings. S-MOS Systems’ SMC62L35 single-chip microcomputer is designed to run from a single 1.5 volt battery. It has an absolute maximum voltage (damage could result) of 2 volts. The recommended limit for individual transients is 2 volts peak.

The recommended limit for individual transients is 2 volts peak.

6.3 Limits to Prevent Overheating Due to Steady-State Leakage Most semiconductor junctions are intentionally designed, but in integrated circuits, there are also unavoidable intrinsic junctions. Also, there are junctions that are never supposed to be operated in the forward direction (i.e., JFETs and tuning diodes). The devices are not well characterized by the manufacturer regarding the maximum forward current. Regardless of the nature of the junction, simultaneous forward current and voltage drop results in power dissipation. If the junction power results in a sufficient temperature increase, the junction may be changed or destroyed. It is possible to prevent forward current from flowing through a junction simply by keeping the applied voltage below the forward junction voltage rating. Two semiconductors discussed here represent the lowest forward junction voltage ratings: Schottky diodes and germanium diodes. Motorola’s MBD201 Schottky diode and most common germanium diodes begin to conduct at 220 millivolts. The test method apparatus represents these by including commonly available 1N34 germanium diodes. To be sure no junction heating can be caused by the UUT, the current should be zero. But practically, since zero is difficult to measure, a 1 microamp maximum tolerance can be permitted without fear of overheating the junction. The recommended limit for current leakage is 1 microamp (flowing through a closed circuit, which includes parallel head-to-tail germanium diodes).
### 6.4 Test Results
Complete ALL shaded areas.

**Description of UUT (brand, model configuration, etc.):**

<table>
<thead>
<tr>
<th>Test</th>
<th>Procedure</th>
<th>Pass/Fail Criteria</th>
<th>Value Recorded</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Measurements</td>
<td>(2.5.33.1)</td>
<td>≤5 Ω</td>
<td>Ω</td>
<td>Pass</td>
</tr>
<tr>
<td>Transient Measurements/Pass 1</td>
<td>(2.5.33.2)</td>
<td>≤2 V peak</td>
<td>V</td>
<td>Pass</td>
</tr>
<tr>
<td>Transient Measurements/Pass 2</td>
<td>(2.5.33.2)</td>
<td>≤2 V peak</td>
<td>V</td>
<td>Pass</td>
</tr>
<tr>
<td>Transient Measurements/Pass 3</td>
<td>(2.5.33.2)</td>
<td>≤2 V peak</td>
<td>V</td>
<td>Pass</td>
</tr>
<tr>
<td>Current Leakage Measurements</td>
<td>(2.5.33.3)</td>
<td>≤1.0 µ-amp DC</td>
<td>µ-amp DC</td>
<td>Pass</td>
</tr>
<tr>
<td>Current Leakage Measurements</td>
<td>(2.5.33.3)</td>
<td>≤1.0 µ-amp ACrms</td>
<td>µ-amp ACrms</td>
<td>Pass</td>
</tr>
</tbody>
</table>

**Description of Test Equipment and Configuration**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Function</th>
<th>Brand</th>
<th>Model</th>
<th>Calibration Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC millivoltmeter</td>
<td>true mvAC/rms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC millivoltmeter</td>
<td>60 mv DC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ohmmeter</td>
<td>resistances beyond 5 MΩ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage Oscilloscope</td>
<td>100 Mhz bandwidth or faster, 1 MΩ input vertical amplifier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant Current Source</td>
<td>10 milliamps DC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Additional Comments:**

---

**Test Completed by:**

<table>
<thead>
<tr>
<th>NAME:</th>
<th>DATE:</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPANY:</td>
<td>PHONE:</td>
</tr>
</tbody>
</table>
6.5 Reference

MIL-STD-1686\(^1\) Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

MIL-HDBK-263 Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

EOS/ESD-S6.0-1994\(^2\) Grounding - Recommended Practice

1. Standardization Documents Order Desk, 700 Robbins Avenue, Bldg. 4D, Philadelphia, PA 19111-5094
2. ESD Association, 7902 Turin Rd., Ste. 4, Rome, NY 13440-2069
1 Scope  This test method describes the measurement of the DC tip-to-ground resistance of an electric hand soldering/desoldering tool designed with a grounded tip. Measurement of tip-to-ground AC reactance is outside the scope of this test method. Also, measurement of soft grounded or equipment with insulated tips is outside the scope of this test method.

There are three times when ground testing should be done:

- Equipment qualification for purchase
- Incoming inspection of new or repaired equipment
- Process monitoring (periodic checks)

Determination of tip-to-ground resistance is accomplished by using a basic ohmmeter circuit, passing a current through the tip and its grounding circuit and measuring the resultant voltage drop. The values used in this test eliminate error caused by the Seebeck (thermocouple) effect.

Warning  This is a laboratory test procedure that may, of necessity, expose terminals that carry line voltages. All standard laboratory safety procedures regarding the setup and performance of tests with line voltage equipment must be observed at all times.

Caution  This test is performed with soldering systems at their normal operating temperature. Test personnel must take adequate precautionary steps to protect themselves and others from potential burns.

2 Applicable Documents.

ANSI/J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies.

2.5.33 Measurement of Electrical Overstress from Soldering Hand Tools

3 Test Specimens  Test specimens for this procedure are detailed in Method 2.5.33.

4 Equipment/Apparatus

4.1 Test electrode per Method 2.5.33

4.2 Constant current source capable of providing 10 milliamps DC

4.3 DC millivoltmeter capable of measuring at least 60 mv DC and having a resolution of 1 mv DC

4.4 Resistor, 4.99Ω 1% precision ¼w or greater (any commercially available brand carbon or metal film)

4.5 Preparation of Apparatus  Connect the apparatus as illustrated in Figure 1. The negative electrode of the test apparatus shall make a good electrical connection to the ground reference point of the Unit Under Test (UUT). The UUT shall be turned on and adjusted (if applicable) to achieve normal operating temperature.

Note: The plug is in the receptacle during measurements. It’s shown unplugged in Figure 1 for clarity. Non-US power receptacles may be different from that illustrated.

4.6 Calibration and Standardization  The apparatus is checked by separately placing two resistive elements across the test apparatus’s electrodes: a shorting wire (0.0Ω) and 4.99Ω 1% precision ¼w or greater resistor. The combination of the current source and the measuring/indicating device will be accurate to within ± 0.2Ω (± 4% of upper limit).

5 Procedure  Once the electrodes are in position and the test apparatus is operating, touch the HOT tip of the UUT to the tinned area of the test electrode. Apply solder to form a good electrical contact. Wait for the reading to stabilize, then record the reading.

5.1 Calculation and Interpretation of Results  Even though the meter reads out millivolts, using 10 ma DC for excitation current results in the displayed numbers representing the resistance in ohms without calculation, except for decimal place shifting (i.e., a readout of 30 mv dc indicates 3.0Ω).

The reading shall be equal to or less than 5.0Ω.

6 Notes  If tracking test results, record the measured values on a copy of the form found in Method 2.5.33.
6.1 **Ground Measurement**  Determination of tip-to-ground resistance is accomplished by using a basic ohmmeter circuit as represented in Figure 2. It works by passing a current through the tip and its grounding circuit and measuring the resultant voltage drop. This test method recognizes the thermocouple effect present due to the assembly comprising different metallic materials whose junctions operate at different temperatures (including the test apparatus electrodes). Testing using ohmmeters having too low excitation current has resulted in the thermocouple voltage introducing a significant error or even causing a negative resistance reading. Error from the thermocouple effect is made insignificant by increasing the excitation current, thus increasing the voltage drop. Testing has demonstrated an excitation current of 10 milliamps suffices.

The voltage measuring device must indicate the voltage drop in such a manner that the reading the operator sees directly reflects the resistance in ohms and tenths of ohms. No calculations other than decimal place shifting should be used.

6.2 **Constant Current Source**  The constant current source can be an off-the-shelf unit, a custom-built active circuit, or a simple passive circuit. Figure 3 shows a very simple way to achieve a 10 ma source accurate enough for measuring soldering systes.

This circuit works because the battery voltage is high compared to the drop across the UUT. Assume a battery voltage of 48 volts and a dropping resistor of 4800 ohms. When the resistance of the UUT equals zero, the current will be 10 ma.
If the resistance of the UUT rises to the upper limit of 5Ω, the current will be 9.989 ma, just outside 0.1% on the low side. This inaccuracy is well within the limits of the standard.

### Table 1  Examples for Battery, Dropping Resistor, and Accuracy

<table>
<thead>
<tr>
<th>V</th>
<th>R</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>600</td>
<td>-0.8%</td>
</tr>
<tr>
<td>9</td>
<td>900</td>
<td>-0.6%</td>
</tr>
<tr>
<td>12</td>
<td>1200</td>
<td>-0.4%</td>
</tr>
<tr>
<td>24</td>
<td>2400</td>
<td>-0.2%</td>
</tr>
<tr>
<td>48</td>
<td>4800</td>
<td>-0.1%</td>
</tr>
</tbody>
</table>
1 Scope  This test method deals only with transients generated within the Unit Under Test (UUT) and not with transients originating elsewhere (i.e., power line transients), which propagate through the UUT. This procedure measures transient voltage events appearing at the hot tip of an electric hand soldering/desoldering tool, which could be seen by the workpiece. The test electrode and measuring equipment represent a workpiece having a high impedance.

There are two times when transients testing should be done:
• Equipment qualification for purchase
• Incoming inspection of new or repaired equipment

A storage oscilloscope is used to observe and measure transient events. The test electrode is coupled to the vertical input of the oscilloscope via a 10 MΩ probe. The UUT may be isolated from ambient electronic noise by placing it in a screen room or shielded enclosure and supplying filtered AC power. Inside the shield, the hot tip of the UUT is touched to the test electrode.

This test may be falsely influenced by radio frequency interference and electromagnetic interference from lighting and equipment found in the workplace and testing area. This will normally be demonstrated by ambient transients of 1.5 V peak being present. At a minimum, shielded test leads should be utilized. To avoid these influences it may be necessary to perform the leakage and transient tests in a screen room. In lieu of a screen room a separate test procedure, see Method 2.5.33.4, which makes a low cost shielded enclosure, which should provide adequate shielding for the performance of these test procedures.

Warning:  This is a laboratory test procedure that may of necessity expose terminals that carry line voltages. All standard laboratory safety procedures regarding the setup and performance of tests with line voltage equipment must be observed at all times.

Caution:  This test is performed with soldering systems at their normal operating temperature. Test personnel must take adequate precautionary steps to protect themselves and others from potential burns.

2 Applicable Documents

ANSI/J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies
2.5.33  Measurement of Electrical Overstress from Soldering Hand Tools
2.5.33.4  Measurement of Electrical Overstress from Soldering Hand Tools - Shielded Enclosure

3 Test Specimens  Test specimens for this procedure are detailed in Method 2.5.33.

4 Equipment/Apparatus  Apparatuses utilized by the procedures that make up this test method are given in 4.1 through 4.5.2.

4.1 Test electrode (see Section 3)

4.2 Storage oscilloscope, 100 Mhz bandwidth or faster, 1 MΩ input vertical amplifier

4.3 Power line filter, 20 ampere @ 115 VAC, 50 dB insertion loss @ 5 Mhz/50Ω

4.4 Oscilloscope probe - X10 Attenuation

4.5 Optional

4.5.1 Screen camera, diskette, or hard copy waveform printer

4.5.2 Screen room or shielded enclosure capable of accommodating the entire UUT, cord, and handpiece. A filtered AC power receptacle shall be available from within (see Method 2.5.33.4).

4.6 Preparation of Apparatus  Turn on the oscilloscope and allow it to warm up.

Connect the UUT to a shielded AC line filter assembly as shown in Figure 1 and configure for typical operation.

Note:  The plugs are in power receptacles during measurements. They are shown unplugged in Figure 1 for clarity.
Non-US power receptacles may be different from those illustrated.

4.7 Calibration and Standardization  The oscilloscope (vertical and horizontal amplifiers) shall bear a current calibration sticker. The scope probe shall be adjusted/compensated to display the square wave calibration signal generated by the oscilloscope without undershoot or overshoot.

5 Procedure

5.1 Baseline Measurement  Turn on the UUT and allow it to warm up to a normal operating temperature. Touch the hot tip to the tinned area of the test electrode. Apply solder to form good electrical contact. Turn off the UUT. Adjust the oscilloscope controls as required and record any ambient signals that are displayed by the oscilloscope. Attempt this for a minimum of two minutes. Repeat this baseline test for a minimum of three trials. If any ambient transients are greater than 1.5 V peak, measures must be taken to reduce the effects of the ambient interference to below 1.5 V peak.

Place the UUT in a screen room or the shielded enclosure (see Figure 2) if the test is to be conducted in a shielded enclosure. If the shielded enclosure is utilized, arrange for support and/or remote movement of the handpiece. Configure the UUT for typical operation. In cases where function switches must be operated, arrange for remote switch actuation, such as by using a non-metallic rod through a small hole in the enclosure. Position the tip of the handpiece for remote placement onto the test electrode.

5.2 Test Measurement  Turn on the UUT. Let the tip dwell on the electrode while the UUT cycles power to maintain temperature for a minimum of two minutes. Operate various other functions of the UUT if present, such as the vacuum pump or...
air solenoid by actuating the UUT’s finger switch or foot switch. Repeat these operations, fine-adjusting the oscilloscope for best display of any transient peaks for a minimum of three measurable trials.

5.3 Calculation and Interpretation of Results  Record the peak amplitude (see Figure 3). All three measurement trials must have peak voltages ≤ 2.0 volts.

The peak voltage shall be ≤ ± 2.0 volts.

6 Notes  If tracking test results, record the measured values on a copy of the form found in Method 2.5.33.

6.1 Oscilloscope Adjustments  A good initial setup for the oscilloscope was found to be as shown in Table 1.

It’s important to start from a position of low trigger sensitivity and work toward high sensitivity. If one were to start with high sensitivity, weak transients would trigger the oscilloscope before the strong, more potentially damaging ones.
and control motor-pumps and solenoids. To facilitate observing or capturing a transient event, the UUT should be operated in such a manner where switching takes place. The UUT should be brought to a state where heater power is cycling off-and-on. Heaters that are running at 100% duty cycle (constantly on) may not generate any measurable transients. For UUTs that incorporate relays, solenoids, or motors the UUT’s functions should also be operated in such a manner where these devices energize and de-energize.

As the UUT is cycled, the oscilloscope’s trigger should be adjusted to a more sensitive setting until a transient causes a trigger. The event may have to be repeated as the oscilloscope’s storage controls are re-adjusted for best picture. Sometimes the event has a peak amplitude better observed on a different vertical scale.

### Table 1 Oscilloscope Setup

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
<td>500 mv/div. DC coupling</td>
</tr>
<tr>
<td>Horizontal</td>
<td>100 ns/div.</td>
</tr>
<tr>
<td>Trigger Source</td>
<td>Internal</td>
</tr>
<tr>
<td>Level</td>
<td>Full cw or ccw rotation</td>
</tr>
<tr>
<td>Mode</td>
<td>(large peaks cause trigger)</td>
</tr>
<tr>
<td></td>
<td>single sweep</td>
</tr>
<tr>
<td>Polarity</td>
<td>+ or -</td>
</tr>
<tr>
<td>Storage (for analog scopes)</td>
<td>fast variable persistence auto erase</td>
</tr>
</tbody>
</table>
1 Scope  This test method measures DC and AC current leakage from the tip of the Unit Under Test (UUT) to ground. The AC frequency range measured is in the 20 Hz to 20 MHz range, which covers the currently known equipment base. If soldering systems with oscillator or microprocessor frequencies higher than 20 MHz are to be qualified, then wider bandwidth measuring equipment should be considered. Failure to do so is likely to qualify equipment that might otherwise be disqualified.

There are three times when current leakage measurements should be done:

• Equipment qualification for purchase
• Incoming inspection of new or repaired equipment
• Process monitoring (periodic checks)

Current leakage is measured and indicated by measuring the voltage developed across a resistor, which closes the circuit between the tip of the UUT and ground. DC and true rms AC measurements will be made separately.

This test may be falsely influenced by radio frequency interference and electromagnetic interference from lighting and equipment found in the workplace and testing area. At a minimum, shielded test leads should be utilized. To avoid these influences it may be necessary to perform the leakage and transient tests in a screen room. In lieu of a screen room, a separate test procedure (see Method 2.5.33.4) has been provided to make a low cost shielded enclosure, which should provide adequate shielding for the performance of these test procedures.

Warning: These are laboratory test procedures that may, of necessity, expose terminals that carry line voltages. All standard laboratory safety procedures regarding the setup and performance of tests with line voltage equipment must be observed at all times.

Caution: These tests are performed with soldering systems at their normal operating temperature. Test personnel must take adequate precautionary steps to protect themselves and others from potential burns.

2 Applicable Documents

ANSI/J-STD-001  Requirements for Soldered Electrical and Electronic Assemblies
2.5.33 Measurement of Electrical Overstress from Soldering Hand Tools
2.5.33.4 Measurement of Electrical Overstress from Soldering Hand Tools - Shielded Enclosure

3 Test Specimens  Test specimens for this procedure are detailed in Method 2.5.33.

4 Equipment/Apparatus  The apparatus, materials, and preparation of apparatus and materials used to perform this test shall be as stated in 4.1 through 4.7.

4.1 Test Electrode (see Section 3)

4.2 AC millivoltmeter capable of measuring true mvAC/rms having a resolution of 0.1 mv AC. The frequency response of the millivoltmeter shall be 20 Hz-to-20 Mhz. (MilliVac MV814A, Hewlett-Packard HP3400B, or equivalent).

4.3 DC millivoltmeter capable of measuring at least 60 mv DC and having a resolution of 1 mv DC

4.4 Test box (see Section 6)

4.5 Optional

4.5.1 Storage oscilloscope, (with rms math function), 100 Mhz bandwidth or faster, 1 MΩ input vertical amplifier

4.5.2 Oscilloscope probe - X10 attenuation

4.5.3 Screen room/shielded enclosure - capable of accommodating the entire UUT, cord, and handpiece. A filtered AC power receptacle shall be available from within (see Method 2.5.33.4).
4.5.4 Resistor, 1.00 KΩ, 1% (any commercially available brand carbon or metal film)

4.5.5 Diodes (two) shall be of the lowest practicable known forward bias devices. 1N34 diodes have been found satisfactory for this purpose.

4.5.6 AC Receptacles (two)

4.5.7 Line cord

4.5.8 Strain relief

4.5.9 BNC connector

4.5.10 Edge Card Connector w/mounting hardware

4.5.11 Metal (bud) box

4.6 Preparation of Apparatus  Connect the apparatus as illustrated in Figure 1. The diodes shall be wired head-to-tail to be effective regardless of the applied signal’s polarity (± DC or AC). The negative electrode of the apparatus must make good electrical contact with the ground reference point. These connections will be automatic when using the test box detailed in Figure 2. Configure the UUT for typical operation. In those UUT’s that utilize additional functions (such as pressure or vacuum), provide switching actuation for these functions.

Note: The plugs are in power receptacles during measurements. They are shown unplugged here for clarity. Non-US power receptacles may be different from those illustrated.

4.7 Calibration & Standardization  The millivoltmeter shall bear a current calibration sticker. If an oscilloscope is used, the probe shall be adjusted to display the square wave calibration signal generated by the oscilloscope without undershoot or overshoot.

5 Procedure

5.1 DC Measurement  Configure the millivoltmeter for measuring DC. Turn on the UUT and allow it to warm up to a normal operating temperature. Touch the hot tip of the UUT to the tinned area of the test electrode. Apply solder to form good electrical contact. Let the tip dwell on the electrode while the UUT cycles power to maintain temperature. Operate various other functions of the UUT if present, such as the vacuum pump or air solenoid by actuating the UUT’s finger switch or foot switch. Wait for the reading to stabilize, then record the reading.

5.2 AC Measurement  The procedure for measuring AC is the same as for DC except the millivoltmeter is configured for AC.

5.3 Calculation and Interpretation of Results  Even though the meter reads out in millivolts, using 1.00 KΩ for the resistor value results in the displayed numbers representing the current in microamps without calculation (i.e., a readout of 0.8 mv indicates 0.8 µA).

The DC reading shall not exceed 1.0 µA. The AC reading shall not exceed 1.0 µA.

6 Notes  If tracking test results, record the measured values on a copy of the form found in Method 2.5.33.

Testing has shown that for UUTs that utilize high frequency circuits, layout and cord positioning can influence the AC current leakage reading. A compact configuration such as the one shown in Figure 2 minimizes those influences.
Figure 1  Apparatus for Current Leakage Measurement

Figure 2  Current Leakage Test Circuit Configuration (Cover Removed)
1 Scope The following information is a supporting document in support of Method 2.5.33. The test methods within this group of procedures can be falsely influenced by radio frequency interference and electromagnetic interference from lighting and equipment found in the workplace and testing area. To avoid these influences, the leakage and transient tests should be performed in a screen room. In lieu of a screen room, this test method has been provided to make a low cost shielded enclosure, which should provide adequate shielding for the performance of these test procedures.

2 Applicable Documents.

ANSI/J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies.

3 Test Specimens None required

4 Equipment/Apparatus Only general guidelines are provided. The enclosure can be made from readily available materials obtainable from any hardware store or lumber yard. Dimensions may be adjusted up or down to accommodate equipment to be tested. Experience has shown that best results will be obtained with a full length piano hinge across the back of the lid. The lid should be secured in the closed position with a metal, cam-type locking mechanism. The screening material from the lid should contact the material covering the sides to ensure a complete seal.

In addition to information on the enclosure, Section 6 also includes information on the filtered AC power module and test electrode mounting that should be incorporated into the local design to achieve best performance.

5 Procedure No construction procedure is provided. Each local activity should construct the enclosure to meet their specific needs based on the information in Section 6.

6 Notes

6.1 Shielded Enclosure High measuring impedance is used so as not to load down the signal being generated by the UUT. Because a high measuring impedance is used, there’s a threat that transients emanating from sources other than the UUT might be displayed. To prevent the apparatus from picking up ambient EMI/RFI, the UUT is placed inside a “benchtop” shielded enclosure. Filtered AC line voltage is available from within.

Some construction suggestions are given in 6.2 and 6.3.

6.2 Basic Enclosure Although Figure 1 illustrates wire mesh walls, sheet metal walls also work. Metals other than copper or brass may be used. If mesh is used, it should be 6.5 mm or tighter weave. Whatever metallic materials are used, continuity across seams and to the lid should be ensured.

Figure 2 suggests a way for mounting to an AC power entry.

6.3 Test Electrode The test electrode (see Figure 3) is shown mounted to the sidewall of the enclosure to facilitate connection of test equipment to the UUT. Moving this structure entirely into shielded enclosure and providing an access port through which test cables may be routed will slightly increase the construction cost, but will also serve to better isolate the test setup.
Figure 2  AC Power Entry Mounting Suggestion
Figure 3 Test Electrode Mounting Suggestion
1.0 **Scope**  The fungus resistance test is used to determine the resistance of materials to fungi and to determine if such material is adversely affected by fungi under conditions favorable for their development, namely high humidity, warm atmosphere, and presence of inorganic salts.

2.0 **Applicable Documents**  None

3.0 **Test Specimen**  Specimens must be a minimum size of 50 mm x 50 mm with copper foil (if applicable) removed by etching using standard commercial practices.

4.0 **Apparatus and Reagents**

4.1 **Test Chamber**  The autoclave shall be capable of maintaining 30 ± 1°C and 95 ± 2% relative humidity and an ultraviolet (360 nm) source for subsequent decontamination. Provisions shall be made to prevent condensation from dripping on the test item. There shall be free circulation of air around the test item and the contact area of fixtures supporting the test item shall be kept to a minimum.

4.2 Sterilizer

4.3 Centrifuge

4.4 pH Meter

4.5 Colony Counter

4.6 Incubator

4.7 Dishwasher

4.8 Petri Dishes

4.9 Filter Paper

4.10 Media Solutions

4.11 Micro-organisms

4.12 Atomizer, 15,000 ± 3000 spores

5.0 **Procedures**

5.1 **Preparation of Test Media**

5.1.1 **Mineral-Salts Solution**
Prepare the solution to contain the following:
- Potassium dihydrogen orthophosphate (KH$_2$PO$_4$) ...............0.7g
- Potassium monohydrogen orthophosphate (K$_2$HPO$_4$)........0.7g
- Magnesium sulfate heptahydrate (MgSO$_4$·7H$_2$O)............0.7g
- Ammonium Nitrate ((NH$_4$NO$_3$))..........................1.0g
- Sodium chloride (NaCl)...........................................0.005g
- Ferrous sulfate heptahydrate (FeSO$_4$·7H$_2$O)...............0.002g
- Zinc sulfate heptahydrate (ZnSO$_4$·7H$_2$O)...............0.002g
- Manganous sulfate monohydrate (MnSO$_4$·H$_2$O)...........0.001g
- Distilled water ....................................................1000 ml

Sterilize the mineral salts solution by autoclaving at 121°C for 20 minutes. Adjust the pH of the solution by the addition of 0.01 normal solution of NaOH so that after sterilization the pH is between 6.0 and 6.5. Prepare sufficient salt solution for the required tests.

5.1.2 **Purity of Reagents**  Reagent grade chemicals shall be used in all tests. Unless otherwise specified, it is intended that all reagents shall conform to the specification of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

5.1.3 **Purity of Water**  Unless otherwise specified, references to water shall be understood to mean distilled water or water of equal purity.

5.1.4 **Preparation of Mixed Spore Suspension**

The following test fungi shall be used:
- Description..........................................................ATCC
- Aspergillus niger .................................................9642
- Chaetomium globosum .............................................6205
- Gliocladium virans .............................................6945
- Aureobasidium pullulans .......................................9348
- Penicillium funiculosum ........................................9644

5.1.5 Maintain cultures of these fungi separately on an appropriate medium such as potato dextrose agar. However, the culture of chaetomium globosum shall be cultured on strips of filter paper on the surface of mineral salts agar. (Mineral salts agar is identical to mineral salts solution, but contains in addition 15.0 g of agar per liter.)
5.1.6 The stock cultures may be kept for not more than 4 months at 6 ± 4°C at which time subcultures shall be made and new stocks shall be selected from the subcultures.

5.1.7 If genetic or physiological changes occur, obtain new cultures as specified above. Subcultures used for preparing new stock cultures or the spore suspension shall be incubated at 30 ± 1°C for 9 to 12 days or longer.

5.1.8 Prepare a spore suspension of each of the five fungi by pouring into one subculture of each fungus, a 10-ml portion of a sterile solution containing 0.05 g per liter of a non-toxic wetting agent such as sodium dioctyl sulfosuccinate or sodium lauryl sulfate.

5.1.9 Use a sterile platinum or nichrome inoculating wire to scrape gently the surface growth from the culture of the test organism.

5.1.10 Pour the spore charge into a sterile 125-ml glass-stoppered Erlenmeyer flask containing 45 ml of sterile water and 50 to 75 solid glass beads, 5 mm in diameter.

5.1.11 Shake the flask vigorously to liberate the spores from the fruiting bodies and to break the spore clumps.

5.1.12 Filter the dispersed fungal spore suspension, through a 6 mm layer of glass wool contained in a glass funnel, into a sterile flask.

5.1.13 This process should remove large mycelial fragments and clumps of agar which could interfere with the spraying process.

5.1.14 Centrifuge the filtered spore suspension aseptically and discard the supernatant liquid.

5.1.15 Resuspend the residue in 50 ml of sterile water and centrifuge. Wash the spores obtained from each of the fungi in this manner three times.

5.1.16 Dilute the final washed residue with sterile mineral-salts solution in such a manner that the resultant spore suspension shall contain 1,000,000 ± 200,000 spores per ml as determined with a counting chamber.

5.1.17 Repeat this operation for each organism used in the test and blend equal volumes of the resultant spore suspension to obtain the final mixed spore suspension. The spore suspension may be prepared fresh each day or may be held at 6 ± 4°C for not more than 7 days.

5.2 Viability of Inoculum Control With each daily group of tests, place each of 3 pieces of sterilized filter paper, 1 inch square, on hardened mineral-salts agar in separate Petri dishes. Inoculate these with the spore suspension by spraying the suspension from a sterilized atomizer until initiation of droplet coalescence. Incubate these at 30 ± 1°C at a relative humidity not less than 85% and examine them after 7 days of incubation. There shall be copious growth on all three of the filter paper control specimens. Absence of such growth requires repetition of the test.

5.3 Control Items

5.3.1 In addition to the viability of inoculum control, known susceptible substrates shall be inoculated along with the test item to insure that proper conditions are present in the incubation chamber to promote fungus growth.

5.3.2 The control items shall consist of cotton duck 8.25-ounce strips that are 5 cm, that have been dipped into a solution containing 10% glycerol, 0.1% potassium dihydrogen orthophosphate (KH₂PO₄), 0.1% ammonium nitrate (NH₄NO₃), 0.025% magnesium sulfate (MgSO₄ 7H₂O), and 0.05% yeast extract (pH 5.3), and from which the excess liquid has been removed.

5.3.3 The strips should be hung to air dry before being inoculated and placed into the chamber.

5.4 Inoculation of Test and Control Item

5.4.1 Mount the test and control items on suitable fixtures or suspend from hangers. No cleaning of the test item shall be permitted for 72 hours prior to the beginning of the fungus test. Equipment handling prior to and during the fungus test shall be accomplished without contamination of the equipment.

5.4.2 Precondition the chamber and its contents at: 30 ± 1°C and 95 ± 2% relative humidity for at least 4 hours.

5.4.3 Inoculate the test and control items with the mixed fungus spore suspension (3.1.2) by spraying it on and into the test and control items (if not hermetically sealed) in the form of a fine mist from a previously sterilized atomizer or nebulizer. In spraying the test and control items, care should be taken to
spray all surfaces which are exposed during use or maintenance. If the surfaces are nonwetting, spray until initiation of droplet coalescence. Incubation is to be started immediately following the inoculation.

5.5 Test Incubation of Test Items

5.5.1 Incubate test items under cyclic temperature and humidity conditions to include 20 hours of relative humidity at 95 ± 5% at an air temperature of 30 ± 1°C followed by 4 hours of 100% relative humidity at 25 ± 1°C.

5.5.2 After 7 days, inspect the growth on the control items to be assured that the environmental conditions are suitable for growth. If inspection reveals that the environmental conditions are unsuitable for growth, the entire test shall be repeated.

5.5.3 If the control items show satisfactory fungus growth, continue the test for a period of 28 days from the time of inoculation, or as specified.

5.6 Evaluation

5.6.1 Report those specimens which were found to be nutrient to fungus growth.

5.6.2 Corrosion should be noted separately from the fungus test results.

6.0 Notes

6.1 Source for Micro-organisms

6.1.1 American Type Culture Collection
12301 Parklawn Drive
Rockville, MD 20852 USA
(301) 881-2600 TELEX: 908768 ATCC ROVE

6.2 Secondary Sources for Microorganisms

6.2.1 Pioneering Research Division
U.S. Army Natick Laboratories
Natick, Massachusetts 01760

6.2.2 North University St.
Peoria, IL 61604
Contact: Dr. Stephen Peterson
309-685-4011

6.3 After evaluation, the materials and the test chamber must be decontaminated by exposure on all sides to ultraviolet rays (360 nm) for a minimum of two hours, or sprayed with a solution of 1:750 zephiran chloride solution. (One part zephiran chloride to 750 parts distilled water).

6.4 Safety Observe all appropriate precautions on MSDS for chemicals involved in this test method.
1.0 Scope

The fungus resistance test is used to determine the resistance of materials to fungi and to determine if such material is adversely affected by fungi under conditions favorable for their development, namely high humidity, warm atmosphere, and presence of inorganic salts.

2.0 Applicable Documents

None

3.0 Test Specimen

Standard laboratory glass slides of 50 mm x 50 mm [2.0 in x 2.0 in] minimum size.

4.0 Apparatus and Reagents

4.1 Test Chamber

The autoclave shall be capable of maintaining 30 ± 1°C [86 ± 1.8°F] and 95 ± 2% relative humidity and an ultra violet (360 nm) source for subsequent decontamination. Provisions shall be made to prevent condensation from dripping on the test item. There shall be free circulation of air around the test item and the contact area of fixtures supporting the test item shall be kept to a minimum.

4.2 Sterilizer

4.3 Centrifuge

4.4 pH Meter

4.5 Colony Counter

4.6 Incubator

4.7 Dishwasher

4.8 Petri Dishes

4.9 Filter Paper

4.10 Media Solutions

4.11 Micro-organisms

4.12 Atomizer, 15,000 ± 3000 spores

5.0 Procedures

5.1 Preparation of Test Media

5.1.1 Mineral-Salts Solution

Prepare the solution to contain the following:

- Potassium dihydrogen orthophosphate (KH$_2$PO$_4$) ........... 0.7g
- Potassium monohydrogen orthophosphate (K$_2$HPO$_4$) ... 0.7g
- Magnesium sulfate heptahydrate (MgSO$_4$•7H$_2$O) ......... 0.7g
- Ammonium Nitrate ([NH$_4$NO$_3$] ........................................ 1.0g
- Sodium chloride (NaCl) .............................................. 0.005g
- Ferrous sulfate heptahydrate (FeSO$_4$•7H$_2$O) .............. 0.002g
- Zinc sulfate heptahydrate (ZnSO$_4$•7H$_2$O) ................... 0.002g
- Manganese sulfate monohydrate (MnSO$_4$•H$_2$O) ........ 0.001g
- Distilled water ........................................................... 1000 ml

Sterilize the mineral salts solution by autoclaving at 121°C [249.8°F] for 20 minutes. Adjust the pH of the solution by the addition of 0.01 normal solution of NaOH so that after sterilization the pH is between 6.0 and 6.5. Prepare sufficient salts solution for the required tests.

5.1.2 Purity of Reagents

Reagent grade chemicals shall be used in all tests. Unless otherwise specified, it is intended that all reagents shall conform to the specification of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

5.1.3 Purity of Water

Unless otherwise specified, references to water shall be understood to mean distilled water or water of equal purity.

5.1.4 Preparation of Mixed Spore Suspension

The following test fungi shall be used:

- Aspergillus niger ............................................................ ATCC 9642
- Chaetomium globosum ................................................. 6205
- Gliocladium virans ..................................................... 9645
- Aureobasidium pullulans ............................................ 9348
- Penicillium funiculosum .............................................. 9644

5.1.5 Maintain cultures of these fungi separately on an appropriate medium such as potato dextrose agar. However, the culture of chaetomium globosum shall be cultured on strips of filter paper on the surface of mineral salts agar. (Mineral salts agar is identical to mineral salts solution, but contains in addition 15.0 g of agar per liter.)
5.1.6 The stock cultures may be kept for not more than four months at 6 ± 4°C [42.8 ± 7.2°F] at which time subcultures shall be made and new stocks shall be selected from the subcultures.

5.1.7 If genetic or physiological changes occur, obtain new cultures as specified above. Subcultures used for preparing new stock cultures or the spore suspension shall be incubated at 30 ± 1°C [86 ± 1.8°F] for nine to 12 days or longer.

5.1.8 Prepare a spore suspension of each of the five fungi by pouring into one subculture of each fungus, a 10-ml portion of a sterile solution containing 0.05 g per liter of a non-toxic wetting agent such as sodium dioctyl sulfosuccinate or sodium lauryl sulfate.

5.1.9 Use a sterile platinum or nichrome inoculating wire to scrape gently the surface growth from the culture of the test organism.

5.1.10 Pour the spore charge into a sterile 125-ml glass-stoppered Erlenmeyer flask containing 45 ml of sterile water and 50 to 75 solid glass beads, 5 mm in diameter.

5.1.11 Shake the flask vigorously to liberate the spores from the fruiting bodies and to break the spore clumps.

5.1.12 Filter the dispersed fungal spore suspension, through a 6 mm layer of glass wool contained in a glass funnel, into a sterile flask.

5.1.13 This process should remove large mycelial fragments and clumps of agar which could interfere with the spraying process.

5.1.14 Centrifuge the filtered spore suspension aseptically and discard the supernatant liquid.

5.1.15 Resuspend the residue in 50 ml of sterile water and centrifuge. Wash the spores obtained from each of the fungi in this manner three times.

5.1.16 Dilute the final washed residue with sterile mineral-salts solution in such a manner that the resultant spore suspension shall contain 1,000,000 ± 200,000 spores per ml as determined with a counting chamber.

5.1.17 Repeat this operation for each organism used in the test and blend equal volumes of the resultant spore suspension to obtain the final mixed spore suspension. The spore suspension may be prepared fresh each day or may be held at 6 ± 4°C [42.8 ± 7.2°F] for not more than seven days.

5.2 Viability of Inoculum Control With each daily group of tests, place each of three pieces of sterilized filter paper, 1 inch square, on hardened mineral-salts agar in separate Petri dishes. Inoculate these with the spore suspension by spraying the suspension from a sterilized atomizer until initiation of droplet coalescence. Incubate these at 30 ± 1°C [86 ± 1.8°F] at a relative humidity not less than 85% and examine them after seven days of incubation. There shall be copious growth on all three of the filter paper control specimens. Absence of such growth requires repetition of the test.

5.3 Control Items

5.3.1 In addition to the viability of inoculum control, known susceptible substrates shall be inoculated along with the test item to insure that proper conditions are present in the incubation chamber to promote fungus growth.

5.3.2 The control items shall consist of cotton duck 8.25-ounce strips that are 5 cm, that have been dipped into a solution containing 10% glycerol, 0.1% potassium dihydrogen orthophosphate (KH2PO4), 0.1% ammonium nitrate (NH4NO3), 0.025% magnesium heptahydrate sulfate (MgSO4·7H2O), and 0.05% yeast extract (pH 5.3), and from which the excess liquid has been removed.

5.3.3 The strips should be hung to air dry before being inoculated and placed into the chamber.

5.4 Inoculation of Test and Control Item

5.4.1 Mount the test and control items on suitable fixtures or suspend from hangers. No cleaning of the test item shall be permitted for 72 hours prior to the beginning of the fungus test. Equipment handling prior to and during the fungus test shall be accomplished without contamination of the equipment.

5.4.2 Precondition the chamber and its contents at: 30 ± 1°C [86 ± 1.8°F] and 95 ± 2% relative humidity for at least four hours.

5.4.3 Inoculate the test and control items with the mixed fungus spore suspension by spraying it on and into the test and control items (if not hermetically sealed) in the form of a
fine mist from a previously sterilized atomizer or nebulizer. In spraying the test and control items, care should be taken to spray all surfaces which are exposed during use or maintenance. If the surfaces are nonwetting, spray until initiation of droplet coalescence. Incubation is to be started immediately following the inoculation.

5.5 Test Incubation of Test Items

5.5.1 Incubate test items under static temperature of 28-30°C [82.4-86°F] with a minimum 85% relative humidity.

5.5.2 After seven days, inspect the growth on the control items to be assured that the environmental conditions are suitable for growth. If inspection reveals that the environmental conditions are unsuitable for growth, the entire test shall be repeated.

5.5.3 If the control items show satisfactory fungus growth, continue the test for a period of 28 days from the time of inoculation, or as specified.

5.6 Evaluation

5.6.1 Report those specimens which were found to be nutrient to fungus growth.

5.6.2 Corrosion should be noted separately from the fungus test results.

6.0 Notes

6.1 Source for Micro-organisms

6.1.1 American Type Culture Collection
10801 University Blvd.
Manassas, VA 20110-2209 (USA)
703-365-2700
http://www.atcc.org

6.2 Secondary Sources for Microorganisms

6.2.1 Pioneering Research Division
U.S. Army Natick Laboratories
Natick, Massachusetts 01760

6.2.2 North University St.
Peoria, IL 61604
Contact: Dr. Stephen Peterson
309-685-4011

6.3 After evaluation, the materials and the test chamber must be decontaminated by exposure on all sides to ultraviolet rays (360 nm) for a minimum of two hours, or sprayed with a solution of 1:750 zephiran chloride solution. (One part zephiran chloride to 750 parts distilled water).

6.4 Safety Observe all appropriate precautions on MSDS for chemicals involved in this test method.
1 Scope  This test method defines the procedures to determine the moisture absorption properties of copper clad or unclad flexible dielectrics.

2 Applicable Documents  None

3 Test Specimen  Prepare three specimens 10 cm x 10 cm.

4 Apparatus

4.1 Apparatus Approved Method

4.1.1 Test Chamber  Oven capable of maintaining the specimen at 105°C to 110°C.

4.1.2 Analytical Balance  Analytical balance having an accuracy of ± 0.001 gram.

4.1.3 Miscellaneous  Vessel for holding distilled water, etcher, and chemical etchants, desiccator, and 40 mm x 100 mm weighing bottles.

5 Procedure

5.1 Procedure Approved Method

5.1.1 Preparation

5.1.1.1 If the sample under test is a copper clad dielectric, proceed to 5.1.1.2. If it is an adhesive coated dielectric, laminate it to copper foil using time, temperature, and pressure, which will impart a normal state of cure to the adhesive. If it is a bare dielectric, proceed to 5.1.2.

5.1.1.2 Etch away the copper and wash thoroughly with water.

5.1.1.3 Dry a glass-stoppered weighing bottle for each specimen at 105°C to 110°C for one hour. Immediately place in a desiccator, allow to cool to room temperature, and weigh to nearest 0.001 gram. Return weighing bottles to desiccator.

5.1.2 Test

5.1.2.1 Dry the specimen(s) from 5.1.1.2 in an oven at 105°C to 110°C for one hour. Place each specimen in a tared weighing bottle stopper and weigh to nearest 0.001 gram. Repeat until constant weight is reached. Return weighing bottles to desiccator.

5.1.2.2 Immerse the specimen for 24 hours in distilled water at a temperature of 23°C ± 1°C. Specimens should rest individually in the container and not be stacked up or in surface-to-surface contact with each other.

5.1.2.3 Remove each specimen from the water and lay on a panel of dry polyethylene film, which, in turn, is laid on a flat surface (e.g., plate glass). Using a 2.54 cm diameter elastic roller (hardness of 70-80 durometer Shore A) roll the surface of the specimen three or four times in one direction until the surface is free of water. Turn the specimen over on a dry area of the polyethylene film and repeat the preceding step. Place the specimen between layers of absorbent paper and roll three or four times. Repeat until there is no apparent absorption by the paper. Place immediately into the tared weighing bottle, cover and weigh to the nearest 0.001 gram.

This is the most critical part of the test; care must be given to removing moisture from the samples. Limit time between removal from water to putting in weighing bottle to 30 seconds.

5.1.3 Evaluation  Calculate the water absorption as follows:

$$\text{Percent of Absorption} = \frac{W_2 - W_1}{W_1} \times 100$$

where:

$W_1$ = weight before immersion
$W_2$ = weight after immersion

Average the results of the three specimens and report this average.

NOTE: If the results for the specimens vary more than 1%, the test must be repeated.
1.0 Scope  This test method is designed for use in determining the amount of water absorbed by plastic laminates when immersed in distilled water for 24 hours.

2.0 Applicable Documents

IPC-TM-650  Method 2.3.6, Etching Ammonium Persulfate Method
IPC-TM-650  Method 2.3.7, Etching, Ferric Chloride Method
IPC-TM-650  Method 2.3.7.1, Etching Cupric Chloride

3.0 Test Specimens

3.1 Dimensions  The test specimens used in this test shall be 2.0 inches long by 2.0 inches wide by the thickness of the material (unless otherwise specified). Tolerance on length and width shall be ±0.03.

3.2 Edge Finish  The edges of the specimens shall be milled or sanded smooth with 400 grit sandpaper.

3.3 Number of Specimens  Three specimens shall be used for this test.

3.4 Removal of Metal Cladding  The metal cladding shall be removed by etching per IPC-TM-650, Methods 2.3.6, 2.3.7 or 2.3.7.1, or other suitable method which does not affect the surface of the laminate.

4.0 Apparatus

4.1 Circulating air oven capable of maintaining a uniform temperature of 105° to 110°C (221° to 230°F).

4.2 Desiccator  A stabilization chamber (drying cabinet) capable of maintaining less than 20% R.H. at 21 ±2°C.

4.3 Analytical Balance

5.0 Procedure

5.1 Cleaning  The specimens shall be cleaned by at least three repeated wipings with a clean damp cloth.

5.2 Conditioning  The specimens shall be conditioned by drying in an oven for 1 hour at 105° to 110° (221° to 230°F), cooled to room temperature in a desiccator, and weighed immediately upon removal from the desiccator.

5.3 Weighing  The weight of each conditioned specimen shall be determined to the nearest 0.1 milligram and recorded.

5.4 Immersion  The conditioned specimens shall be placed in a container of distilled water maintained at 23° ±1.1°C (73.5 ±2°F) and shall rest on edge entirely immersed. At the end of 24 hours minus 0 plus 30 minutes, the specimens shall be removed from the water one at a time, all surface water removed with a dry cloth, and weighed immediately. A weighing bottle shall be used for materials where water absorption during weighing has been demonstrated to significantly affect results.

5.5 Calculations  Calculate and record the percent increase in weight for each specimen to the nearest 0.01 percent as follows:

\[
\text{Increase in weight, percent} = \frac{\text{wet weight} - \text{conditioned weight}}{\text{conditioned weight}} \times 100
\]

5.6 Report  Report the average for the three specimens. Report individual specimen results when requested.
1.0 Scope  This test method is to determine the degradation of insulating materials by examination of the visual and electrical insulation resistance properties of printed board specimens after exposure to high humidity and heat conditions. This method allows testing with (Method A) or without (Method B) Conformal Coating. When not specified, Method A is the default method.

2.0 Applicable Documents
MIL-I-46058  Insulating Compound, Electrical (For Coated Printed Circuit Assemblies)
IPC-CC-830  Qualification and Performance, Insulating Compounds for Printed Circuits Assemblies

3.0 Test Specimens
3.1 Test specimens shall be comprised of a minimum of two conductor lines per conductive layer, sufficient to allow resistance testing between adjacent conductor patterns both between layers and on the same layer. See Note 6.1 for examples of test specimen patterns recommended for this test method.

4.0 Apparatus or Material
4.1 A clean test chamber capable of programming and recording an environment of temperature ranging between 25 ± 2°C (77 ± 4°F) and 65 ± 2°C (149 ± 4°F), and 85 to 93% relative humidity.

4.2 A power supply capable of producing a standing bias potential of 100 volts DC with a tolerance of ±10%.

4.3 A resistance meter capable of reading high resistance at the voltage described in the procurement documentation.

4.4 Solder or Flux-Cored Solder  Flux shall be removable in a manner which will not adversely affect the test specimen.

4.5 Soft Bristle Brush.

4.6 Deionized or distilled water (2 megohm-cm, minimum resistivity recommended).

4.7 Isopropyl alcohol.

4.8 Drying oven(s) capable of maintaining 50 ± 5°C (122 ± 9°F) and 125 ± 5°C (248 ± 9°F).

4.9 Insulating compound (conformal coating) which conforms to MIL-I-46058 or IPC-CC-830.

4.10 Equipment necessary to apply and cure conformal coating.

5.0 Procedure
5.1 Specimen Preparation
5.1.1 Mark specimen with positive, permanent, and non-contaminating identification.

5.1.2 Visually inspect the test specimens for any obvious defects, as described in the applicable performance specification. If any test specimen is non-compliant, the test specimen should be replaced and the replacement noted.

5.1.3 Solder single stranded (to decrease the opportunity for flux contamination from the wire) insulated wire which is not affected by the test environment to each of the connection points of the test specimens. These wires will be used to connect the test patterns of the test specimens to the power supply and for insulation resistance testing.

5.1.4 Clean test lead terminals with isopropyl alcohol and scrub with a soft bristle brush for a minimum of 30 seconds. During the remainder of the test specimen preparation, handle test specimens by the edges only. (See Note 6.2.)

5.1.5 Spray rinse thoroughly with fresh isopropyl alcohol. Hold test specimen at an approximate 30° angle and spray from top to bottom.

5.1.6 Rinse cleaned area thoroughly with fresh deionized or distilled water. Hold test specimen at an approximate 30° angle and spray from top to bottom.
5.1.7 Dry test specimens in a drying oven for a minimum of three hours at an oven temperature of between 50 ± 5°C (122 ± 9°F). (See Note 6.3.)

5.1.8 Specimen preparation for METHOD B is now completed, continue the procedure with paragraph 5.2.

5.1.9 METHOD A - Application of Conformal Coating. Continuation of Sample Preparation

Apply coating to the appropriate area of the test specimen, in a manner concurrent with user’s production techniques or as specified by the coating supplier.

5.1.10 After the application of coating, the test specimens are to be cured, as specified by the coating supplier.

5.1.11 After curing, stabilize to ambient temperature.

5.2 Test

5.2.1 Take the initial insulation resistance measurements at laboratory ambient temperature. Apply the voltage specified in the procurement documentation on the test specimen’s test points as specified in paragraph 5.2.2 with the resistance meter, and take the reading after measurement stabilization.

5.2.2 Test points on the test specimens shall be connected in a manner that will allow adjacent conductor patterns, both between conductor layers and on the same conductor layer, to alternate between the positive (+) and negative (–) terminals of the power supply or resistance meter.

5.2.3 Place test specimens in chamber in a vertical position and under a condensation drip shield. Connect the DC voltage source to the test specimen test points as indicated in paragraph 5.2.2. Apply a 100 ± 10 volts DC polarization voltage to all test specimens.

5.2.4 Expose test specimens to one of the following specified test conditions: (See Note 6.4.)

(a) Class 1 35 ± 5°C (95 ± 9°F), 85 to 93% relative humidity, for 4 days (static).
(b) Class 2 50 ± 5°C (122 ± 9°F), 85 to 93% relative humidity, for 7 days (static).
(c) Class 3 20 cycles of temperature ranging from 25+5/-2°C (77+9/-4°F) to 65 ± 2°C, 85 to 93% relative humidity, 160 hours total.

5.2.4.1 Temperature cycling The following constitutes one complete cycle (for the class 3 test condition).

(a) Start test at 25+5/-2°C (77+9/-4°F), and raise temperature at 65 ± 2°C (149 ± 4°F) over a time span of 150 ± 5 minutes.
(b) Maintain temperature at 65 ± 2°C (149 ± 4°F) over a time span of 180 ± 5 minutes.
(c) Lower temperature from 65 ± 2°C (149 ± 4°F) to 25+5/-2°C (77+9/-4°F) over a time span of 150 ± 5 minutes.

There shall be no delay between cycles. Polarizing voltage shall be maintained throughout the 20 cycle period. The humidity may drop a minimum of 80% relative humidity when going from high to low temperature. See Figure 1 for a graphical illustration of temperature cycling.

5.3 Measurement

5.3.1 Disconnect 100 volts DC polarized voltage source before taking any insulation resistance measurement. Insulation resistance shall be read as specified in paragraph 5.2.1. Voltage polarity for measurement should be identical to that of the polarizing voltage.

5.3.2 Final resistance measurements shall be made after removal of specimen from the chamber, and after 1 hour and before 2 hours stabilization at laboratory ambient temperatures.

Any reasons for deleting values, i.e., scratches, condensation, bridged conductors, etc., must be noted.

5.4 Evaluation

5.4.1 Each test specimen shall be evaluated for insulation resistance quality for its class, following and/or during the initial, wet and/or dry conditions, as applicable.

5.4.2 After completion of all electrical testing, the test specimens shall be examined for evidence of mealing, blistering, delamination, or other forms of degradation, following 24 hour stabilization at laboratory ambient temperatures.

6.0 Notes

6.1 Test Pattern Examples

6.1.1 “Y” Patterns There are a variety of “Y” test patterns (also referred to as “E” test coupons) in various specifications
within the industry. See Figure 2 for an illustration of “Y” pattern test coupons.

6.1.2 Comb Patterns Various “comb patterns” can be properly tested following the procedures in this document. The test points for comb patterns such as in Figure 3 are 1 to 2, 2 to 3, 3 to 4, and 4 to 5. Test points 1-3-5 are connected to the positive (+) terminal, and test points 2-4 are connected to the negative (−) terminals of the resistance meter.

6.1.3 Production Board Testing Occasionally, production boards must be tested in lieu of test patterns. When this is required, one must use good judgment and select adjacent conductors for wiring terminal lands for testing, because conductor spacing and placement can affect test results.

6.2 Documented alternative cleaning procedures may be implemented. As an example, if there is a concern that scrubbing will adversely affect test results, i.e., when the test specimens have very fine spacing and/or are plated with soft metals (tin/lead, gold, etc.).

6.3 If printed boards are to be stored before coating, place the boards in a dry non-contaminating environment.

6.4 Performance specifications should specify the method of test specimen preparation, test condition class, and any deviations to this test method.

6.5 The test chamber should be constructed out of materials that will not corrode or add ionic contamination to the test environment.
Figure 2 Insulation Resistance Coupon E (See Table 7-3)

Figure 3 Typical “Comb Pattern” (from IPC-B-25A)
1 Scope  This test method is to determine the moisture and insulation resistances of applied polymer solder mask under two separate prescribed conditions of temperature and humidity. One is for Class T and the other Class H. Raw material qualification testing is performed on designated comb patterns. Production quality conformance testing is performed on a standard “Y” pattern.

2 Applicable Documents
IPC-SM-840  Qualification and Performance of Permanent Solder Mask
J-STD-004  Requirements for Soldering Fluxes
IPC-A-600  Acceptability for Printed Boards

3 Test Specimens
3.1 Qualification Testing
3.1.1 Class H Three IPC-B-25A boards using the D comb patterns with 0.318 mm [12.50 mil] lines/spaces (see Figure 1). Of which, two is to be coated and one uncoated with solder mask according to the solder mask supplier’s recommendations.

3.1.2 Class T Three IPC-B-25A boards using the E and F comb patterns with 0.406 mm [16.00 mil] lines and 0.508 mm [20.00 mil] spaces (see Figure 1). Of which, two are to be coated and one uncoated with solder mask according to the solder mask supplier’s recommendations.

3.2 Conformance Testing IPC-B-25A board C (“Y” shape) pattern with 0.635 mm lines/0.635 mm spacing [25.00 mil lines/25.00 mil spacing] or minimum spacing on the production board (See Figure 1), whichever is smaller, coated with solder mask according to the solder mask suppliers recommendations.

4 Apparatus
4.1 Chamber A clean chamber capable of programming and recording an environment of 25 ± 2°C [77° ± 3.6°F] to at least 65 ± 2°C [149° ± 3.6°F] and 90-98% relative humidity.

4.2 Power Supply Capable of producing a standing bias potential of 100 VDC with a tolerance of ± 10%.

4.3 Resistance Meter Capable of reading high resistance (10^{12} ohms or greater), with a test voltage of 100 VDC.

4.4 Oven Capable of maintaining at least 120°C [248°F].

4.5 Timer

4.6 Solder Pot

4.7 Tongs

4.8 Soldering Iron

4.9 Flux Water white rosin (R or RMA) with halide content less than 0.5%, i.e., type Symbol A and B or ROL0 and ROL1 according to J-STD-004.
5 Test

5.1 Ambient Conditions

Class T and Class H: 25°, +2°, -5°C [77°, +3.6°, -9°F] and 40-50% relative humidity.

5.2 Test Conditions

5.2.1 Class T

65° ± 2°C [149° ± 3.6°F], with 90 ± 3% relative humidity, no bias, static, 24 hours.

5.2.2 Class H

25° to 65° ± 2°C [77 to 149° ± 3.6°F], with 90, -5, +3% relative humidity, 50 VDC bias, cycling, 6 2/3 days.

5.3 Specimen Preparation (Both Classes)

5.3.1 Positive, permanent and noncontaminating identification of the test specimens is of paramount importance.

5.3.2 Visually inspect the test specimens for any obvious defects, as described in the IPC-A-600. If there is any doubt about the overall quality of any test specimen, the test specimen should be discarded.

5.3.3 One uncoated specimen subjected to the same processing (except solder mask coating) as the coated specimens shall be supplied with each set of coated samples for testing as a control.

5.3.4 Subject one of the IPC-B-25A boards which has been coated with solder mask to solder in accordance with J-STD-004. Clean the residual flux from the boards surface. First rinse with deionized or distilled water (30 seconds minimum), followed by immersing the board in 2-propanol and agitate (30 seconds maximum). While the board is immersed, gently scrub the surface with a soft bristle brush. Then spray the board with clean 2-propanol.

5.3.5 Bake in an oven maintained at 50°C [122°F] for three hours minimum.

5.4 Electrical Connections (Both Classes)

5.4.1 For qualification specimens, solder a single strand PTFE insulated wire or equivalent to each pad of the appropriate comb pattern as specified in 3.1. These wires will be used to connect each pad of the designated comb pattern to polarization and insulation resistance testing. When soldering the wires onto the pads care should be taken to ensure that the flux does not splatter onto the combs. A simple off-contact shield fixture should be used to protect the test patterns from flux spitting during soldering.

Note: An alternate method is to use gold plated alligator clips.

5.4.2 For quality conformance specimens, solder single strand PTFE insulated wire or equivalent to each pad of the connection points of the C pattern. These wires will be used to connect the C pattern to polarization and insulation resistance testing.

5.5 Soldering Flux

The flux shall not be removed.

Note: If the flux has contaminated the pattern on the control, the sample shall be discarded and a new one used. It cannot be cleaned because it will not represent the cleaning process that was used prior to solder mask application.

5.6 Specimen Handling

For the remainder of the test, the surface of the test specimens either uncoated or coated with solder mask should not be handled or exposed to any other contaminating influence.

5.7 Class H Procedures

5.7.1 Class H Testing

5.7.1.1 Condition the specimens at 50 ± 2°C [122 ± 3.6°C] with no added humidity, for a period of 24 hours.

5.7.1.2 Allow the specimens to cool, measure and record the initial insulation resistance measurements at ambient laboratory conditions. Apply 100 VDC on the specimen’s test points as specified in 3.1.1 or 3.2 with the resistance meter and take the reading after one minute. See note 6.2.

5.7.1.3 Place specimens in a chamber, in a vertical position and under a condensation drip shield. Connect the 50 VDC voltage source to the specimen’s test points as indicated in 3.1.1 or 3.2. Each chamber load shall contain at least one uncoated board that is representative of the cleaning process used prior to solder mask application for each solder mask tested.

5.7.1.4 The test points for qualification tests are 1 to 2, 3 to 4 and 5 to 4 on the D comb pattern. On the D comb pattern, test points 1, 3 and 5 are connected to the positive terminal and test points 2 and 4 are connected to the negative terminal of the resistance meter. For quality conformance, the pair of test points is 1 to 2 on the C pattern. One side of
the C pattern should be connected to the negative terminal and the other side to the positive.

5.7.1.5 Close chamber door and apply a 50 volt bias to all comb patterns (D or C patterns) tested.

5.7.1.6 Expose test specimens to 20 cycles of temperature and humidity (see Figure 2). Polarizing voltage shall be maintained throughout the entire 20-cycle period. Humidity shall be maintained at 85% minimum through the cycles except that when going to low temperature in Step c below, the humidity may drop to 80% minimum.

One cycle is as follows:

a. Start test at 25°C [77°F] and raise the temperature to 65°C [149°F] over a time span of 1.75 ± 0.75 hours

b. Maintain temperature at 65°C [149°F] for 3, +0.5, -0 hours

c. Lower the temperature from 65°C [149°F] to 25°C [77°F] over 1.75 ± 0.5 hours

Note: There shall be no delay between cycles.

5.7.2 Class H Measurement

5.7.2.1 Disconnect 50 VDC polarizing voltage source before taking the insulation resistance measurements. Insulation resistance shall be read as specified in 5.7.1.4. Electrical connections to specimens shall be made so that electrical polarization voltage and the test voltage, of the same polarity are connected to the same terminal.

5.7.2.2 For qualification testing, measure and record resistance once every 24 hours (if required - see 5.7.3.1), between the same terminals.
the 2nd and 3rd hour of the high phase of each cycle. These measurements are to be conducted without opening the chamber. Completion of qualification testing shall be accomplished by disconnecting the bias voltage; remove the specimens from the chamber, read and record insulation resistance after one hour and before two hours at ambient laboratory conditions.

5.7.2.3 For conformance testing with the C pattern, the measurements must be taken after disconnecting the bias voltage, removal of the specimens from the chamber and after one hour and before two hours stabilization at ambient laboratory conditions. See note 6.2.

5.7.3 Class H Evaluation

5.7.3.1 Each test specimen shall be evaluated for insulation resistance quality following and/or during the stated conditions. Although several insulation resistance readings may be taken during the test, only the final (18th cycle) readings in high temperature phase in the chamber and the reading taken outside the chamber shall be used to determine pass/fail criteria. Other readings are optional and may be used for diagnostic information or aborting the test.

5.7.3.2 After completion of all electrical testing, the test specimens shall be examined for mealing, blisters, delamination or other forms of degradation following the 24-hour stabilization at ambient laboratory conditions. See note 6.2.

5.8 Class T Procedures

5.8.1 Class T Testing

5.8.1.1 Condition the specimens at 50 ± 2°C [122 ± 3.6°C] with no added humidity, for a period of 24 hours.

5.8.1.2 Remove the specimens from the oven and cool to laboratory ambient temperature. Apply 100 VDC on the specimen’s pair of test points on comb patterns E and F. See note 6.2.

5.8.1.3 Test points for qualification are at each pair of terminals on the E and F comb patterns. One of the test points is connected to the negative terminal and the other to the positive terminal. For quality conformance, the pair of test points is 1 to 2 on the C pattern. One side of the C pattern should be connected to the negative terminal and the other side to the positive.

5.8.1.4 Place the specimens in the test chamber in the vertical position under a condensation drip shield.

5.8.1.5 Each chamber load shall contain at least one uncoated board that is representative of the cleaning process used prior to solder mask application for each solder mask tested.

5.8.1.6 Close the chamber door and bring the chamber to 65°C [149°F] and 90% relative humidity.

5.8.1.7 Allow specimens to stabilize at test conditions for 24 hours.

5.8.2 Class T Measurement

5.8.2.1 Connect the resistance meter to the appropriate test points. For qualification testing, one of the test points of the two terminal E and F patterns are connected to the negative terminal and the other test point to the positive. For quality conformance testing, one side of the C pattern ("Y" pattern) should be connected to the negative terminal and the other side to the positive.

5.8.2.2 Apply 100 VDC on the specimens test points with the resistance meter and take the reading after one minute with the patterns under test conditions.

5.8.3 Class T Evaluation

5.8.3.1 Three separate sets of measurements are to be recorded for the uncoated specimen, the ‘as received’ specimen, and the specimen after solder exposure. Each set of readings shall be averaged and shall be greater than the minimum listed in the relevant specification. No individual insulation resistance value may be less than 0.1 x IRmin. Two measurements may be excluded from calculating the average if there is an assignable cause of low insulation resistance that can be attributable to the laminate itself or to the process used to produce the board. Such assignable causes include:

a. Contamination of the insulating surface of the board such as lint, solder splints, or water droplets from the conditioning chamber.

b. Incompletely etched patterns that decrease the insulating space between conductors by more than the amount allowed in the appropriate design requirements drawing.

c. Scratched, cracked or obviously damaged insulation between conductors.
5.8.1.1 The average insulation resistance (IR_{avg}) is calculated from:

\[
IR_{avg} = 10^{\frac{1}{N} \sum_{i=1}^{N} \log IR_i}
\]

Where:

N = Number of test points (12 nominal)
IR_i = Individual insulation resistance measurements.

5.8.1.2 After completion of all electrical testing, the test specimens shall be examined for mealing, blisters, delamination or other forms of degradation following 24-hour stabilization at laboratory ambient temperatures.

6 Notes

6.1 Initial wire placement must be maintained to ensure reproducible results.

6.2 Specimens may be stabilized at ambient conditions specified, inside the chamber.
1.0 Scope  This test method defines the procedures for determining the moisture and insulation resistance of a copper foil clad flexible dielectric material.

The moisture resistance test is performed for the purpose of evaluating, in an accelerated manner, the resistance of materials to the deteriorative effects of high humidity and heat conditions, typical of tropical environments.

2.0 Applicable Documents

IPC-A-600  Acceptability Guidelines

3.0 Test Specimen  The test specimen shall consist of an etched conductor pattern in accordance with Figure 1. Test a minimum of three test specimens per clad side. For double clad material, a separate sample unit shall be prepared for each side.

4.0 Apparatus

4.1 Test Chambers

4.1.1 For static test conditions (Class 1 and 2 material), a test chamber capable of producing and recording an environment of 35° ±2°C [95° ±3.6°F] and 90 -0, +5 percent relative humidity and which will allow the insulation resistance to be measured while the specimens are under the specified conditions.

4.1.2 For cycling test conditions (Class 3 material), a programmable test chamber capable of producing and recording an environment of 25° +10°, -2°C [77° +18°, -3.6°F] to 65° ±2°C [149° ±3.6°F] and 90-98 percent relative humidity and which will allow the insulation resistance to be measured while the specimens are under the specified conditions.

4.2 A power supply capable of producing a bias potential of 100 volts dc with a tolerance of ±10%.

4.3 A resistance meter capable of reading 10⁸ to 10¹² ohms or greater, with a measurement error not to exceed 10%, with a test voltage range of 500 volts dc or greater.

4.4 Soft bristle brush.

4.5 Deionized or distilled water (2 megohm cm minimum resistivity recommended).

4.6 Isopropyl alcohol.

4.7 Single-stranded insulated wire. (Shielded wire recommended.)

4.8 Soldering iron (25 to 40 watt).

4.9 Drying oven capable of maintaining at least 60°C.

5.0 Procedure

5.1 Test Conditions

5.1.1 Class 1 and 2 material: 35° ±2°C [95° ±3.6°F], 90 -0, +5% RH, 4 days (static).
5.1.2 Class 3 material: 25°±10°, -2°C [77° ±18°, -3.6°F] to 65°±2°C [149°±3.6°F], 90-98% RH, may drop to 80% RH minimum during temperature drop, 6-2/3 days (cycling). Number of days cycling can be decreased based on statistical sampling. (See graph 1.)

5.2 Specimen Preparation

5.2.1 Permanently identify each test specimen.

5.2.2 Visually inspect the test specimens for any obvious defects, as described in IPC-A-600. If there is any doubt about the overall quality of a test specimen, the test should be discarded.

5.2.3 Solder single-strand Teflon insulated wire to each land of the test specimen. The solder or rosin must not spread beyond the land areas. These wires will be used to connect each land for polarization and for insulation resistance testing.

5.2.4 Immerse test specimen in deionized water and scrub with a soft bristle brush for a minimum of 30 seconds. During the remainder of the specimen preparation, handle test specimens by the edges only.

5.2.5 Spray rinse thoroughly with deionized water. Hold test specimen at an approximate 30° angle and spray from top to bottom.

5.2.6 Immerse test specimen in clean isopropyl and agitate for a minimum of 30 seconds. Scrub with a soft bristle brush to remove flux residue.

5.2.7 Rinse specimen thoroughly with clean isopropyl alcohol.

5.2.8 Dry test specimens in a drying oven for a minimum of three hours at 49° to 60°C [120° to 140°F].

5.3 Test Condition A—Initial Insulation Resistance at Standard Laboratory Conditions (Ambient).

5.3.1 Condition test specimens a minimum of 24 hours at standard laboratory conditions of 23°±2°C [77°±3.6°F] and 50±10% relative humidity.

5.3.2 Take an initial insulation resistance measurement between each pair of terminals, 1 to 2, 2 to 3, 3 to 4, and 4 to 5 at standard laboratory conditions. Before taking the measurement, apply a polarizing potential of 500 ± 50 volts dc, with the resistance meter for one minute, then take the measurement at 500 ± 50 volts dc.

5.4 Test Condition B—Insulation Resistance at Elevated Temperature and Humidity.

5.4.1 Place the test specimens from Test Condition A in the test chamber, in a vertical position, and under a condensation drip shield. Apply a 100 volt dc polarization potential to each pair of terminals of the test specimens.

5.4.2 Expose the Class 1 and 2 material test specimens to the static conditions of 35°±2°C [95°±3.6°F] and 90-0, +5% relative humidity for four days.

5.4.3 Expose the Class 3 material test specimens to 20 cycles of temperature and humidity. The humidity (90-98% relative humidity) and polarizing potential (100 volts dc) shall be maintained throughout the entire 20 cycle period.1 One cycle is made up of the following three steps:

A. Start test at 25°±2°C [77°±3.6°F] and raise temperature to 65°±2°C [149°±3.6°F] over a time span of 2-1/2 ±0.1 hours.

B. Maintain temperature at 65°±2°C [149°±3.6°F] for three hours minimum.

C. Lower temperature from 65°±2°C [149°±3.6°F] to 25°±2°C [77°±3.6°F] over a time span of 2-1/2 ±0.1 hours.

This constitutes one complete cycle. There shall be no delay between cycles. See Graph 1.

5.4.4 Disconnect the 100 volt dc polarization potential.

5.4.5 Apply a reverse polarization potential of 500 ± 50 volts dc with the resistance meter for one minute, then take the measurement at 500 ± 50 volts dc between each pair of terminals, 1 to 2, 2 to 3, 3 to 4, and 4 to 5, of the test specimen.

5.4.6 For Class 3 material test specimens, measure and record the insulation resistance once every 24 hours, during the high temperature phase of the conditioning cycle. For Class 1 and 2 material test specimens, measure and record

1. The relative humidity may drop to 80% RH minimum during temperature drop (step C).
2. Cycles can be reduced to 10 if statistical data correlates to 20 cycle test.
the insulation resistance at the end of the four-day static conditioning period. These tests are to be conducted without opening the chamber.

5.5 Test Condition C—Insulation Resistance After Recovery from Elevated Temperature and Humidity Cycle.

5.5.1 Remove the test specimens from Method B from the test chamber after disconnecting the bias voltage (100 volts dc).

5.5.2 Condition the test specimens, at 23°C ±2°C [73.4° ±3.6°F] and 50% ±10% relative humidity, for 2 to 24 hrs,3 stabilization.

5.5.3 Take the insulation resistance measurements at laboratory ambient temperature (23°C ± 2°C [73.4° ± 3.6°F] ) after the above conditioning.

5.5.4 Apply a reverse polarization potential of 500 ± 50 volts dc with the resistance meter for one minute, then take the measurement at 500 ± 50 volts dc between each pair of terminals, 1 to 2, 2 to 3, 3 to 4, and 4 to 5, of the test specimen.

5.5.5 The test points for comb patterns are 1 to 2, 2 to 3, 3 to 4, and 4 to 5. Test points 1-3-5 are connected to the positive (+) terminal, and test points 2-4 are connected to the negative (-) terminals of the resistance meter.

5.5.6 Any reason for deleting values, i.e., scratches, condensation, bridged conductors, etc., must be noted.

5.6 Evaluation

5.6.1 The value to be reported shall be the average of at least three readings taken as described per 5.5 through 5.5.6. See graph 2 for typical IR plot.

5.6.2 After completion of all electrical testing, the test specimens shall be examined for measling, blisters, delamination, or other forms of degradation, following 24 hour stabilization at laboratory ambient temperatures.

6.0 Notes

6.1 Documented alternative cleaning procedures may be implemented if there is a concern that scrubbing will adversely affect test results, i.e., when the test specimens have very fine spacing and/or are plated with soft metals (tin/lead, gold, etc.).

6.2 A failure due to measling, blistering, delamination, or any other form of degradation, may be due to several factors, and not necessarily inferior coatings. Such a system failure (solder mask and/or conformal coating on a substrate) should not be grounds for coating rejection. In such cases, a retest of the entire system is mandatory.

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3. Conditioning can be reduced to 2 hours if statistical data correlates to 24 hours conditioning.
Graph 1  Moisture/Insulation resistance test

Graph 2  Typical IR and MIR plot

IR Initial = 3.57E+014 ohms
M & IR = 6.47E+010 ohms
2 hr Recov = 4.20E+013 ohms
24 hr Recov = 4.49E+013 ohms

GRAPH 2 TYPICAL IR & MIR PLOT
1.0 Scope  This test method is to characterize fluxes by determining the degradation of electrical insulation resistance of rigid printed wiring board specimens after exposure to the specified flux. This test is carried out at high humidity and heat conditions.

2.0 Applicable Documents
IPC-B-24  Surface Insulation Resistance Test Board
IPC-A-600  Acceptability Guidelines

3.0 Test Specimens
3.1 Comb Patterns  Use the IPC-B-24 test pattern which consists of four comb patterns per coupon. The individual comb, pictured in Figure 1, has 0.4 mm lines and 0.5 mm spacing. The test coupon shall be unpreserved bare copper metallization.

3.2 Laminate  The laminate material for this test shall be FR-4 epoxy-glass.

4.0 Apparatus
4.1  A clean test chamber capable of programming and recording an environment of 25 ±10/-2°C to at least 85 ±2°C and 85% ±2% relative humidity. A salt solution and desiccator may be used to maintain humidity if a tight temperature control is maintained on the temperature of the chamber.

4.2  A power supply capable of producing a standing bias potential of 45–50 volts DC with a tolerance of ±10%.

4.3  A resistance meter capable of reading high resistance (10¹² ohms) with a test voltage of 100 volts or an ammeter capable of reading 10⁻¹⁰ amps in combination with 100 volts DC power supply.

4.4  Three 2000 ml beakers

4.5  Exhaust ventilation hood.

4.6  Metal tongs.

4.7  Soft bristle brush

4.8  Deionized or distilled water (2 megohm-cm, minimum resistivity recommended).

4.9  Drying oven capable of maintaining at least 50°C.

5.0 Test

5.1 Test Conditions  All fluxes will be tested at 85 ±2°C, 85±2% relative humidity for 168 hours.

5.2 Specimen Preparation  There shall be 3 test coupons for each liquid flux to be tested in the cleaned state (see Table 1, A). When testing liquid fluxes which are intended to remain in the uncleaned state, six test coupons are required. Three uncleaned test coupons shall be wave soldered pattern side down (Table 1, B) and three shall be wave soldered pattern side up (Table 1, C).

Solder paste coupons shall be reflowed pattern side up and either cleaned (Table 1, D) or not cleaned (Table 1, E). In addition, there shall be at least 2 unprocessed control coupons for comparison purposes (Table 1, F).

5.2.1  Positive, permanent and non-contaminating identification of test specimens is of paramount importance. (For example, a vibrating scribe.)

5.2.2  Visually inspect the test specimens for any obvious
defects, as described in IPC-A-600. If there is any doubt about the overall quality of any test specimen, the test specimen should be discarded.

5.2.3 Clean the test coupon with deionized or distilled water and scrub with a soft bristle brush for a minimum of 30 seconds. Spray rinse thoroughly with deionized or distilled water. Rinse cleaned area thoroughly with fresh 2-propanol.

An alternative cleaning method is to place the test coupon in an ionic contamination tester containing 75% 2-propanol, 25% deionized water and process the solution until all ionics have been removed.

During the remainder of the specimen preparation, handle test specimens by the edges only, or use non-contaminating rubber gloves.

5.2.4 If boards are to be stored before treatment, place the boards in Kapak bags or other contamination-free containers and close bags (do not heat seal). (Kapak bags are available from Fischer, VWR and other distributors).

5.3 Procedure

5.3.1 Sample Preparation Flux application and soldering.

5.3.1.1 Liquid Flux or Flux Extract Coat the comb pattern with a thin coating of the liquid flux or flux extract under test.

5.3.1.1.1 The test coupons shall be exposed to solder by floating the fluxed comb patterns of the test specimens face down on the solder pot at 245-260°C for 4 ±1 seconds. Wave solder of comb patterns face down at 245-260°C and a conveyor speed with a contact time of 3 ±1 seconds. For fluxes to be tested in the uncleaned state, a second set of comb patterns shall be fluxed and floated pattern up on the solder pot or passed pattern up over the solder wave.

5.3.1.2 Solder PasteStencil print the solder paste on to the comb pattern using a 0.2 mm thick stencil (the IPC-A-24 artwork contains the stencil design).

5.3.2 Cleaning of Samples

5.3.2.1 After exposure to flux and solder, samples to be tested in an uncleaned state shall be evaluated as in 5.3.3 through 5.4.1.

5.3.2.2 After exposure to flux and solder, samples to be tested in the cleaned state shall be cleaned using one of the procedures listed below. The cleaning parameters shall be reported in the Qualification Test Report (Appendix A).

5.3.2.2.1 The samples to be cleaned shall be cleaned with an appropriate environmentally safe solvent or aqueous cleaning medium. The use of a commercial in-line or batch cleaner is preferred. If this is not available, the following laboratory cleaning process shall be followed.

Three samples shall be cleaned (within 30 minutes or less) after soldering. For solvent or aqueous detergent cleaning, three 2000 ml beakers each containing 1000 ml of solvent shall be used such that one beaker serves as the primary cleaning stage and the other two are used for rinsing purposes. Each test coupon shall be agitated in each beaker for 1 minute. In the case of aqueous detergent, one beaker shall contain the cleaning agent and the remaining beakers shall contain deionized water for rinsing purposes. After the cleaning procedure is complete, samples are dried for 2 hours at 50°C. Following cleaning, the specimens shall be tested as outlined in 5.3.3 through 5.4.1.

5.3.3 Preparation of Samples for Chamber

Visually inspect all combs and discard any combs with bridging of conductors. Use water white rosin to solder teflon-insulated wires to the connection points of the specimens. Do not attempt to remove the flux residues. Connectors may be used in lieu of soldering wires but are not recommended. In the

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Table 1  Coupons for SIR Testing

<table>
<thead>
<tr>
<th>Sample Group</th>
<th>Flux/Solder</th>
<th>Clean</th>
<th>Number of Coupons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>yes</td>
<td>yes</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>yes</td>
<td>no</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>yes</td>
<td>no</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>yes</td>
<td>yes</td>
<td>3</td>
</tr>
<tr>
<td>E</td>
<td>yes</td>
<td>no</td>
<td>3</td>
</tr>
<tr>
<td>F</td>
<td>no</td>
<td>no</td>
<td>2</td>
</tr>
</tbody>
</table>

A = Pattern down/clean
B = Pattern down/no clean
C = Pattern up/no clean
D = Solder paste/reflow/clean
E = Solder paste/reflow/no clean
F = Control (precleaned, unprocessed)
event of a dispute, the samples with soldered wires shall be used as a referee.

5.3.4 Place the specimens in the environmental chamber in a vertical position such that the air flow is parallel to the direction of the board in the chamber. Set the chamber temperature at $85 \pm 2^\circ C$ and humidity at 20% RH and allow the oven to stabilize at this temperature for 3 hours. Then, slowly ramp the humidity to $85 \pm 2\%$ over a minimum 15 minute period. Allow the specimens to come to equilibrium for at least 1 hour before applying the bias voltage to begin the test. If a salt solution and dessicator are used for humidity, specimens shall be held for 24 hours before beginning the test.

5.3.5 Connect the 45–50v DC voltage source to the specimen test points to apply the bias voltage to all specimens.

5.4 Measurements

5.4.1 Measurements shall be made with test specimens in the chamber under the test conditions of temperature and humidity at 24, 96 and 168 hours. To take these measurements, the 45 - 50v DC bias voltage source must be removed from the test specimen and a test voltage of -100v DC shall be applied. (Test voltage polarity is opposite the bias polarity.)

5.5 Evaluation

5.5.1 Each comb pattern on each test specimen shall be evaluated by the insulation resistance values obtained at 96 and 168 hours. If the control coupon readings are less than 1000 megohms, a new set of test coupons shall be obtained and the entire test repeated. The reading at 24 hours may fall below the required value provided that it recovers by 96 hours. Any reason for deleting values (scratches, condensation, bridged conductors, outlying points, etc., must be noted).

5.5.2 All specimens shall also be examined under a 10x to 30x microscope using backlighting within 24 hours of completing the testing. If the coupons are to be held longer, they shall be placed in Kapak or other noncontaminating container and stored in a dessicator. All samples must be evaluated within 7 days. If dendritic growth or corrosion is observed, it shall be determined if the dendrite spans 25% or more of the original spacing. This latter condition will constitute a failure. It should be determined whether dendritic growth is due to condensation from the chamber (see paragraph 6.1).

5.5.3 Rejection of results for more than 2 combs for a given condition shall require the test to be repeated.

6.0 Notes

6.1 If condensation occurs on the test specimens in the environmental chamber while the samples are under voltage, dendritic growth will occur. This can be caused by a lack of sufficient control of the humidification of the oven. Water spotting may also be observed in some ovens where the air flow in the chamber is from back to front. In this case, water condensation on the cooler oven window can be blown around the oven as microdroplets which deposit on test specimens and cause dendritic growth if the spots bridge the distance between two electrified conductors. Both of these conditions must be eliminated for proper testing.

6.2 IPC-B-24 test board artwork and electronic data is available from IPC.
## Appendix A
### Qualification Test Report

| I.D. Number: |  |
| Flux Classification: | Date of Manufacture: |
| Manufacturer’s Identification: | Original Use by Date: |
| Manufacturer’s Batch Number: | Requalified Use by Date: |
| Date Original Qualification Tests Completed: | Date Requalification Tests Completed: |

| Tested By: | Pass: _ | Tested By: | Pass: _ |
| Witnessed By: | Fail: _ | Witnessed By: | Fail: _ |

**Certification Test**  
IPC-TM-650 Method | Test Requirement | Result Pass/Fail/NA

| Copper Mirror | 2.3.32 |
| Silver Chromate | 2.3.33 |
| Fluoride Spot | 2.3.35.1 |

### Halides Qualitative

- Silver Chromate: 2.3.33
- Fluoride Spot: 2.3.35.1

### Halides Quantitative

- Chloride, Bromide: 2.3.35, 2.3.28
- Fluoride: 2.3.35.2
- Nonvolatile Determination: 2.3.34
- Total as Chloride
- Corrosion: 2.6.15
- SIR: 2.6.3.3  
  - Cleaned
  - Not Cleaned
- Fungus (optional): 2.6.1

### Cleaning Procedure for Flux Characterization

- Cleaning Material
- Cleaning Equipment
- Cleaning Process Parameters
1 Scope This test method is used to determine the moisture and insulation resistance of applied conformal coating under prescribed conditions of temperature and humidity. Raw material qualification testing is performed on designated comb patterns.

2 Applicable Documents

- IPC-CC-830 Qualification and Performance of Electrical Insulating Compound for Printed Board Assemblies
- J-STD-004 Requirements for Soldering Fluxes
- IPC-A-600 Acceptability of Printed Boards

3 Test Specimens

3.1 Class 1, 2 and 3 Five IPC-B-25A boards (See Figure 1) using the D comb patterns, one uncoated and four coated with conformal coating according to the coating suppliers recommendations.

4 Apparatus

4.1 Chamber A clean chamber capable of programming and recording an environment of 25 ± 5°C [77° ± 9°F] to at least 65 ± 2°C [149° ± 3.6°F] and 90-98% relative humidity. Power Supply Capable of producing a standing bias potential of 100 VDC with a tolerance of ± 10%.

4.3 Resistance Meter Capable of reading high resistance (10^{12} ohms or greater), with a test voltage of 100VDC.

4.4 Oven Capable of maintaining at least 120°C [248°F].

4.5 Timer

4.6 Solder Pot

4.7 Tongs

4.8 Soldering Iron

4.9 Flux Water white rosin (R or RMA) with halide content less than 0.5%, i.e., type Symbol A and B or ROL0 and ROL1 according to J-STD-004.

5 Test

5.1 Ambient Conditions 25°, +2°, -5°C [77°, +3.6°, -9°F]. 40-50% relative humidity.

5.2 Test Conditions 25° to 65° ± 2°C [77° to 149° ± 3.6°F], with 90, -5, +3% relative humidity, 50VDC bias, cycling, 6/3 days.

5.3 Specimen Preparation

5.3.1 Positive, permanent and noncontaminating identification of the test specimens is of paramount importance.

5.3.2 Visually inspect the test specimens for any obvious defects, as described in the IPC-A-600. If there is any doubt about the overall quality of any test specimen, the test specimen should be discarded.
5.3.3 One uncoated specimen subjected to the same processing (except coating) as the coated specimens shall be supplied with each lot of samples as a test control.

5.4 Electrical Connections

5.4.1 Solder a single strand PTFE insulated wire, using the flux specified in 4.9, to each pad of the D comb pattern. These wires will be used to connect each pad of the designated comb pattern to polarization and insulation resistance testing. When soldering the wires onto the pads care should be taken to ensure that the flux does not splatter onto the combs. A simple off-contact shield fixture should be used to protect the test patterns from the flux spitting during soldering.

Note: An alternate method is to use gold plated alligator clips.

5.5 Soldering Flux Removal The flux shall not be removed. If the flux has contaminated the comb pattern on the control, the sample shall be discarded and a new one used. It cannot be cleaned because it will not represent the cleaning process that was used prior to conformal coating application.

5.6 Specimen Handling For the remainder of the test, the surface of the test specimens either uncoated or coated with conformal coating should not be handled or exposed to any other contaminating influence.

5.7 Procedure

5.7.1 Condition the specimens at 50 ± 2°C [122 ± 3.6°F] with no added humidity, for a period of 24 hours.

5.7.2 Testing

5.7.2.1 Allow the specimens to cool. Measure and record the initial insulation resistance measurements at ambient laboratory conditions. Apply 100 VDC on the specimen’s test points with the resistance meter and take the reading after one minute. On the D comb pattern, test points 1, 3 and 5 are connected to the positive terminal and test points 2 and 4 are connected to the negative terminal of the resistance meter.

5.7.2.2 Place specimens in a chamber, in the vertical position and under a condensation drip shield. Each chamber load shall contain at least one uncoated board that is representative of the cleaning process used prior to conformal coating application for each lot tested.

5.7.2.3 Close chambers door and apply a 50 VDC polarizing bias to all test patterns. Electrical connections to specimens shall be made so that electrical polarization voltage and the test voltage of the same polarity are connected to the same terminal.

5.7.2.4 Expose test specimens to 20 cycles of temperature and humidity. Polarizing voltage shall be maintained throughout the entire 20-cycle period. Humidity shall be maintained at 85% minimum through the cycles except that when going to low temperature in Step c below, the humidity may drop to 80% minimum.

One cycle is as follows:

a. Start test at 25°C [77°F] and raise the temperature to 65°C [149°F] over a time span of 1.75 ± 0.75 hours.
b. Maintain temperature at 65°C [149°F] for 3, +0.5, -0 hours

5.7.3 Measurement/Evaluation

5.7.3.1 Disconnect 50 VDC polarizing voltage source before taking the insulation resistance measurements. Insulation resistance shall be read as specified in 5.7.2.1.

5.7.3.2 Measure and record the resistance at the first, fourth, seventh and tenth cycle, between the 2nd and 3rd hour of the high phase of each cycle. These measurements are to be conducted without opening the chamber.

5.7.3.3 Upon completion of the 20 cycles, the test comb patterns shall be maintained at 25° ± 2°C [77° ± 3.6°F] relative humidity of 50 ± 5% for 24 hours.

5.7.3.4 After the 24-hour stabilization, the insulation resistance shall be measurements as previously stated in section 5.7.2.1.

5.7.3.5 The comb patterns will be examined for appearance and dielectric withstanding voltage in accordance with IPC-CC-830.
1.0 Scope
This test method is used to determine the total mass loss (TML) and collected volatile condensable material (CVCM) of materials when exposed to a heated vacuum environment. Mass loss may be due to outgassing of low molecular weight materials present in printed boards such as trapped plating solutions, improper lamination, and uncured adhesives which are known to cause contamination or corrosion of spacecraft equipment.

2.0 Applicable Documents


3.0 Test Specimens
The test specimen shall be cut into small pieces that can fit into the specimen boats and whose total mass shall be about 200 mg. If smaller masses are used the accuracy of the TML and CVCM determinations may be impaired. It is imperative that the specimens not be contaminated during the preparation process. Specimens are not to be handled with bare hands since human skin oils are volatile and condensable by this method thereby creating misleading TML and CVCM results. If there is any doubt about specimen contamination the specimens should be cleaned using solvents known to be nonreactive and that leave no residue. An average of at least three (3) samples shall be made for each test.

4.0 Apparatus or Material

4.1 Multiple specimen vacuum chamber capable of maintaining a vacuum of at least $7 \times 10^{-3}$ Pa ($5 \times 10^{-5}$ Torr) with resistance heated copper bars capable of maintaining $125^\circ \pm 1^\circ$C ($257^\circ \pm 1.8^\circ$F) during the 24 hour test run and typically containing 24 specimen chambers. Typically, three (3) of the specimen chambers are maintained as controls. The open end of each specimen chamber allows vapors from the specimen to pass through a hole into a collector chamber where the vapors are condensed on a collector plate that is maintained at $25^\circ \pm 1^\circ$C ($77^\circ \pm 1.8^\circ$F) throughout the test. See ASTM E 595 for further details and requirements for the construction and cleaning of the test apparatus.

4.2 An analytical balance capable of measuring the specimens, boats, and collector plate mass to the nearest microgram (0.000001 gram).

4.3 Glass desiccator using active silica gel desiccant. Low vapor pressure grease shall be used for the ground glass joints.

4.4 Conditioning chamber capable of maintaining 50% $\pm$ 5% relative humidity and $23^\circ \pm 2^\circ$C ($73.4^\circ \pm 3.6^\circ$F).

4.5 Prepared aluminum foil specimen boats.

4.6 Suitable cleaning solvents Mixtures of 1:1:1 by volume chloroform:acetone:ethanol and 1:1 by volume acetone:ethanol solvent blends have been successfully used for cleaning and degreasing the apparatus, aluminum boats, and collector plates. All solvents shall be spectrophotometer grade purity or equivalent. See Annex A1 of ASTM E 595 for details regarding cleaning and storage procedures for the equipment used in this test.

4.7 Nitrogen gas, 99.9% pure, or better, with a dew point of -60°C (-76°F) or less. The nitrogen gas shall be filtered using a Molecular Sieve 5A or equivalent.

4.8 Wiping materials and swabs for cleaning. These material shall be preextracted using solvents with which they will be used.

4.9 Suitable gloves or finger cots to be used during sample preparation.

5.0 Procedure

5.1 Weigh a prepared aluminum foil boat to the nearest microgram and return it to the glass storage desiccator.

5.2 Weigh a prepared collector plate to the nearest microgram and mount it into its cooling plate receptacle.

5.3 Add the test specimen to the boat and condition the
specimen at 50 ± 5% relative humidity at 23° ± 2°C for a minimum of 24 hours. Weigh the conditioned specimen and boat to the nearest microgram.

5.4 Exposure

5.4.1 Prior to operation, all temperature-vacuum apparatus such as the heating bar, separators, and cooling plates shall be clean and aligned.

5.4.2 Place the test specimen and boat into the specimen compartment in the temperature-vacuum system. Mount the respective cover plates of each specimen compartment and at least three (3) control compartments.

5.4.3 Close and activate the vacuum system and allow the system to evacuate to 7.0 x 10⁻⁵ Pa (5 x 10⁻⁵ Torr) or less within 1 hour. During this period, control of the collector plate temperature at 25° ± 1°C shall be achieved.

5.4.4 When the required vacuum has been achieved, turn on the heater bar and adjust the controller to heat the bar to 125° ± 1°C within 60 minutes.

5.4.5 Maintain the collector plate temperatures at 25° ± 1°C and the heater bar temperature at 125° ± 1°C for 24 hours. After this time period close the vacuum valve to the pumping system and turn off the current to the heater bars.

5.4.6 Open the vent valve and backfill with clean, dry nitrogen at a gage pressure of 10 to 30 kPa (2 to 4 psi) above atmosphere to rapidly cool the bars to 50°C within 2 hours, nominally.

5.4.7 Turn off the collector-plate heat exchangers, return the vacuum chamber to room pressure using clean, dry nitrogen, and open the chamber. Remove the aluminum specimen boats and their respective collector plates and the control collector plates and immediately store in the dry desiccator (see 4.3).

5.4.8 After allowing the specimens to cool to approximately room temperature, but after no more than 1/2 hour, weigh the specimens and boats and the collector plates to the nearest 1 microgram within 2 minutes of removal from the desiccators.

5.5 Evaluation of Test

5.5.1 Measurements of the control collector plates are used to detect contamination and/or poor technique. Mass loss of greater than 20 micrograms is an indication of poor cleaning of the collector plates. Mass gain of greater than 50 micrograms is an indication of poor cleaning of elements of the apparatus, cross contamination between specimen compartments, or poor vacuum technique. Any change of 50 micrograms or greater calls for a review of or change in technique. All data obtained during such runs shall be discarded and the test rerun when the system(s) are corrected.

5.5.2 Calculation of Total Mass Loss (TML). Calculate the TML as follows:

<table>
<thead>
<tr>
<th>Initial Mass</th>
<th>Final Mass</th>
</tr>
</thead>
</table>
| Specimens Weights:
| $S_i = (S_i + B) - B$ |
| $S_f = (S_f + B) - B$ |
| Mass Loss ($L$) = $S_i - S_f$ |
| Total Mass Loss (TML) (%) = $\frac{L}{S_i} \times 100$ |

Where:
- $B$ = Mass of boat in grams
- $S_i$ = Initial specimen mass in grams
- $S_f$ = Final Specimen mass in grams
- $L$ = Mass Loss in grams

5.5.3 Calculate the Collected Condensable Volatile Material (CVCM) as follows:

$$\text{CVCM} \text{ (%) } = \frac{(C_F - C_i)}{S_i} \times 100$$

Where:
- $C_F$ = Final mass of collector plate in grams
- $C_i$ = Initial mass of collector plate in grams
- $C_O$ = Mass of condensable material in grams
- $S_i$ = Initial specimen mass in grams

6.0 Notes.

6.1 A useful outgassing test data sheet format can be found in Appendix X1 of ASTM E 595.

6.2 Additional information regarding this test method and suggested requirements for certain spacecraft applications can be found in NASA SP-R-0022.
1.0 Scope
This test method is used to determine the total mass loss (TML) and collected volatile condensable material (CVCM) of materials when exposed to a heated vacuum environment. Mass loss may be due to outgassing of low molecular weight materials present in printed boards such as trapped plating solutions, improper lamination, and uncured adhesives which are known to cause contamination or corrosion of spacecraft equipment.

2.0 Applicable Documents

3.0 Test Specimens
The test specimen shall be cut into small pieces that can fit into the specimen boats and whose total mass shall be about 200 mg. If smaller masses are used the accuracy of the TML and CVCM determinations may be impaired. It is imperative that the specimens not be contaminated during the preparation process. Specimens are not to be handled with bare hands since human skin oils are volatile and condensable by this method thereby creating misleading TML and CVCM results. If there is any doubt about specimen contamination the specimens should be cleaned using solvents known to be nonreactive and that leave no residue. An average of at least three (3) samples shall be made for each test.

4.0 Apparatus or Material
4.1 Multiple specimen vacuum chamber capable of maintaining a vacuum of at least 7 X 10⁻³ Pa (5 X 10⁻⁵ Torr) with resistance heated copper bars capable of maintaining 125° ± 1°C (257° ± 1.8°F) during the 24 hour test run and typically containing 24 specimen chambers. Typically, three (3) of the specimen chambers are maintained as controls. The open end of each specimen chamber allows vapors from the specimen to pass through a hole into a collector chamber where the vapors are condensed on a collector plate that is maintained at 25° ± 1°C (77° ± 1.8°F) throughout the test. See ASTM E 595 for further details and requirements for the construction and cleaning of the test apparatus.

4.2 An analytical balance capable of measuring the specimens, boats, and collector plate mass to the nearest microgram (0.000001 gram).

4.3 Glass desiccator using active silica gel desiccant. Low vapor pressure grease shall be used for the ground glass joints.

4.4 Conditioning chamber capable of maintaining 50% ± 5% relative humidity and 23° ± 2°C (73.4° ± 3.6°F).

4.5 Prepared aluminum foil specimen boats.

4.6 Suitable cleaning solvents Mixtures of 1:1:1 by volume chloroform:acetone:ethanol and 1:1 by volume acetone:ethanol solvent blends have been successfully used for cleaning and degreasing the apparatus, aluminum boats, and collector plates. All solvents shall be spectrophotometer grade purity or equivalent. See Annex A1 of ASTM E 595 for details regarding cleaning and storage procedures for the equipment used in this test.

4.7 Nitrogen gas, 99.9% pure, or better, with a dew point of -60°C (-76°F) or less. The nitrogen gas shall be filtered using a Molecular Sieve 5A or equivalent.

4.8 Wiping materials and swabs for cleaning. These material shall be preextracted using solvents with which they will be used.

4.9 Suitable gloves or finger cots to be used during sample preparation.

5.0 Procedure
5.1 Weigh a prepared aluminum foil boat to the nearest microgram and return it to the glass storage desiccator.

5.2 Weigh a prepared collector plate to the nearest microgram and mount it into its cooling plate receptacle.

5.3 Add the test specimen to the boat and condition the
specimen at 50 ± 5% relative humidity at 23° ± 2°C for a minimum of 24 hours. Weigh the conditioned specimen and boat to the nearest microgram.

5.4 Exposure

5.4.1 Prior to operation, all temperature-vacuum apparatus such as the heating bar, separators, and cooling plates shall be clean and aligned.

5.4.2 Place the test specimen and boat into the specimen compartment in the temperature-vacuum system. Mount the respective cover plates of each specimen compartment and at least three (3) control compartments.

5.4.3 Close and activate the vacuum system and allow the system to evacuate to 7.0 X 10⁻⁵ Pa (5 X 10⁻⁵ Torr) or less within 1 hour. During this period, control of the collector plate temperature at 25° ± 1°C shall be achieved.

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5.4.6 Open the vent valve and backfill with clean, dry nitrogen at a gage pressure of 10 to 30 kPa (2 to 4 psi) above atmosphere to rapidly cool the bars to 50°C within 2 hours, nominally.

5.4.7 Turn off the collector-plate heat exchangers, return the vacuum chamber to room pressure using clean, dry nitrogen, and open the chamber. Remove the aluminum specimen boats and their respective collector plates and the control collector plates and immediately store in the dry desiccator (see 4.3).

5.4.8 After allowing the specimens to cool to approximately room temperature, but after no more than 1/2 hour, weigh the specimens and boats and the collector plates to the nearest 1 microgram within 2 minutes of removal from the desiccators.

5.5 Evaluation of Test

5.5.1 Measurements of the control collector plates are used to detect contamination and/or poor technique. Mass loss of greater than 20 micrograms is an indication of poor cleaning of the collector plates. Mass gain of greater than 50 micrograms is an indication of poor cleaning of elements of the apparatus, cross contamination between specimen compartments, or poor vacuum technique. Any change of 50 micrograms or greater calls for a review of or change in technique. All data obtained during such runs shall be discarded and the test rerun when the system(s) are corrected.

5.5.2 Calculation of Total Mass Loss (TML). Calculate the TML as follows:

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</thead>
<tbody>
<tr>
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<td></td>
</tr>
<tr>
<td>( S_I = (S_I + B) - B )</td>
<td>( S_F = (S_F + B) - B )</td>
</tr>
<tr>
<td>Mass Loss (L)</td>
<td>( S_I - S_F )</td>
</tr>
<tr>
<td>Total Mass Loss (TML) (%)</td>
<td>( \frac{L}{S_I} \times 100 )</td>
</tr>
</tbody>
</table>

Where:

- \( B \) = Mass of boat in grams
- \( S_I \) = Initial specimen mass in grams
- \( S_F \) = Final Specimen mass in grams
- \( L \) = Mass Loss in grams

5.5.3 Calculate the Collected Condensable Volatile Material (CVCM) as follows:

\[
CVCM (\%) = \left( \frac{C_F}{S_I} \right) \times 100
\]

Where:

- \( C_F \) = Final mass of collector plate in grams
- \( C_I \) = Initial mass of collector plate in grams
- \( C_O \) = Mass of condensable material in grams
- \( S_I \) = Initial specimen mass in grams

6.0 Notes.

6.1 A useful outgassing test data sheet format can be found in Appendix X1 of ASTM E 595.

6.2 Additional information regarding this test method and suggested requirements for certain spacecraft applications can be found in NASA SP-R-0022.
1.0 Scope  This method is to determine the electrical performance of multilayer printed wiring boards by following the shock with the interconnection test in Method 2.5.12 of this publication.

2.0 Applicable Documents  None

3.0 Test Specimen  The entire test pattern board described in part 5.8.4 of this publication.

4.0 Apparatus

4.1 A standard AVCO 150 pneumatic drop shock tester, or equivalent, capable of attaining at least 150 Gs.

4.2 High speed motion picture and oscilloscope photography is not normally necessary and is not recommended for the average “go no-go” testing program.

5.0 Procedure

5.1 Preparation  Fixture the test pattern boards so they are restrained on all four edges. Fabricate the fixtures so that it can be oriented to test the boards on three principle planes.

5.2 Test  Subject each specimen to three shock pulses of 100 Gs with a duration of 6.5 milliseconds in each of the three principle planes—a total of 9 blows.

5.3 Evaluation  Subject each specimen to the Interconnection Resistance, Multilayer Printed Wiring test in Method 2.5.12 of this publication.

6.0 Notes  None
1.0 Scope  This test is conducted for the purpose of deter-
moving the resistance of a material such as a laminate or mul-
tilayer circuit board, to the shock of repeated exposures to
extremes of high and low temperatures for comparatively
short periods of time.

2.0 Applicable documents  None

3.0 Test specimen  The test specimen for this test shall be
a sheet of laminate material at least 6 inch x 6 inch by the
thickness of the laminate. In the case of multilayer boards, the
test specimen shall be the entire qualification specimen
detailed in part 5.8.4 of this publication.

4.0 Apparatus  A chamber automatic temperature cycling
equipment suitable for the temperature extremes specified
herein. The air temperature shall be maintained by forced air
circulation. The chamber shall have sufficient heating or cool-
ing capacity to maintain the specified air temperature.

5.0 Procedure

5.1 Conditions  During the exposures, maintain the cham-
ber at the temperatures shown below:

<table>
<thead>
<tr>
<th>Step</th>
<th>Temp. (°C)</th>
<th>Time (Min.)</th>
<th>Temp. (°C)</th>
<th>Time (Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>125±3/–0</td>
<td>30</td>
<td>85±3/–0</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>25±10/–5</td>
<td>10–15</td>
<td>25±10/–5</td>
<td>10–15</td>
</tr>
<tr>
<td>3</td>
<td>65±0/–5</td>
<td>30</td>
<td>65±0/–5</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>25±10/–5</td>
<td>10–15</td>
<td>25±10/–5</td>
<td>10–15</td>
</tr>
</tbody>
</table>

5.2 Preparation  The test specimen must be cleaned of
dirt, grease, and other contaminants prior to the thermal
exposure. The test specimen should be cleaned by wiping
with a dry, clean lint-free cloth, or wiped with a clean lint-free
cloth dampened with acetone or isopropyl alcohol. The speci-
men must be allowed to air dry prior to thermal exposure.

5.3 Test exposure  The test specimen must be placed in
the thermal chamber maintained at the temperature specified
in Step 1 for the appropriate test condition. The test specimen
must be maintained at each temperature in the order speci-
fied. Throughout the test, the specimen must be placed in
such a position so that there is essentially no obstruction to
the flow of air around them. The specimen should be sub-
jected to the specified temperatures in the sequence specified
for a total of five cycles performed continuously.

5.4 Upon copulation of the five temperature cycles, allow
the specimen to return to room temperature. Visually inspect
the specimen in accordance with detailed requirements.
1.0 Scope  The purpose of this method is to determine the physical endurance of printed boards to sudden exposure to extreme changes in temperature and the effect of alternate exposures to these extremes. The exposure of the printed board specimens to the high and low temperature extremes is designed to cause physical damage, deterioration, or significant changes in resistance.

2.0 Applicable Documents


3.0 Test Specimen  Test coupon “D” from IPC-D-275 or other suitable test coupon (see 6.1a).

4.0 Apparatus

4.1 An automatically controlled dual temperature environmental test chamber or other dual chamber apparatus capable of maintaining –65, –55, –40 or 0°C + 0 –5°C [–85, –67, –40, +32°F + 0 –9°F] in the low temperature chamber and 70, 85, 105, 125, 150 or 170 °C [158, 185, 221, 257, 302 or 338°F +9 –0°F] in the high temperature chamber.

NOTE: The temperature extremes (high and low) that are required is dependent on the base material of the specimen that is to be tested (see 6.1b). The recovery capacity of the test chambers shall be such that the internal chamber air temperature shall reach the specified temperature within 2 minutes after the specimen(s) have been transferred to the test chamber.

4.2 An electrical resistance meter capable of accuracies of 0.5 milliohm or better with Kelvin (4 terminal) type leads. A Kelvin type double bridge or potentiometer of the specified accuracy may also be used (see 6.2).

5.0 Preparation  Wire up test specimen with Kelvin-type leads at the points where measurements will be made.

5.1 Preparation  Wire up test specimen with Kelvin-type leads at the points where measurements will be made.

5.1.1 Operate chamber (or chambers) and allow to stabilize at the high and low temperature required. Clamp or suspend specimen in the approximate center of the high temperature chamber. First specimens shall be placed approximately 13 mm [0.5 in] apart and aligned in a manner to permit maximum heat transfer to the test specimen(s).

5.2 Test

5.2.1 Thermal Shock Cycle

5.2.1.1 The specimens shall be subjected to 100 temperature cycles in accordance with the applicable test condition of Table 1.

5.2.1.2 Transfer time between chambers shall be less than 2 minutes. The thermal capacity of the test chamber used shall be such that the ambient temperature shall reach the specified temperature within 2 minutes after the specimen has been transferred to the appropriate chamber.

5.2.1.3 Interconnection resistance measurements shall be taken before the test, during the first cycle at high temperature, and during the last cycle at high temperature. In-chamber resistance measurements should be taken during the last few minutes of chamber exposure. Care should also be taken to measure samples after approximately the same duration at chamber temperature.

5.3 Evaluation  The maximum change in resistance between the first and 100th cycle shall be evaluated for acceptability to the requirements of the applicable specification.

6.0 Notes

6.1 The following details are to be specified in the applicable performance specification:

a. Test specimen, if other than specified in 3.0.
b. Test condition, if other than specified in 4.1.
c. Maximum change in resistance.
6.1.1 Unless otherwise specified by the applicable performance specification, the following base material types/temperature ratings are recommended.

### Table 1

<table>
<thead>
<tr>
<th>Step</th>
<th>Test Condition A</th>
<th>Test Condition B</th>
<th>Test Condition C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temperature</td>
<td>Time</td>
<td>Temperature</td>
</tr>
<tr>
<td>1</td>
<td>0, +0/-5</td>
<td>15</td>
<td>-40, +0/-5</td>
</tr>
<tr>
<td>2</td>
<td>25, +10/-5</td>
<td>0</td>
<td>25, +10/-5</td>
</tr>
<tr>
<td>3</td>
<td>+70, +5/-0</td>
<td>15</td>
<td>+85, +5/-0</td>
</tr>
<tr>
<td>4</td>
<td>25, +10/-5</td>
<td>0</td>
<td>25, +10/-5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step</th>
<th>Test Condition D</th>
<th>Test Condition E</th>
<th>Test Condition F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temperature</td>
<td>Time</td>
<td>Temperature</td>
</tr>
<tr>
<td>1</td>
<td>-55, +0/-5</td>
<td>15</td>
<td>-65, +0/-5</td>
</tr>
<tr>
<td>2</td>
<td>25, +10/-5</td>
<td>0</td>
<td>25, +10/-5</td>
</tr>
<tr>
<td>3</td>
<td>+125, +5/-0</td>
<td>15</td>
<td>+150, +5/-0</td>
</tr>
<tr>
<td>4</td>
<td>25, +10/-5</td>
<td>0</td>
<td>25, +10/-5</td>
</tr>
</tbody>
</table>

Tolerance shall be +2 and -0 minutes.

### Table 2

<table>
<thead>
<tr>
<th>Rigid Type</th>
<th>NEMA</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP, GT, GX, GY</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>GE</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>AF, BF, BI, CF, GF, GB</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>GH, GM</td>
<td>E</td>
<td>A</td>
</tr>
<tr>
<td>AI, GI, QI</td>
<td>F</td>
<td>A</td>
</tr>
</tbody>
</table>

6.2 Suggested sources for capable test equipment:

Cambridge Technology  
Model 510A Micro-Ohmmeter  
23 Elm Street  
Watertown, MA 02172  
(617) 923-1181

Hewlett-Packard  
Model 4338A Milliohmmeter  
9800 Muirlands Avenue  
Irvine, CA 92718  
(714) 472-3000

Keithly Instruments  
Model 580  
Micro-ohmmeter  
28775 Aurora Road  
Cleveland, OH 44139  
(800) 552-1115
1 Scope  This test method is to determine the physical endurance of applied conformal coating to sudden changes of high and low temperature excursions that cause physical fatigue.

2 Applicable Documents

IPC-CC-830  Qualification and Performance of Electrical Insulating Compound for Printed Board Assemblies

3 Test Specimens  Five IPC-B-25A boards (see Figure 1) coated with conformal coating per coating supplier’s recommendations.

4 Apparatus  Test chamber - automatically controlled dual temperature environmental test equipment or two separate chambers capable of maintaining -65\degree \pm 5\degree C [-85\degree \pm 9\degree F] and 250\degree \pm 5\degree C [482\degree \pm 9\degree F] respectively. Please note, while most requests state 125\degree \pm 5\degree C [257\degree \pm 9\degree F] on the high side, there are cases (such as polyimide board applications) where a higher temperature will be required. Test conditions, if not otherwise stated as below, shall be -65\degree C [-85\degree F] and 125\degree C [257\degree F].

<table>
<thead>
<tr>
<th>Class</th>
<th>Low Temperature</th>
<th>High Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>-40\degree C [-40\degree F]</td>
<td>125\degree C [257\degree F]</td>
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<td>-65\degree C [-85\degree F]</td>
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</tr>
<tr>
<td>4</td>
<td>-65\degree C [-85\degree F]</td>
<td>250\degree C [482\degree F]</td>
</tr>
</tbody>
</table>

5 Procedure

5.1 Specimen Preparation  Operate the chamber(s) to high and low temperatures and stabilize. Clamp or suspend the five conformal coated IPC-B-25A boards in the thermal shock chamber.

5.1.1 Set the cold portion of chamber at -65\degree C [-85\degree F] and the hot portion of chamber at 125\degree C [257\degree F].

5.2 Evaluation

5.2.1 Upon completion of the thermal shock test, the specimens shall meet the requirements of appearance and dielectric withstanding voltage in accordance with IPC-CC-830.
1 Scope  This test method is to determine the physical endurance of applied conformal coating to sudden changes of high and low temperature excursions that cause physical fatigue.

2 Applicable Documents

IPC-CC-830  Qualification and Performance of Electrical Insulating Compound for Printed Board Assemblies

3 Test Specimens  Five IPC-B-25A boards (see Figure 1) coated with conformal coating per coating supplier’s recommendations.

4 Apparatus  Test chamber - automatically controlled dual temperature environmental test equipment or two separate chambers capable of maintaining -65° ± 5°C [-85° ± 9°F] and 250° ± 5°C [482° ± 9°F] respectively. Please note, while most requests state 125° ± 5°C [257° ± 9°F] on the high side, there are cases (such as polyimide board applications) where a higher temperature will be required. Test conditions, if not otherwise stated as below, shall be -65°C [-85°F] and 125°C [257°F].

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<td>125°C [257°F]</td>
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<td>125°C [257°F]</td>
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<tr>
<td>4</td>
<td>-65°C [-85°F]</td>
<td>250°C [482°F]</td>
</tr>
</tbody>
</table>

5 Procedure

5.1 Specimen Preparation  Operate the chamber(s) to high and low temperatures and stabilize. Clamp or suspend the five conformal coated IPC-B-25A boards in the thermal shock chamber.

5.1.1 Set the cold portion of chamber at -65°C [-85°F] and the hot portion of chamber at 125°C [257°F].

5.1.2 Set the dwell time for 15 minutes.

5.1.3 Set the temperature recovery time for less than two minutes.

5.1.4 Set the chamber for 100 cycles.

5.1.5 Activate the test chamber and begin testing.

5.2 Evaluation

5.2.1 Upon completion of the thermal shock test, the specimens shall meet the requirements of appearance and dielectric withstanding voltage in accordance with IPC-CC-830.

Figure 1  IPC-B-25A Test Board
1.0 Scope  This method is to determine the physical endurance of printed boards to sudden changes of temperature. It is designed to expose specimens to a series of high and low temperature excursions to cause physical fatigue.

2.0 Applicable Documents


3.0 Test Specimen  Coupon D from IPC-D-275 or other suitable test coupon (see 6.1a).

4.0 Apparatus

4.1 An automatically controlled dual temperature environmental test chamber or other dual chamber apparatus capable of maintaining –65, –55, –40 or 0°C + 0 –5°C [–85, –67, –40, +32°F + 0 –9°F] in the low temperature chamber and 70, 85, 105, 125, 150 or 170 +5 –0°C [158, 185, 221, 257, 302 or 338 +9 –0°F] in the high temperature chamber.

NOTE: The temperature extremes (high and low) that are required is dependent on the base material of the specimen that is to be tested (see 6.1b and the temperatures listed in Table 2). The recovery capacity of the test chambers shall be such that the internal chamber temperature shall reach the specified temperature within 2 minutes after the specimen(s) have been transferred to the test chamber. Test conditions, if not otherwise stated in the applicable performance specification (see 6.1b), shall meet the requirements of Table 2.

4.2 An electrical resistance meter capable of accuracies of 0.5 milliohm or better with Kelvin (4 terminal) type leads. A Kelvin type double bridge or potentiometer of the specified accuracy may also be used (See 6.2).

5.0 Procedure

5.1 Preparation  Wire up test specimen with Kelvin-type leads at the points where measurements will be made.

5.1.1 Operate chamber (or chambers) and allow to stabilize at the high and low temperature required. Clamp or suspend test specimen in the approximate center of the high temperature chamber. Test specimens shall be placed approximately 13 mm [0.5 inches] apart and aligned in a manner to permit maximum heat transfer to test specimen(s).

5.2 Test

5.2.1 Thermal Shock Cycle

5.2.1.1 The test specimens shall be subjected to 100 temperature cycles in accordance with Table 1.

5.2.1.2 Transfer time between chambers shall be less than 2 minutes. The thermal capacity of the test chamber used shall be such that the ambient temperature shall reach the specified temperature within 2 minutes after the test specimen has been transferred to the appropriate chamber.

5.2.1.3 Interconnection resistance measurements shall be taken before the test, during the first cycle at high temperature, and during the last cycle at high temperature.

5.3 Evaluation  The maximum change in resistance between the first and 100th cycle shall be evaluated for acceptability to the requirements of the applicable performance specification (see 6.1c). After testing, a minimum of 3 plated-through holes shall be microsectioned and shall be evaluated for acceptability to the requirements of the applicable performance specifications.

6.0 Notes

6.1 The following details are to be specified in the applicable performance specification:

a. Test specimen, if other than specified in 3.0.
b. Test condition, if other than specified in 4.1.
c. Maximum allowable change in resistance.
6.1.1 Unless otherwise specified by the applicable performance specification, the following base material types/temperature ratings are recommended.

### Table 1

<table>
<thead>
<tr>
<th>Step</th>
<th>Temperature A</th>
<th>Time</th>
<th>Temperature B</th>
<th>Time</th>
<th>Temperature C</th>
<th>Time</th>
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<th>Time</th>
<th>Temperature E</th>
<th>Time</th>
<th>Temperature F</th>
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<td>25, +10/-5</td>
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Tolerance shall be +2 and -0 minutes.

### Table 2

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<td>AF, BF, BI, CF, GF, GB</td>
<td>FR-4</td>
</tr>
<tr>
<td>GH, GM</td>
<td>FR-5</td>
</tr>
<tr>
<td>AI, GI, QI</td>
<td>F</td>
</tr>
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</table>

6.2 Suggested sources for capable test equipment:

Cambridge Technology  
Model 510A Micro-Ohmmeter  
23 Elm Street  
Watertown, MA 02172  
(617) 923-1181

Hewlett-Packard  
Model 4338A Milliohmmeter  
9800 Muirlands Avenue  
Irvine, CA 92718  
(714) 472-3000

Keithly Instruments  
Model 580  
Micro-ohmmeter  
28775 Aurora Road  
Cleveland, OH 44139  
(800) 552-1115
1 Scope  This test method is to determine the physical endurance of applied polymer solder mask to sudden changes of high and low temperature excursions to cause physical fatigue.

2 Applicable Documents

IPC-CC-830  Qualification and Performance of Electrical Insulating Compounds for Printed Board Assemblies

IPC-SM-840  Qualification and Performance of Permanent Coating (Solder Mask) for Printed Boards

3 Test Specimens

3.1 Qualification Testing  Six IPC-B-25A test boards (see Figure 1) coated with solder mask and cured in accordance with solder mask supplier’s recommendations.

3.2 Conformance Testing  Six IPC-B-25A boards (see Figure 1) containing the C pattern (“Y” pattern) with 0.635 mm lines/0.635 mm spacing [25.00 mil lines/25.00 mil spacing] or minimum spacing on the production board, whichever is smaller, coated with solder mask according to the coating supplier’s recommendations.

4 Apparatus

4.1 Chamber  Automatically controlled dual temperature environmental test equipment or two separate chambers capable of maintaining -65° ± 5°C [-85° ± 9°F] and +125° ± 5°C [+257° ± 9°F].

5 Procedure

5.1 Specimen Preparation  In order to test the compatibility of solder mask with conformal coating, conformal coat three of the above test specimens with a coating in accordance with IPC-CC-830 and cure in accordance with the coating supplier’s recommendations.

5.2 Test

5.2.1 Place the test specimens into the test chamber, so that they do not touch one another, and set the parameters as follows:


b. Dwell Time at Temperature Extremes: 15 minutes

c. Transfer Time: Less than two minutes

d. Number of Cycles: 100

5.2.2 Activate the test chamber and begin testing.

5.2.3 One thermal cycle consists of the following:

a. Expose the specimens to the high temperature for 15 minutes.

b. Transfer the specimens to the low temperature in less than two minutes.

c. Expose the specimens to the low temperature for 15 minutes.

d. Transfer the specimens to the high temperature in less than two minutes.

---

Figure 1  IPC-B-25A Test Board

b. Dwell Time at Temperature Extremes: 15 minutes
c. Transfer Time: Less than two minutes
d. Number of Cycles: 100

Activate the test chamber and begin testing.

One thermal cycle consists of the following:

a. Expose the specimens to the high temperature for 15 minutes.

b. Transfer the specimens to the low temperature in less than two minutes.

c. Expose the specimens to the low temperature for 15 minutes.

d. Transfer the specimens to the high temperature in less than two minutes.
5.2.4 Repeat the above cycle to 100 cycles without interruption.

5.2.5 Remove the specimens and allow them to reach laboratory conditions as specified in IPC-SM-840.

5.2.6 Evaluation Examine the specimens, on both sides, for all visual requirements of IPC-SM-840 using 10X magnifications (Referee of 30X magnifications).

Note: The presence of cracks in solder mask is not a sufficient reason for rejection unless the conformal coating has also cracked. Report findings and support results with the photographs, if appropriate.
1.0 Scope
This test is performed for the purpose of determining whether plated through-holes can withstand the thermodynamic effects of the extreme heat to which they may be exposed during the assembly, rework, or repair process.

2.0 Applicable Documents
J-STD-001  Requirements for Soldered Electrical and Electronic Assemblies
J-STD-004  Requirements for Soldering Fluxes
IPC-TM-650 Method 2.1.1, Microsectioning
IPC-TM-650 Method 2.1.1.2, Microsectioning—Semi or Automatic Technique Microsection Equipment (Alternate)

3.0 Test Specimen
3.1 The test specimen shall be a printed board or test coupon which will allow at least three of the smallest size plated through-holes to be viewed in the finished microsection.
3.2 The test specimen shall be removed from a printed board or test coupon as specified in IPC-TM-650, Method 2.1.1 or Method 2.1.1.2.

4.0 Apparatus or Material
4.1 Drying oven capable of maintaining a uniform temperature between 121°C to 149°C.
4.2 Solder pot, electrically heated, thermostatically controlled, of sufficient size, containing at least 0.9 kg of Sn60Pb40 or Sn63Pb37 solder conforming to the contaminant level specified in J-STD-001.
4.3 Thermocouple indicator or other devices to measure the solder temperature 19 mm ± 6.4 mm below the surface.
4.4 Desiccator with suitable desiccant
4.5 Microscope (100X to 200X magnification).
4.6 Stop Watch or Timer
4.7 Rosin Flux, type ROL1 per J-STD-004, or flux agreed upon between customer and vendor.
4.8 Tongs
4.9 Suitable solvent for flux removal following the thermal stress such as isopropyl alcohol.

5.0 Procedure
5.1 The test specimen shall be conditioned by drying in an oven for an appropriate period at 121°C to 149°C to remove the moisture in the specimen. For referee purposes, a dry for a minimum of 6 hours at 121°C to 149°C shall be used. Thicker or more complex specimens may require longer baking times.
5.2 Place the test specimen in a desiccator on a ceramic plate to cool to room temperature.
5.3 Remove the test specimen from the desiccator using tongs. Flux coat the surface and plated through-holes to insure solder filling.
5.4 Verify that the temperature of the solder (at a probe depth of 19 mm ± 6.4 mm from the surface of the solder) is maintained at one of the following specified test conditions (see note 6.1):
   (a) Test condition A (default) 288°C ± 5°C
   (b) Test condition B 260°C ± 5°C
   (c) Test condition C 232°C ± 5°C
5.5 Remove the dross from the solder pot surface and lay the test specimen on the solder for 10 seconds +1, -0 seconds (see note 6.2).
5.6 Using tongs, carefully remove the test specimen from the solder and place it on a piece of insulator to cool to room temperature. See note 6.3.

5.7 Evaluation
5.7.1 After cleaning, microsection the specimen as defined in IPC-TM-650, Method 2.1.1 or Method 2.1.1.2.

5.7.2 Examine the microsection for compliance of the plated through-holes to the applicable performance specification requirements. Any non-conformities shall be noted.

6. Notes

6.1 Performance specifications should specify the test condition and any deviations to this test method. If no test condition is specified, use test condition A.

6.2 The test specimen is not to be held against the surface of the molten solder.

6.3 Do not physically shock specimen while the solder in the plated through-holes is still liquid.
1.0 Scope  
To determine the resistance of the laminate to thermal stress in both the etched and unetched state.

2.0 Applicable Documents
IPC-TM-650  Methods 2.3.6, 2.3.7, 2.3.7.1

3.0 Apparatus
3.1 Solder pot capable of maintaining the temperature on the applicable specification sheet for the material ± 2°F and accepting a 2 x 2 inch test specimen or equivalent.

3.2 Dow Corning Fluid #704 or equivalent.

4.0 Test Specimens
4.1 One (1) test specimen 2 x 2 inch will be cut from each sample sheet for the unetched specimen.

4.2 One (1) test specimen 2 x 2 inch from each sample sheet for the etched specimen.

4.3 The edges of the 2 x 2 inch specimen shall be sanded.

5.0 Procedure
5.1 Etch specimen required for thermal stress etched according to IPC-TM-650, Methods 2.3.6, 2.3.7, or 2.3.7.1.

5.2 Apply silicon fluid to side of specimen that will be in contact with solder.

5.3 Float the specimen on the solder for the time and at the temperature specified on the applicable specification sheet for the material.

5.4 The clad or unclad surface should show no evidence of charring, loss of surface resin, softening delamination, blistering, or weave exposure.
1.0 Scope  This test describes a procedure which may be conducted to determine if a printed wiring board is constructed to withstand the dynamic vibrational stresses that may be encountered during field service. This test method provides specific parameters for one application in order to present the proper procedures. Specific test conditions must be agreed upon by the customer and the vendor.

2.0 Applicable Documents

IPC-6012  Qualification and Performance Specification for Rigid Printed Boards

3.0 Test Specimen  The preproduction or production printed wiring board.

4.0 Apparatus

4.1 Vibration  A vibration system capable of producing an input of 25 g’s over a frequency range from 20 to 2000 to 20 Hz performed in 16 minutes.

4.2 Mounting Fixtures

4.3  The test fixture must be designed such that resonant vibration inherent in the fixture within the frequency range specified for the test shall be minor. The magnitude of the applied vibration should be monitored on the test fixture near the specimen mounting points.

4.4  The test specimen shall be restrained from movement by fixturing at all four edges and with the flat surface of the boards mounted perpendicular to the axis of vibration.

5.0 Test Procedures

5.1  The boards shall successfully pass the interconnection resistance test in accordance with IPC-6012 before and after the vibration test.

5.2  The boards shall be subjected to both a cycling and a resonance dwell test. 5.2.1  The cycling test shall consists of one sweep from 20 to 2000 to 20 Hz performed in 16 minutes. The input acceleration (g’s) over the 20-2000-20 Hz frequency range shall be maintained at 15 g’s.

5.2.2  The boards shall be subjected to a 30 minute resonance dwell with 25 g’s input or a maximum of 100 g’s output measured at the geometric center of the board.

5.3 Evaluation  Examine boards for warp or delamination and interconnection resistance after exposure to the vibration test.

6.0 Notes  None
1.0 Scope
The purpose of this test method is to provide a consistent procedure to test the sensitivity of electronic components to ultrasonic energy. There has been a reluctance in the electronics industry to use ultrasonic energy for printed board assemblies cleaning because of the possibility of damage to wire bonds in active, hermetically sealed components or other damage that might cause latent failures.

Recent work has shown that electronic components have a low potential for damage from ultrasonics (See 6.1) under conditions seen in most cleaning processes. In addition, MIL-STD-2000 Rev. A and J-STD 001 now allow for the use of ultrasonic cleaning, as does the proposal for IEC TC91 International Standards based on an updated revision of the J-STD-001.

1.1 Definitions

Ultrasound: All sound in frequencies above the range of human hearing. For the purpose of ultrasonic cleaning, frequencies between 18-800 kHz are in commercial use. In the lower frequency ranges, fluid cavitation is the primary agitation method. In the higher frequency ranges, microstreaming (i.e., fluid pumping) is believed to be the form of mechanical agitation.

Frequency: The number of periodic oscillations, vibrations of waves per unit of time, usually expressed in cycles per second.

Generator: An electronic system which converts the 50 or 60 Hz power line electricity into an ultrasonic frequency drive signal which powers the transducers in their resonant frequency range.

Transducers: Convert electrical energy from the generator into mechanical (vibratory) energy, producing high intensity sound waves in a liquid and causing cavitation. Transducers are primarily of two types.

Piezoelectric: Piezoelectric ceramics, which change dimensions in the presence of an electric field. Thickness varies in response to an applied voltage. Conversion efficiency = 70-90%

Magneostriuctive: Made of nickel or its alloys, it changes length when placed in a magnetic field. Conversion efficiency = 20-50%

Cavitation: The rapid formation and oscillation or violent collapse of microscopic bubbles or cavities in a liquid, produced by introducing high frequency (ultrasonic) sound waves into a liquid. The agitation from countless implosions of these bubbles create a highly effective scrubbing of both exposed and hidden surfaces of parts immersed in the cleaning solution.

Degas: The act of removing entrained gas from cleaning fluid. Gas bubbles tend to absorb ultrasonic energy, thereby decreasing the amount of energy available for cleaning.

2.0 Applicable Documents

2.1 Institute for Interconnecting and Packaging Electronic Circuits (IPC)

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Assemblies
IPC-CH-65 Guidelines for Cleaning of Printed Boards and Assemblies

2.2 Joint Industry Standards

J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

2.3 Military MIL-STD-2000 Rev. A Standard Requirements for Soldered Electrical and Electronic Assemblies

2.4 Other Publications

IEC-TC-91 Proposed International Standard (based on J-STD-001) International Requirements for Soldered Electrical and Electronic Assemblies Using Surface Mount and Related Assembly Technologies

3.0 Test Specimens
The board mounted components to be tested should be the exact type and configuration the tester intends to use in production. A statistically valid number of each type and package style of component of interest should be tested. For example, if actual production boards are used for testing and only one of a particular component is contained on the board, then a statistically valid number of boards will have to be tested. If, instead of production boards, dummy boards are used, they
should be of the same general size and construction as production boards. A minimum of five boards shall be run.

4.0 Apparatus

4.1 Tank

Testing shall be done in an ultrasonic tank, preferably in the equipment to be used in production. Water is to be used as the ultrasonic transmission testing fluid, regardless of the cleaning agent to be used in the production process. Water will degas, transmit ultrasonics, and cavitate more easily than most new cleaning agents and is, therefore, considered a “worst case” ultrasonic testing fluid. Care must be taken to maintain water level during testing. Water temperatures should be maintained at 60°C ±5°C (140°F ±10°F).

It is recommended that testing equipment operate near 40 KHz or higher and have a power output in the range listed in the chart below. Power is measured as the output from the generator to the transducers. Note in the chart that the amount of power necessary is scaled for various tank sizes.

If power densities or frequencies differing from the ranges listed above are to be used in production, they should be used in testing as well, and noted on the Ultrasonic Test Data Record.

5.0 Procedure and Evaluation

Note: Standard ESD handling methods should be used in handling and assembly so as not to have ESD damage misinterpreted as damage by ultrasonic exposure.

5.1 Procedure

5.1.1 Solder components into (onto) a test circuit board. Perform functional electrical tests on components to be subjected to ultrasonic energy. It is suggested that all components go through standard prescreening tests to eliminate infant mortality. Note any anomalies and ignore any malfunctions in further testing.

5.1.2 Visually inspect the solder joints of SMD leads at 10-15x for conformance with J-STD-001. Document any observed defects with notes or photos.

5.1.3 Fill the test tank with deionized water. Turn on ultrasonics and allow a minimum of 15 minutes for the water to degas. Evidence of cavitation should be obtained by placing a piece of aluminum foil in the water for one minute and inspecting for an erosion pattern (evidence of cavitation activity). If the surface of the foil is not disrupted, continue to degas until the foil confirms ultrasonic activity.

Test components in the equipment described above. Boards should be placed in the tank in the same quantity and orientation as will be the case in production, taking into consideration the size of the test tank in relation to the production unit. Boards should be positioned perpendicular to the radiating surface (tank surface where transducers are mounted) and should not be allowed to rest on the radiating surface (Figure 1).

Subject specimens to ultrasonics for a time period 10 times longer than the expected exposure anticipated under normal cleaning conditions or thirty minutes, whichever is longer.

5.1.3 (Optional) Conduct any environmental stressing test(s) as specified by the reliability requirement of the product line in concern.

5.2 Evaluation Method

5.2.1 Repeat the functional electrical test in 5.1.1. Any failures should be analyzed for cause of failure. Any failure, excluding those noted in 5.1.1 or attributable to a documented defect, will be considered caused by the ultrasonics.

5.2.2 Repeat the visual inspections as described in 5.1.2. Any defect which is not assignable to a previously documented defect will also be considered caused by ultrasonics.

5.2.3 Any component exhibiting no failures or 100% reliability after ultrasonic testing will be considered safely resistant to ultrasonics under the conditions tested. Any component with less than 100% reliability will be suspect unless subsequent testing can demonstrate that it is 100% reliable. Unless classified or proprietary, please report test results to the Ultrasonic Cleaning Task Group of the IPC for compilation in the attached list.
Note: It is important that the IPC receives as much data as possible, whether it be to support previously submitted data, add new data, or provide conflicting data on certain components. All information received will be entered into a database for all IPC members to access. The database will prove more useful as the volume of data increases.

6.0 Notes Contact IPC for a list of tested components.

6.1 References


Test to Determine Sensitivity of Electronic Assemblies to Ultrasonic Energy

Figure 1

U/S = ULTRASONIC ENERGY (TRANSUDCERS)
Ultrasonic Test Data Record

Name of tester ___________________________ Date __________________
Company ________________________________
Address __________________________________
Phone __________________ Fax ____________
Make and model of equipment ________________
Tank size ______________ Dimensions (cm cm x cm) ______________
Generator output power __________________ Frequency (KHz) ______________
No. of boards tested per trial ______________ Substrate ______________
Exposure time ______________
Other stress testing (pre- or post-) ______________
Describe ________________________________

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Mail to: IPC  
2215 Sanders Road  
Northbrook, IL 60062-6135  
Attn: Ultrasonic Cleaning Task Group  
Fax to: 847-509-9798
1.0 Scope

The purpose of this test method is to provide a consistent procedure to test the sensitivity of electronic components to ultrasonic energy. There has been reluctance in the electronics industry to use ultrasonic energy for printed board assembly cleaning because of the possibility of damage to wire bonds in active, hermetically sealed components or other damage that might cause latent failures.

Recent work has shown that electronic components have a low potential for damage from ultrasonics (References 1-7) under conditions seen in most cleaning processes. In addition, MIL-STD-2000 Rev. A and J-STD-001 now allow for the use of ultrasonic cleaning, as does the proposal for IEC TC91 International Standards based on an updated revision of the J-STD-001.

1.1 Definitions

Ultrasound: All sound in frequencies above the range of human hearing. For the purpose of ultrasonic cleaning, frequencies between 18-800 KHz are in commercial use. In the lower frequency ranges, fluid cavitation is the primary agitation method. In the higher frequency ranges, microstreaming (i.e., fluid pumping) is believed to be the form of mechanical agitation.

Frequency: The number of periodic oscillations, vibrations of waves per unit of time, usually expressed in cycles per second (Hertz).

Generator: An electronic system which converts the 50 or 60 Hz power line electricity into an ultrasonic frequency drive signal which powers the transducers in their resonant frequency range.

Transducers: Convert electrical energy from the generator into mechanical (vibratory) energy, producing high intensity sound waves in a liquid and causing cavitation of microstreaming. Transducers are primarily of two types, piezoelectric and magnetostrictive.

Piezoelectric: Piezoelectric ceramics, which change dimensions in the presence of an electric field. Thickness varies in response to an applied voltage. Conversion efficiency = 70-90%.

Magnetostrictive: Made of nickel or its alloys, it changes length when placed in a magnetic field. Conversion efficiency = 20-50%.

2.0 Applicable Documents

2.1 Institute for Interconnecting and Packaging Electronic Circuits (IPC)

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Assemblies

IPC-CH-65 Guidelines for Cleaning of Printed Boards and Assemblies.

2.2 Joint Industry Standards

J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

2.3 Military


2.4 Other Publications


3.0 Test Specimens

The components to be tested should be the exact type and package style the tester intends to use in production. A statistically valid number of each type and package style of interest should be tested.

4.0 Apparatus
4.1 **Tank**  Testing shall be done in an ultrasonic tank, preferably in the equipment to be used in production. Water is to be used as the ultrasonic transmission testing fluid, regardless of the cleaning agent to be used in the production process. Water will degas, transmit ultrasonics, and cavitate more easily than most new cleaning agents and is, therefore, considered a “worst case” ultrasonic testing fluid. Care must be taken to maintain water level during testing. Water temperatures should be maintained at 60°C ±5°C (140°F ± 10°F).

It is recommended that testing equipment operate near 40Khz or higher and have a power output in the range listed in the chart below. Power is measured as the output from the generator to the transducers. Note in the chart that the amount of power necessary is scaled for various tank sizes.

<table>
<thead>
<tr>
<th>Tank Size liters (gallons)</th>
<th>Power Density watts/liter (watts/gallon)</th>
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<tbody>
<tr>
<td></td>
<td>Magnetostrictive</td>
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<tr>
<td>19 (5)</td>
<td>66-76 (250-290)</td>
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<tr>
<td>38 (10)</td>
<td>53-68 (200-220)</td>
</tr>
<tr>
<td>95 and greater (25 and greater)</td>
<td>21-32 (80-120)</td>
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</tbody>
</table>

If frequencies other than 40 KHz range or power densities or frequencies differing from the ranges listed above are to be used in production, they should be used in testing as well, and noted on the Ultrasonic Test Data Record.

4.2 **Basket**  Loose components will be placed randomly in a basket or in a beaker (pyrex or stainless steel) for testing. If a basket is used, it should be made of stainless steel and preferably have a solid bottom for optimal ultrasonic transmission. Tight mesh should always be avoided. If a beaker is chosen, plastic is not acceptable as it will dampen ultrasonic transmission.

5.1 **Procedure**

Note: Standard ESD handling methods should be used in handling and assembly so as not to have ESD damage misinterpreted as damage by ultrasonic exposure.

5.1.1 Perform functional electrical tests on components to be subjected to ultrasonic energy. All components should go through standard prescreening tests to eliminate infant mortality. Note any anomalies and ignore any malfunctions in further testing.

5.1.2 Fill the test tank with de-ionized water. Turn on ultrasonics and allow a minimum of 15 minutes for the water to degas. Evidence of cavitation should be obtained by placing a piece of aluminum foil in the water for one minute and inspecting for an erosion pattern (evidence of cavitational activity). If the surface of the foil is not disrupted, continue to degas until the foil confirms ultrasonic activity.

Test components in the equipment described above. Place components randomly in basket or in a beaker. Baskets should be suspended off the bottom of the tank or contain stand off legs to keep it from setting directly on the bottom of the tank. If a beaker is to be used, it should be filled with deionized water and degassed as described in the above paragraph. The beaker should be suspended in the water-filled tank and not placed on the tank bottom.

Subject specimens to ultrasonics for a time period 10 times longer than the expected exposure anticipated under normal cleaning conditions or thirty minutes, whichever is longer.

5.1.3 (Optional) Conduct any environmental stressing test(s) as specified by the reliability requirement of the product line in concern.

5.2 **Evaluation Method**

5.2.1 Repeat the functional electrical test in 5.1.1. Any failures should be analyzed for cause of failure. Any failure, excluding those noted in 5.1.1 or attributable to a documented defect will also be considered caused by the ultrasonics.

5.2.2 Any defect which is not assignable to a previously documented defect will also be considered caused by ultrasonics.

5.2.3 Any component exhibiting no failures or 100% reliability after ultrasonic testing will be considered safely resistant to ultrasonics under the conditions tested. Any component with less than 100% reliability will be suspect unless subsequent testing can demonstrate that it is 100% reliable. Unless classified or proprietary, please report test results to the Ultrasonic Energy Task Group through the IPC for compilation in the attached list.

It is important that the IPC receives as much data as possible, whether it be to support previously submitted data, add new data, or provide conflicting data for certain components. All information received will be entered into a database for all IPC members to access. The data will prove more useful as the volume of data increases.
6.0 Notes  Contact IPC for a list of test components.

6.1 References


Ultrasonic Test Data Record

Name of tester ___________________________ Date __________________
Company __________________________________________________________
Address __________________________________________________________
Phone __________________ Fax __________________
Make and model of equipment _________________________________________
Tank size (liters) __________________ Dimensions (cm x cm x cm) __________
Generator output power (watts) __________________ Frequency (KHz) __________
No. of boards tested per trial __________________ Substrate ________________
Exposure time (minutes) __________________
Other stress testing (pre- or post-) __________________
Describe _________________________________

<table>
<thead>
<tr>
<th>Component tested</th>
<th>No. tested</th>
<th>Passed</th>
<th>Failed</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>Type</td>
<td>Mfr</td>
<td>Part #</td>
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Mail to: IPC
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Northbrook, IL 60062-6135
Attn: Ultrasonic Cleaning Task Group

Fax to: 847-509-9798
1.0 Scope  This non-destructive inspection method is needed to ascertain the following conditions:
   a. Innerlayer shift is within acceptable tolerances.
   b. One or more inner layers have not been reversed.
   c. Drilled holes are aligned with pads to the extent that any break-out is within acceptable tolerances.
   d. The minimum distance between a drilled hole and a ground plane clearance is within acceptable tolerances.

The test method will entail passing X-rays through the test specimen and converting the transmitted X-ray image into a visual image through the use of either X-ray film or a fluoroscopic (real time) device.

Cautionary notes:
The construction of the multilayer with respect to; number of layers, thickness of copper and presence other metals such as heat sinks (e.g. Invar), will determine the power and sensitivity of the X-ray apparatus which can be used. All X-ray apparatus should be registered with the appropriate state or regional Radiation Control agency. A radiation safety program should be implemented.

2.0 Applicable Documents
MIL-STD-883 Method 2012.5, Radiography

3.0 Test Specimen  The Test specimen shall be a multi-layer printed wiring board having a maximum size of 20 x 24 inches.

4.0 Apparatus or Material  (Ref. MIL-STD-883C).
The apparatus and materials for this test shall include:

4.1 A radiographic (X-ray) source for generating X-rays of sufficient voltage and power to penetrate the test specimen. The focal distance and focal spot size of the source shall be adequate to produce a well defined image of a 0.001 inch copper wire.

4.2 If film is the imaging medium  The film used is to be a fine grain single emulsion X-ray film with resolution capable of resolving a 0.001 copper wire and fray scale capable of detecting the shift of a single layer.

4.3 Film holder  A lead backed film holder to prevent back scatter of radiation.

4.4 Radiographic Viewer  Capable of 0.001 inches resolution.

4.5 Radiographic quality standards  Suitable Image Quality Indicator capable of verifying the ability to detect all specified defects.

4.6 Film processing means  Manual tray development or a film processor is to be used. If the film processor has a glove box and suitable film holders, a dark room is not required. If manual tray development is used, a dark room is required.

4.7 Silver film densitometer  Capable of measuring silver film density up to 3.0.

4.8 If a fluoroscopic (real time) X-ray inspection system is used, the X-ray image detecting device or x-ray camera should be capable of resolving a 0.001 copper wire and a gray scale capable of detecting the shift of a single layer of the specimen.

4.8.1 A means is to be provided for recording or making a hard copy of the fluoroscopic (real time) X-ray image.

4.9 Image Identification  Each radiographic image (film or real time) shall be identified with the following information:
   • Manufacturer’s name
   • Part number
   • Serial number (when applicable)
   • Date code (if marked on specimen)
   • View number
   • Reference code for x-ray procedures used.

5.0 Procedure
5.1 Preparation  Alignment of the X-ray beam center line, specimen inspection area and image detector field of view must be insured so that parallax distortion does not adversely effect the interpretation of the result. (See reference)
Parallax displacement distortion will be indicated when round holes appear oval or “cats eyed” on the X-ray image. For a hole drilled through a panel of thickness, $t$, and offset from the center of the X-ray beam axis by the angle $A$, the parallax displacement between the top and bottom of the hole will be equal to $tx_{\text{Tran}}A$.

5.2 Radiographic Quality Standard  A radiographic quality standard such as an ASTM Image Quality Indicator or other agreeable indicator shall be used on all radiographic studies.

5.3 Exposure when film is used  The necessary X-ray penetration exposure will depend on the construction of the multilayer, X-ray source anode voltage, the anode current, the distance from the source to the film plane and the speed or sensitivity of the film. The exposure should be sufficient to produce an optical density of at least 2.0 at those portions of the film receiving the highest X-ray exposure, such as, holes or unattenuated areas. In addition the conditions of paragraph 1.0 with respect to resolution and gray scale must be met. The exposure apparatus for film can consist of an industrial shielded X-ray cabinet with a nominal anode voltage of 80 kilovolts, nominal anode current of 3 milligrams and a focal spot to film distance adequate to avoid parallax distortion of the X-ray film image.

5.4 Exposure for realtime systems  The X-ray source operating parameters must be matched to the X-ray camera sensitivity of the system to produce an X-ray image of sufficient quality to comply with the conditions of paragraph 1.0.

6.0 Notes  None
1 Scope  This test method is to determine the resistance of the applied solder mask or conformal coating to reverting to liquid when exposed to high humidity at a specific temperature and time condition for each class. This test method is to evaluate the quality of the coated printed boards under storage conditions (non-operating).

2 Applicable Documents  None

3 Test Specimens  Approximately 102 mm x 102 mm copper sheet or copper clad laminate, coated with solder mask and/or conformal coating and cured, according to the coating supplier’s recommendations.

4 Apparatus

4.1 Reagent grade potassium sulfate

4.2 Desiccator, 25 cm diameter minimum

4.3 Cotton swabs

4.4 Test chamber (oven) capable of maintaining up to 100°C ± 1°C.

5 Procedure

5.1 Preparation

5.1.1 Prepare a saturated solution of distilled water and potassium sulfate (35 grams per 100 cc) at temperature of test as indicated in paragraph 5.1.5. Pour into desiccator to a level just below the ceramic plate. Crystals of potassium sulfate should remain visible in the saturated solution at the chamber operating temperature.

Note: RH is not to exceed 98%.

5.1.2 Clean the test specimen thoroughly using the coating supplier’s recommended solutions and procedures.

5.1.3 Coat the specimen with solder mask and/or conformal coating and cure according to the coating supplier’s recommended procedure.

5.1.4 Place the test specimen position on the ceramic plate (specimens shall not touch one another), seal the desiccator lid with silicone grease, and close desiccator.

5.1.5 Place the desiccator in the test chamber (oven), then preset at the following conditions:

<table>
<thead>
<tr>
<th>Class</th>
<th>Temperature</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>35°C ± 2°C</td>
<td>four days</td>
</tr>
<tr>
<td>2</td>
<td>85°C ± 2°C</td>
<td>seven days</td>
</tr>
<tr>
<td>3</td>
<td>97°C ± 2°C</td>
<td>28 days</td>
</tr>
</tbody>
</table>

For Conformal Coating

<table>
<thead>
<tr>
<th>Class</th>
<th>Temperature</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35°C ± 1°C</td>
<td>four days</td>
</tr>
<tr>
<td>2</td>
<td>85°C ± 2°C</td>
<td>seven days</td>
</tr>
<tr>
<td>3</td>
<td>85°C ± 2°C</td>
<td>120 days</td>
</tr>
</tbody>
</table>

5.2 Evaluation

5.2.1 After the required time exposure, remove test specimens and visually examine for chalking, blistering, cracking, and general degradation.

5.2.2 Touch the surface of the coating with a swab of absorbent cotton and observe for particles of the cotton adhering to the coating.

6 Notes  Examination and testing may be done at intervals between the test chamber time requirements, if there is suspicion of an early failure and evaluation time is critical.
1 Scope  This test method is to determine the resistance of the applied solder mask to reverting to liquid when exposed to high humidity at a specific time and temperature condition for each class. This test method is to evaluate the stability of the coated printed boards under storage (nonoperating) conditions.

2 Applicable Documents

IPC-SM-840  Qualification and Performance of Permanent Solder Mask

3 Test Specimens  Three copper clad or copper clad laminates, approximately 10 cm x 10 cm [3.94 in x 3.94 in], coated with solder mask and cured according to the supplier’s recommendations.

4 Equipment

4.1 Desiccator  At least 25 cm [9.84 in] in diameter

4.2 Potassium Sulfate  Reagent grade potassium sulfate

4.3 Cotton Swabs

4.4 Oven  Capable of maintaining temperature up to 100°C [212°F]

4.5 Test Chamber  Capable of maintaining a constant temperature of 97° ± 2°C [206.6° ± 3.6°F] with 94 ± 4% relative humidity.

4.6 High Temperature Silicone Grease

5 Procedures

5.1 Desiccator Method

5.1.1 Prepare a saturated solution of distilled or deionized water and potassium sulfate [35 grams per 100 cm³] at a temperature of 97° ± 2°C [206.6° ± 3.6°F]. Pour the solution into the desiccator just below the ceramic plate. Crystals of potassium sulfate should remain visible in the saturated solution during testing.

Note: Relative humidity is not to exceed 98%.

5.1.2 Place the three test specimens on the ceramic plate in the desiccator so that they are not touching each other.

5.1.3 Seal the desiccator with high temperature silicone grease and close the desiccator.

5.1.4 Place the desiccator in the oven maintained at 97° ± 2°C [206.6° ± 3.6°F].

5.1.5 Allow the desiccator, containing the test specimens, to remain in the oven for 28 days.

5.2 Chamber Method

5.2.1 Place the three test specimens into the test chamber, by placing them in a rack so that they do not touch each other. Close the chamber door.

5.2.2 Set the chamber’s parameters at 97° ± 2°C [206.6° ± 3.6°F] and 95 ± 4% relative humidity. Activate the test chamber and begin testing.

5.2.3 Allow the specimens to remain in the test chamber for 28 days.

5.3 Evaluation

5.3.1 After the required time exposure, remove the test specimens and visually examine the specimens for evidence of reversion as indicated by softening, chalking, blistering, cracking, tackiness, loss of adhesion or liquefaction.

5.3.2 Touch the surface of the solder mask coating with a swab of absorbent cotton and observe for particles of the cotton adhering to the coating.

Note: Examination and testing may be done at intervals within the required exposure time, if there is suspicion of early failure and evaluation time is critical.
1 Scope  This test method is to determine the resistance of the applied conformal coating to reverting to liquid when exposed to high humidity at a specific temperature and time condition for each class. This test method is to evaluate the quality of the coated printed boards under storage conditions (nonoperating).

2 Applicable Documents
IPC-CC-830  Qualification and Performance of Electrical Insulating Compound for Printed Board Assemblies
FED-STD-141  Method 4061 (Dry-Through For Varnish, Lacquers And Enamels)

3 Test Specimens  Five coated “Y” shape patterns (see Figure 1) containing two resistors, one with marking ink and one with color code bars, coated with conformal coating per the coating supplier’s recommendations.

4 Equipment
4.1 Desiccator  At least 25 cm [9.84 in] in diameter
4.2 Potassium Sulfate  Reagent grade potassium sulfate
4.3 Cotton Swabs
4.4 Oven  Capable of maintaining temperature up to 100°C [212°F].
4.5 Test Chamber  Capable of maintaining a constant temperature of 85° ± 2°C [185° ± 3.6°F] with 95 ± 4% relative humidity
4.6 Soldering Iron  If applicable
4.7 High Temperature Silicone Grease

5.0 Procedures

5.1 Desiccator Method
5.1.1 Prepare a saturated solution of distilled or deionized water and potassium sulfate (35 grams per 100 cm$^3$) at a temperature of 85° ± 2°C [185° ± 3.6°F]. Pour the solution into the desiccator just below the ceramic plate. Crystals of potassium sulfate should remain visible in the saturated solution during testing.

Note: Relative humidity is not to exceed 98%.

5.1.2 Place four of the five test specimens on the ceramic plate in the desiccator so that they are not touching each other. The fifth specimen is used as a control.

5.1.3 Seal the desiccator with high temperature silicone grease and close the desiccator.

5.1.4 Place the desiccator in the oven maintained at 85° ± 2°C [185° ± 3.6°F].

5.1.5 Allow the desiccator, containing the test specimens, to remain in the oven for 120 days.
5.2 Evaluation

5.2.1 During testing, examine the test specimens at 28th, 56th and 84th days. Prior to examining the test specimens, they shall be returned to 25°C [77°F] and 50% relative humidity for two hours. Evaluate the specimens for evidence of reversion as indicated by softening, chalking, blistering, cracking, tackiness, loss of adhesion or liquefaction. Evaluate also legibility of the markings on the board and/or the resistors.

5.2.2 After the 120-day aging period, the panels shall be returned to 25°C [77°F] and 50% relative humidity and held for seven days. The specimens shall be evaluated and compared with the control specimen as per 5.2.1. The specimens shall also be tested for tackiness in accordance with Method 4061 (Dry-Through For Varnish, Lacquers And Enamels) of FED-STD-141.

5.3 Chamber Method

5.3.1 Place four of the five test specimens into the test chamber, by placing them in a rack or hanging, so that they do not touch each other. The fifth specimen is held as a control. Close the chamber door.

5.3.2 Set the chamber’s parameters at 85° ± 2°C [185° ± 3.6°F] and 95 ± 4% relative humidity. Activate the test chamber and begin testing.

5.3.3 Allow the specimens to remain in the test chamber for 120 days.

5.4 Evaluation

5.4.1 During testing, examine the test specimens at 28th, 56th and 84th days. Prior to examining the test specimens, they shall be returned to 25°C [77°F] and 50% relative humidity for two hours. Evaluate the specimens for evidence of reversion as indicated by softening, chalking, blistering, cracking, tackiness, loss of adhesion or liquefaction. Evaluate also legibility of the markings on the board and/or the resistors.

5.4.2 After the 120-day aging period, the panels shall be returned to 25°C [77°F] and 50% relative humidity and held for seven days. The specimens shall be evaluated and compared with the control specimen as per 5.2.1. The specimens shall also be tested for tackiness in accordance with Method 4061 (Dry-Through For Varnish, Lacquers And Enamels) of FED-STD-141.
1 Scope  This test method describes the procedure for temperature testing of flat cable.

2 Applicable Documents  None

3 Test Specimen

3.1 The number of production samples and length should be determined by the manufacturer and/or user and shall be a minimum of one specimen and a minimum length of 3 m.

4 Equipment/Apparatus

4.1 Forced convection test chamber(s) capable of being maintained at the specimen rated high and low temperatures

5 Procedure

5.1 The specimen shall be placed in a forced convection oven at the elevated temperature. After four hours of exposure, the specimen shall be placed in a test chamber at the low rated temperature (the transfer time shall be a maximum of five minutes between temperature extremes). The specimen shall be removed from the cold chamber and allowed to stabilize at room temperature.

5.2 The procedure in 5.1 constitutes one cycle. The specimen shall be subjected to 12 cycles.

5.3 Evaluation  There shall be no cracking of the specific cable.
1.0 Scope  This test method will demonstrate a relative degree to which uncoated printed wiring boards are susceptible to dendritic growth due to the presence of ionic residues and condensed moisture. This test method is particularly suitable for printed wiring board manufacturing process control.

2.0 Applicable Documents

IPC-TR-476  How to Avoid Metallic Growth Problems on Electronic Hardware
MIL-P-55110  Printed Wiring Boards

3.0 Test Specimens  Test pattern is chosen from, but not restricted to e.g., MIL-P-55110 type “Y” pattern with a pair of conductors having typically 15-30 mils separation (See Figure 1). A pair of parallel conductors on an uncoated production printed wiring board, with spacing between conductors of approximately 15-30 mils is suitable as well.

4.0 Equipment/Apparatus

4.1 Power Supply  A dc power supply capable of providing a metered 0-20 V dc, and 100 milliamps current.

4.2 Microscope  50-100 power microscope and means of providing direct and/or indirect lighting on specimen.

4.3 Miscellaneous Items  DI water sample (2 oz.) kept in a plastic bottle, eye dropper, a 1/2 watt-10K ohm current limiting resistor and a stop watch.

5.0 Procedure

5.1 Preparation

5.1.1 Attach a wire to each of the conductors on the “Y” pattern test board, or to corresponding, parallel conductors on a production PWB.

5.1.2 Connect a 10K resistor in series to the power supply as shown in Figure 1. The resistor will limit the current to 1.5 milliamp maximum.

5.1.3 Place the board for viewing on the microscope, so that the parallel conductors are in view. Provide lighting that will illuminate the test board on top and/or underneath.

5.1.4 Using the eye dropper, place a drop of DI water across the conductors that are in view under the microscope, at least 0.5 inch away from the place where external wires are attached to parallel conductors. Adjust power supply to 15 V and turn the power supply on. Simultaneously start the stopwatch.

5.1.5 Carefully observe the action using the microscope. Adjust the power of the microscope so the entire water area is in view.

5.1.6 Bubbles may appear within about 5 seconds. This is hydrogen evolution-electrolysis of water.

5.1.7 Depending on PWB ionic cleanliness level and the characteristics of the PWB surface, there may be a dendritic (tree-like) growth from the negative to positive conductor, appearing within a typical (for a given board) but generally very broad time span of a few seconds to several minutes.

5.1.8 The condition of dendritic growth is much easier to observe with an artificial light source placed under the test board. A clear demonstration of the dendritic growth can be performed if tap water containing ionic contamination is used in place of DI water (see paragraph 5.1.4).

5.1.9 Once the dendritic growth has reached the positively charged conductor, most action will cease; turn off the stopwatch. The elapsed time is a relative measure of susceptibility of the PWB in question to undergo dendritic growth under high humidity (condensed moisture) environment. At least ten
separate measurements are needed to obtain a statistically meaningful result.

6.0 PWB Process Test/Sampling For testing of lot conformity at least ten different PWBs with parallel conductors as per Section 3 shall be tested.

7.0 Test Interpretation Test for susceptibility to metallic dendritic growth is a relative measure of localized ionic residue levels. As such, it does not have direct relationship with absolute PWB reliability measure. The results of this test are found useful in the PWB process control by testing board-to-board and lot-to-lot variations.
1 Scope  This test method is to determine the ability of a polymer solder mask protective coating to withstand an environment conducive to electrochemical migration.

2 Applicable Documents

IPC-SM-840  Qualification and Performance of Permanent Solder Mask
IPC-TR-476  Electrochemical Migration: Electrically Induced Failures in Printed Wiring Assemblies
J-STD-004  Requirements for Soldering Fluxes

3 Test Specimens

3.1 Qualification Testing  Three IPC-B-25A boards (See Figure 1) using the D comb patterns with 0.318 mm [12.50 mil] lines/spaces for both Classes T and H, coated with solder mask according to the solder mask supplier’s recommendations.

3.2 Conformance Testing  Three IPC-B-25A boards (see Figure 1) using the C comb pattern (“Y” shape pattern) which should be 0.635 mm lines/0.635 mm spacing [25.00 mil lines/25.00 mil spaces] or the minimum spacing on the production board, whichever is smaller, coated with solder mask according to the solder mask supplier’s recommendations.

4 Equipment/Apparatus

4.1 Power Supply  Capable of supplying 10 ± 0.5 VDC at 1 amp, maximum.

4.2 Oven  Capable of maintaining up to 90 ± 1°C [194° ± 1.8°F].

4.3 Chamber  Capable of maintaining 85° ± 2°C [185° ± 3.6°F] with 85%, minimum, relative humidity.

4.4 Desiccator  25 cm [9.84 in] diameter minimum, with openings for the connecting wires to pass through while maintaining a hermetic seal.

4.5 Potassium Sulfate  Reagent Grade potassium sulfate.

4.6 RTV  Dow Corning 732 RTV potting compound or equivalent.

4.7 Resistors  10 megohm resistor for Class H testing and 1 megohm resistors for Class T testing

4.8 Magnifier  Capable of supplying 10X magnification

4.9 Soldering Iron

4.10 Flux  Water white rosin (R or RMA) with halide content less than 0.5%, i.e., type Symbol A and B or ROL0 and ROL1 according to J-STD-004.

5 Test Conditions

5.1.1 Class T  85° ± 2°C [185° ± 3.6°F] with 85% relative humidity minimum, 10 VDC bias, for 500 hours (21 days)

5.1.2 Class H  85° ± 2°C [185° ± 3.6°F] with 90% relative humidity, 10 VDC bias for 168 hours (seven days)
5.2 Specimen Preparation

5.2.1 Positive, permanent and noncontaminating identification of the test specimens is of paramount importance.

5.2.2 Visually inspect the test specimens for any obvious defects, as described in the IPC-A-600. If there is any doubt about the overall quality of any test specimen, the test specimen should be discarded.

5.3 Electrical Connections (Both Classes)

5.3.1 For qualification testing, solder single strand PTFE insulated wires or equivalent to the lands of each of the D test patterns using an off-contact shield to protect the patterns from flux spitting. These wires will be used to connect the test specimen to the bias voltage or resistance meter. Test points 1, 3 and 5 are to be connected to the positive terminal and test points 2 and 4 are to the negative terminal of resistance meter or power supply. When resistors are used, they are to be connected between test points 1, 3 and 5 and the positive terminal of power supply.

5.3.2 For conformance testing, solder single strand PTFE insulated wires or equivalent in each of the connecting points of the C pattern using an off-contact shield to protect the patterns from flux spitting. These wires will be used to connect the test specimen to the bias voltage or resistance meter. One side of the pattern should be connected to the positive terminal and the other side to the negative terminal of resistance meter or power supply. When resistors are used, they are to be connected between the pattern and the positive terminal of power supply.

5.3.3 The flux shall not be removed from the test specimens.

5.4 Procedures

5.4.1 Desiccator Test Method

5.4.2 Take insulation resistance measurements of the test specimens using 10 VDC, prior to testing. This step will ensure that the resistance measurements are sufficient to proceed with testing.

5.4.3 Prepare a saturated solution of distilled water and potassium sulfate (approximately 35g per 100 cm³) at a temperature of 85°C [185°F]. Pour the solution into the desiccator just below the ceramic plate. Crystals of potassium sulfate should remain visible in the saturated solution in the oven at operating temperature.

5.4.4 Place the test specimens into the desiccator, such that they do not touch one another. Route the connecting wires to the outside of the desiccator and seal with Dow Corning 732 RTV potting compound or equivalent.

5.4.5 Place the desiccator into an oven maintained at 85°C [185°F]. For the remaining test procedures, see 5.5.4 to 5.6.2 for Class H and 5.7.4 to 5.8.4 for Class T.

5.5 Class H - Test Chamber Method

5.5.1 Prior to testing, take insulation resistance measurements of the test specimens using 10 VDC. This step will ensure that the resistance measurements are sufficient to proceed with testing.

5.5.2 Place the specimens into the test chamber and route the wires through the porthole of the test chamber and seal, if necessary.

5.5.3 Set the chamber’s parameters for 85°C [185°F] with 90% relative humidity. Close the chamber doors and activate the test chamber.

5.5.4 Connect the correct test points as specified in 5.3.1 and 5.3.2 to a 10-megohm resistor before the positive terminal of power supply. (See Figure 2 for configuration for qualification testing.) Apply the bias voltage of 10VDC.

5.5.5 Allow the test specimens to remain in the test chamber for the duration of 168 hours (seven days).

5.5.6 Upon completion of the 168 hours, stop the test chamber and allow the test specimens to return to laboratory ambient conditions.
5.6 Measurements/Evaluation

5.6.1 Upon specimen stabilization at laboratory ambient temperature, take the resistance measurements, as specified in 5.5.1, with 10 VDC and record.

5.6.2 Examine the test specimens with 10X magnification with backlighting for electrochemical migration.

5.7 Class T - Test Chamber Method

5.7.1 Prior to testing, take insulation resistance measurements of the test specimens using 45 - 100 VDC. This step will ensure that the resistance measurements are sufficient to proceed with testing.

5.7.2 Place the test specimens into the test chamber and route the wires through the porthole of the test chamber and seal, if necessary.

5.7.3 Set the chamber’s parameters for 85°C [185°F] with 85% relative humidity minimum. Close the chamber doors and activate the test chamber.

5.7.4 Allow the test specimens to stabilize at test conditions for 96 hours (four days).

5.7.5 After the 96-hour (four days) stabilization period at test conditions, take measurements of initial insulation resistance as specified in 5.7.1 with 45 - 100 VDC.

5.7.6 After obtaining the measurements, connect each test point as specified in 5.3.1 and 5.3.2 to a 1-megohm resistor before the positive terminal of power supply. (See Figure 3 for configuration of qualification testing.) Apply the bias voltage of 10 VDC. The test polarity shall be the same as the measurement polarity stated in 5.7.1.

5.7.7 Allow the specimens to remain in the test chamber an additional 404 hours (500 hours total test time).

5.8 Measurements/Evaluations

5.8.1 Upon completion of the 500 hours (21 days), disconnect the power supply and repeat the measurements as stated in 5.7.5 with the specimens under test conditions.

5.8.2 The chamber is then turned off and the specimens are removed from the test chamber and visually inspected with backlighting at 10X magnification for electrochemical migration.

5.8.3 The individual resistance measurements obtained at 96 hours and 500 hours shall be averaged using the following calculation. These initial and final average insulation resistance readings shall then be reported.

\[
IR_{\text{avg}} = 10 \left[ \frac{1}{N} \sum_{i=1}^{N} \log IR_i \right]
\]

Where:

\(N\) = Number of test points (12 nominal)
\(IR_i\) = Individual insulation resistance measurements

5.8.4 Where an assignable cause can be found, exceptionally low insulation resistance readings can be excluded from calculating the average value, provided that 11 (of the original 12) measurements are included in the average. Such assignable causes are attributable to the laminate itself or to the process used to produce the PWB. They include:

a. Contamination on the insulating surface of the board such as lint, solder splines, or water droplets from the conditioning chamber.

b. Incompletely etched patterns that decrease the insulating space between conductors by more than the amount allowed in the appropriate design requirements drawing.

c. Scratched, cracked or obviously damaged insulation between conductors.

6 Notes

6.1.1 Protective coatings are helpful in preventing electrochemical migration, but there is no assurance that the protection is complete unless the coating is adequately bonded to a good clean board.
1 Scope  This test method is to determine the ability of a polymer solder mask protective coating to withstand an environment conducive to electrochemical migration.

2 Applicable Documents

IPC-SM-840  Qualification and Performance of Permanent Solder Mask

IPC-TR-476  Electrochemical Migration: Electrically Induced Failures in Printed Wiring Assemblies

J-STD-004  Requirements for Soldering Fluxes

3 Test Specimens

3.1 Qualification Testing Three IPC-B-25A boards (See Figure 1) using the D comb patterns with 0.318 mm [12.50 mil] lines/spaces for both Classes T and H, coated with solder mask according to the solder mask supplier’s recommendations.

3.2 Conformance Testing Three IPC-B-25A boards (see Figure 1) using the C comb pattern ("Y" shape pattern) which should be 0.635 mm lines/0.635 mm spacing [25.00 mil lines/25.00 mil spaces] or the minimum spacing on the production board, whichever is smaller, coated with solder mask according to the solder mask supplier’s recommendations.

4 Equipment/Apparatus

4.1 Power Supply Capable of supplying 10 ± 0.5 VDC at 1 amp, maximum.

4.2 Oven Capable of maintaining up to 90 ± 1°C [194° ± 1.8°F].

4.3 Chamber Capable of maintaining 85° ± 2°C [185° ± 3.6°F] with 85%, minimum, relative humidity.

4.4 Desiccator 25 cm [9.84 in] diameter minimum, with openings for the connecting wires to pass through while maintaining a hermetic seal.

4.5 Potassium Sulfate Reagent Grade potassium sulfate.

4.6 RTV Dow Corning 732 RTV potting compound or equivalent.

4.7 Resistors 10 megohm resistor for Class H testing and 1 megohm resistors for Class T testing

4.8 Magnifier Capable of supplying 10X magnification

4.9 Soldering Iron

4.10 Flux Water white rosin (R or RMA) with halide content less than 0.5%, i.e., type Symbol A and B or ROL0 and ROL1 according to J-STD-004.

5 Test Conditions

5.1.1 Class T  85° ± 2°C [185° ± 3.6°F] with 85% relative humidity minimum, 10 VDC bias, for 500 hours (21 days)

5.1.2 Class H  85° ± 2°C [185° ± 3.6°F] with 90% relative humidity, 10 VDC bias for 168 hours (seven days)
5.2 Specimen Preparation

5.2.1 Positive, permanent and noncontaminating identification of the test specimens is of paramount importance.

5.2.2 Visually inspect the test specimens for any obvious defects, as described in the IPC-A-600. If there is any doubt about the overall quality of any test specimen, the test specimen should be discarded.

5.3 Electrical Connections (Both Classes)

5.3.1 For qualification testing, solder single strand PTFE insulated wires or equivalent to the lands of each of the D test patterns using an off-contact shield to protect the patterns from flux spitting. These wires will be used to connect the test specimen to the bias voltage or resistance meter. Test points 1, 3 and 5 are to be connected to the positive terminal and test points 2 and 4 are to the negative terminal of resistance meter or power supply. When resistors are used, they are to be connected between test points 1, 3 and 5 and the positive terminal of power supply.

5.3.2 For conformance testing, solder single strand PTFE insulated wires or equivalent in each of the connecting points of the C pattern using an off-contact shield to protect the patterns from flux spitting. These wires will be used to connect the test specimen to the bias voltage or resistance meter. One side of the pattern should be connected to the positive terminal and the other side to the negative terminal of resistance meter or power supply. When resistors are used, they are to be connected between the pattern and the positive terminal of power supply.

5.3.3 The flux shall not be removed from the test specimens.

5.4 Procedures

5.4.1 Desiccator Test Method

5.4.2 Take insulation resistance measurements of the test specimens using 10 VDC, prior to testing. This step will ensure that the resistance measurements are sufficient to proceed with testing.

5.4.3 Prepare a saturated solution of distilled water and potassium sulfate (approximately 35g per 100 cm³) at a temperature of 85°C [185°F]. Pour the solution into the desiccator just below the ceramic plate. Crystals of potassium sulfate should remain visible in the saturated solution in the oven at operating temperature.

5.4.4 Place the test specimens into the desiccator, such that they do not touch one another. Route the connecting wires to the outside of the desiccator and seal with Dow Corning 732 RTV potting compound or equivalent.

5.4.5 Place the desiccator into an oven maintained at 85°C [185°F]. For the remaining test procedures, see 5.5.4 to 5.6.2 for Class H and 5.7.4 to 5.8.4 for Class T.

5.5 Class H - Test Chamber Method

5.5.1 Prior to testing, take insulation resistance measurements of the test specimens using 10 VDC. This step will ensure that the resistance measurements are sufficient to proceed with testing.

5.5.2 Place the specimens into the test chamber and route the wires through the porthole of the test chamber and seal, if necessary.

5.5.3 Set the chamber’s parameters for 85°C [185°F] with 90% relative humidity. Close the chamber doors and activate the test chamber.

5.5.4 Connect the correct test points as specified in 5.3.1 and 5.3.2 to a 10-megohm resistor before the positive terminal of power supply. (See Figure 2 for configuration for qualification testing.) Apply the bias voltage of 10VDC.

5.5.5 Allow the test specimens to remain in the test chamber for the duration of 168 hours (seven days).

5.5.6 Upon completion of the 168 hours, stop the test chamber and allow the test specimens to return to laboratory ambient conditions.
5.6 Measurements/Evaluation

5.6.1 Upon specimen stabilization at laboratory ambient temperature, take the resistance measurements, as specified in 5.5.1, with 10 VDC and record.

5.6.2 Examine the test specimens with 10X magnification with backlighting for electrochemical migration.

5.7 Class T - Test Chamber Method

5.7.1 Prior to testing, take insulation resistance measurements of the test specimens using 45 - 100 VDC. This step will ensure that the resistance measurements are sufficient to proceed with testing.

5.7.2 Place the test specimens into the test chamber and route the wires through the porthole of the test chamber and seal, if necessary.

5.7.3 Set the chamber’s parameters for 85°C [185°F] with 85% relative humidity minimum. Close the chamber doors and activate the test chamber.

5.7.4 Allow the test specimens to stabilize at test conditions for 96 hours (four days).

5.7.5 After the 96-hour (four days) stabilization period at test conditions, take measurements of initial insulation resistance as specified in 5.7.1 with 45 - 100 VDC.

5.7.6 After obtaining the measurements, connect each test point as specified in 5.3.1 and 5.3.2 to a 1-megohm resistor before the positive terminal of power supply. (See Figure 3 for configuration of qualification testing.) Apply the bias voltage of 10VDC. The test polarity shall be the same as the measurement polarity stated in 5.7.1.

5.7.7 Allow the specimens to remain in the test chamber an additional 404 hours (500 hours total test time).

5.8 Measurements/Evaluations

5.8.1 Upon completion of the 500 hours (21 days), disconnect the power supply and repeat the measurements as stated in 5.7.5 with the specimens under test conditions.

5.8.2 The chamber is then turned off and the specimens are removed from the test chamber and visually inspected with backlighting at 10X magnification for electrochemical migration.

5.8.3 The individual resistance measurements obtained at 96 hours and 500 hours shall be averaged using the following calculation. These initial and final average insulation resistance readings shall then be reported.

\[
IR_{\text{avg}} = 10^{\frac{1}{N} \sum_{i=1}^{N} \log IR_i}
\]

Where:

N = Number of test points (12 nominal)

IR_i = Individual insulation resistance measurements

5.8.4 Where an assignable cause can be found, exceptionally low insulation resistance readings can be excluded from calculating the average value, provided that 11 (of the original 12) measurements are included in the average. Such assignable causes are attributable to the laminate itself or to the process used to produce the PWB. They include:

a. Contamination on the insulating surface of the board such as lint, solder splines, or water droplets from the conditioning chamber.

b. Incompletely etched patterns that decrease the insulating space between conductors by more than the amount allowed in the appropriate design requirements drawing.

c. Scratched, cracked or obviously damaged insulation between conductors.

6 Notes

6.1.1 Protective coatings are helpful in preventing electrochemical migration, but there is no assurance that the protection is complete unless the coating is adequately bonded to a good clean board.
1 Scope This test method provides a means to assess the propensity for surface electrochemical migration. This test method can be used to assess soldering materials and/or processes.

2 Applicable Documents

2.1 IPC
- IPC-B-25 Multipurpose Test Board
- IPC-B-25A Multipurpose Test Board
- IPC-6012A Qualification and Performance Specification for Rigid Printed Boards
- IPC-9201 Surface Insulation Resistance Handbook

2.1 American Society for Testing and Materials (ASTM)
- ASTM D-257-93 Standard Test Methods for DC Resistance or Conductance of Insulating Materials

3 Test Specimens IPC-B-25 (B or E pattern) or IPC-B-25A (D pattern) test boards shall be used, with conductor line widths and spacings of 0.318 mm [0.01250 in]. The method of manufacture should provide optimized conductor edge definition (refer to the Class 2 and 3 conductor width requirements in IPC-6012). The finished test boards should be untreated, bare copper, unless another surface finish is part of the evaluation. Figure 1 shows the IPC-B-25A test board; the D pattern is identical to the IPC-B-25 B or E pattern. For process evaluation, the test pattern board should be made using the same substrate material as will be used in practice to duplicate actual working conditions.

4 Equipment/Apparatus

4.1 Test Chamber A temperature/humidity chamber capable of producing an environment of 40°C ± 2°C [104 ± 3.6°F], 93% ± 2% RH, 65°C ± 2°C [149 ± 3.6°F], 88.5% ± 3.5% RH, or 85°C ± 2°C [185 ± 3.6°F], 88.5% ± 3.5% RH and allowing test boards to be electrically biased and measured without being opened under these temperature and humidity conditions is used.

4.2 Measuring Equipment High resistance measuring equipment, equivalent to that described in ASTM D-257-93, with a range up to $10^{12}$ ohm and capable of yielding an accuracy of ± 5% at $10^{10}$ ohm with an applied potential of 100 VDC (10% tolerance); standard resistors should be used for routine calibration.

4.3 Power Supply Equipment capable of providing 10 VDC at 100 µA, with a 10% tolerance, shall be used.

4.4 Current-Limiting Resistors Use one $10^6$ ohm resistor in each current path. This equates to three current-limiting resistors for each 5-point comb pattern. Note that some test equipment has the current limiting resistors built into the testing system.

4.5 Connecting Wire Use PTFE-insulated, solid-conductor, copper wire, or equivalent. (See IPC-9201 Surface Insulation Resistance Handbook.)
4.6 Other Dedicated Fixtures  Hardwiring is the default connection method. Other dedicated fixtures may be used, provided that the fixture does not change the resistance for more than 0.1 decade compared to a comparable hardwired system, when measured at the test conditions.

5 Procedure

5.1 Test Specimen Preparation

5.1.1 In performing a material qualification (e.g., flux), all specimens are to be cleaned and dried using a process capable of yielding a minimum insulation resistance value of $4 \times 10^{12}$ ohm when tested at 35°C, 85% minimum RH after 24 hours. If this test is being performed as a process qualification, additional pre-test processing is not allowed.

5.1.2 A minimum of three test specimens cleaned per 5.1.1 shall be used for controls.

5.1.3 For liquid flux:

Apply the liquid flux to the entire surface of the test specimen by brushing liberal quantities of the flux onto the specimen, by floating the specimen comb side down on the liquid flux, or by dipping the specimen into the flux. The specimen shall be drained vertically for one minute with the fingers of the comb pattern vertical. Alternatively, flux may be applied by production application processes - spray, foam, or wave. The edge connector fingers should be protected from flux.

It is recommended that production wave soldering equipment be used for soldering the test specimens, with a preheat profile representative of production. A solder fountain may be used (not a solder pot), with a residence time similar to the residence time in a solder wave. Solder composition is usually 60% tin ± 5%, remainder is lead; for such alloys, the solder temperature shall be 250°C ± 6°C [482 ± 10.8°F]. For alloys other than those with compositions near the tin-lead eutectic, the solder temperature will be compatible with the usual soldering temperature for the alloy used.

If any solder bridging occurs, that specimen shall be discarded. A minimum of three specimens from the sample group shall be tested.

5.1.4 For solder paste:

A squeegee or screen printer shall be used with a stencil imaged with the test pattern. It should be noted that the Telcordia GR-78 pattern requires a minimum stencil thickness of 0.20 mm [7.9 mil]. Due to the fact that the minimum stencil thickness is often dependent on the pitch or trace width and spacing, a smaller stencil thickness may be used for fine features and shall be agreed upon between the tester and customer for the purpose of this test method.

Reflow the printed specimens using convection, infrared, or vapor phase reflow equipment using a reflow profile representative of production. Equivalent methods may be used if such equipment is not available.

If any solder bridging occurs, that specimen shall be discarded. The edge connector fingers should be protected from paste.

A minimum of three specimens from the sample group shall be tested.

5.1.5 For flux-cored wires:

Using a hand soldering iron and the cored wire under test, carefully apply solder to the fingers of all comb patterns. The edge connector fingers should be protected from flux.

If any solder bridging occurs, that specimen shall be discarded.

A minimum of three specimens from the sample group shall be tested. Each circuit path will be tested for the presence of solder shorts using a resistance meter (e.g. digital multimeter).

5.1.6 Post solder cleaning shall be performed only when such cleaning is part of the production process used in the final assembly.

5.1.7 When evaluating incoming board quality and/or final finishes, test specimens shall be used as received or as specified by the end user.

5.1.8 Attach test leads to the land areas of all patterns either by mechanical pressure (e.g., edge connectors, spring-loaded pins) or by hand soldering using Rosin (R) cored wire, using a shield to protect the test patterns from flux contamination during soldering; the flux shall not spread into the pattern area. Do not remove the flux.

5.2 Test Procedure

5.2.1 Place the terminated test specimens in a suitable rack that maintains the specimens at least 2.5 cm apart and such that the air flow is parallel to the direction of the test specimens in the chamber. For hardwiring, wires should be
dressed from the bottom to prevent flux residues from the wire attachment from flowing onto the test patterns. With mechanical fixtures, fixtures should be to the side. Insert the limiting resistors in terminating leads 1, 3, and 5 of each pattern.

5.2.2 Place the rack approximately in the center of the test chamber. Route the wires to the outside of the chamber; dress the wiring away from the test patterns. Ensure that drops of condensation cannot fall on the specimens.

5.2.3 Close the chamber and allow all samples to stabilize for 96 hours at the specific temperature and humidity. After the 96-hour stabilization period, the initial insulation resistance measurements shall be made using voltage in the range of 45 VDC to 100 VDC. Due to polarity, measurements should be made between terminals 1 and 2, 3 and 2, 3 and 4, and 5 and 4, at the specific temperature and humidity with the current limiting resistors placed in series with the test circuit. Terminals 2 and 4 shall be at one potential, and terminals 1, 3, and 5 at the opposite potential.

5.2.4 Connect the samples to the power supply with the current limiting resistors placed in series with the test circuit, and apply 10 VDC for the duration of the test. The test polarity shall be the same as the measurement polarity used in section 5.2.3.

5.2.5 After 500 hours of applied bias (596 hours total), disconnect the power supply and repeat the measurements per 5.2.3 with the specimens under test conditions.

5.3 Data Handling The average (geometric mean) insulation resistance (IR_{avg}) is calculated from:

\[
IR_{avg} = 10^{\left(\frac{1}{N} \sum_{i=1}^{N} \log IR_i\right)}
\]

where,

N = number of test points (10 minimum),

IR_i = individual insulation resistance measurements

Where an assignable cause of low insulation resistance, which is properly attributable to the materials of construction or to the process used to produce the test board, can be found, then such a value can be excluded from calculating the average.

Such assignable causes include:

- Contamination on the insulating surface of the board, such as debris, solder splints, or water droplets from the conditioning chamber
- Incompletely etched patterns that decrease the insulating space between conductors by an amount greater than that allowed in the appropriate design requirements drawing
- Scratched, cracked, or obviously damaged insulation between conductors

A minimum of 10 test measurements is required for the test to be valid.

5.4 Visual Examination After completion of the test, the test specimens shall be removed from the test chamber and examined, with back-lighting, at 10x magnification for evidence of electrochemical migration (filament growth), discoloration, and corrosion.

Note: Localized electrochemical migration on one comb may be caused by a testing anomaly.

6 Notes

6.1 Reference Documents

6.1.1 IPC-TR-476A Electrochemical Migration: Electrically Induced Failures in Printed Wiring Assemblies

6.1.2 IPC-9201 Surface Insulation Resistance Handbook

6.1.3 Telcordia GR-78-CORE

6.2 Specification of Test Conditions Users of this test method will need to specify one (1) of the three (3) temperature/humidity conditions called out in section 4.1. Note that IPC-TR-476A recommends using 65°C, 85% RH.
1.0 Scope  This test method is designed to determine the corrosive properties of flux residues under extreme environmental conditions. A pellet of solder is melted in contact with the test flux on a sheet metal test piece. The solder is then exposed to prescribed conditions of humidity and the resulting corrosion, if any, is assessed visually.

2.0 Applicable Documents

2.3.34  Solids Content, Flux
British Standard Institute BS5625  Specification of Purchasing Requirements and Methods of Test for Fluxes for Soft Soldering

3.0 Test Specimen  At least 0.035 g of flux solids, 1 g solder paste, 1 g wire, or 1 g preform with an equivalent amount of solids. Flux solids are defined as the residue from the solids content, fluxes test described in IPC-TM-650, Test Method 2.3.34. All solvent must have been evaporated from the specimen in a chemical fume hood.

4.0 Apparatus and Reagents

1. Solder pot
2. Humidity chamber capable of achieving 50 ±2°C and 95 ± 2% relative humidity.
3. Air circulating drying oven
4. Microscope having 20X minimum
5. Chemicals: All chemicals must be reagent grade and water must be distilled or demineralized:
   a. Ammonium persulphate
   b. Sulfuric acid, % v/v
   c. Degreasing agent, Acetone, Toluene, or Petroleum ether.
6. Analytical balance capable of weighing 0.001 g

5.0 Procedures

5.1 Preparation

5.1.1 Chemicals

5.1.1.1 Ammonium persulphate (25% m/v in 0.5% v/v sulfuric acid). Dissolve 250 g of ammonium persulphate in water and add cautiously 5 ml of 5% sulphuric acid (relative density 1.84). Mix, cool, dilute to 1 liter and mix. This solution should be freshly prepared.

5.1.1.2 Sulfuric acid (5% v/v). To 400 ml of water cautiously add 50 ml of sulfuric acid (relative density 1.84). Mix, cool, dilute to 1 liter and mix.

5.1.2 Test Panel

5.1.2.1 Cut a 0.50 ±0.05 mm thick piece of 99% pure copper 51 mm x 51 mm for each test.

5.1.2.2 Form a circular depression in the center of each test panel 3.2 mm deep by forcing a 19 mm steel ball into a 25.4 mm hole to form a cup.

5.1.2.3 Bend one corner of each test panel up to facilitate subsequent handling with tongs.

5.1.3 Pre-treating Test Panels

5.1.3.1 Immediately before performing test, pretreat as follows using clean tongs for handling.
   A. Degrease with a suitable neutral organic solvent such as acetone, toluene, or petroleum ether.
   B. Immerse in 5% sulfuric acid (by volume) at 65 ±5°C for 1 minute to remove the tarnish film.
   C. Immerse in a solution of 25% m/v ammonium persulphate (0.5% v/v sulfuric acid) at 23 ±2°C for 1 minute to etch the surface uniformly.
   D. Wash in running tap water for a maximum of 5 seconds.
   E. Immerse in 5% sulfuric acid (by volume) at 23 ±2°C for 1 minute.
   F. Wash for 5 seconds in running tap water, then rinse thoroughly in demineralized water.
   G. Rinse with acetone.
H. Allow to dry in clean air.

5.1.3.2 Use the test piece as soon as possible or store up to 1 hour in a closed container.

5.1.4 Preparation of Test Solder

5.1.4.1 Weigh 1.00 gram ± 0.05 gram specimen of solder for each test and place in center of depression of each test panel.

5.1.4.2 Degrease solder specimen with a suitable neutral organic solvent such as acetone, toluene, or petroleum ether.

5.1.4.3 Solder may be in the form of pellets or by forming tight spirals of solder wire.

5.2 Test

5.2.1 Heat solder pot so that solder bath stabilizes at 235 ± 5°C.

5.2.2 Liquid Flux Place 0.035 g of flux solids into the depression in the test panel. Add solder sample.

5.2.2.1 Solder Paste, Cored-Wire or Cored-Preform Place 1 g of solder paste, flux-cored wire or cored-preform into the depression in the test panel.

5.2.3 Using tongs, lower each test panel onto the surface of the molten solder.

5.2.4 Allow the test panel to remain in contact until solder specimen in the depression of the test panel melts. Maintain this position for 5 ± 1 seconds.

5.2.5 Carefully examine test specimen at 20X magnification for subsequent comparison after humidity exposure. Record observations, especially any discoloration.

5.2.6 Preheat test panel to 40 ± 1°C for 30 ± 2 minutes.

5.2.7 Preset humidity chamber to 40 ± 1°C and 93 ± 2% relative humidity.

5.2.8 Suspend each test specimen vertically (and separately) in the humidity chamber.

5.2.9 Expose specimens to the above environment for 240 hours (10 days). M and H may be tested in the cleaned, as well as uncleaned, condition.

5.3 Evaluation Carefully examine specimens prior to placing them in the environmental chamber. Note any discoloration.

5.3.1 After the appropriate exposure period, remove test specimens from humidity chamber, examine at 20X magnification and compare with observations noted in paragraph 5.2.5.

5.3.2 Corrosion is described as follows:
A. Excrecences at the interfaces of the flux residue and copper boundary, or the residues or discontinuities in the residues.
B. Discrete white or colored spots in the flux residues.

5.3.3 An initial change of color which may develop when the test panel is heated during soldering is disregarded, but subsequent development of green-blue discoloration with observation of pitting of the copper panel is regarded as corrosion.

6.0 Notes

6.1 Definition of Corrosion For purposes of this test method, the following definition of corrosion shall prevail. “A chemical reaction between the copper, the solder, and the constituents of the flux residues, which occurs after soldering and during exposure to the above environmental conditions.”

6.2 Color photos before and after the test are valuable tools in identifying corrosion. (See 5.2.5.)

6.3 Safety Observe all appropriate precautions on MSDS for chemicals involved in this test method.
1.0 Scope  This procedure is a rapid means for evaluating glass epoxy laminate integrity on different lots of base laminate materials before placing materials on the production floor, and thereby reducing the cost of processing material which may later prove to be defective.

2.0 Applicable Documents

IPC-A-600  Acceptability of Printed Boards
IPC-MI-660  Guidelines for Incoming Inspection of Raw Materials

3.0 Specimens  The samples of qualification or incoming production test coupons shall be 4.0 inch x 4.0 inch x 1/16 inch thick (see 7.1) and etched using the standard commercial practices procedure of the individual test facility. The test coupons can be taken from any part of the laminate. The test strip may be sheared, but the individual test coupons shall be sawed and their edges sanded.

4.0 Number of Test Coupons to be Tested  Five coupons shall be tested and may arbitrarily contain a known “pass” and “fail” control coupon. However, if a failure mode is established, a second set of 5 samples shall be tested from another laminate and this set must contain a pass and fail control. The number of test coupons tested at any one time should be limited to the capacity of the pressure vessel being used.

5.0 Apparatus

5.1 Any standard laboratory autoclave pressure vessel having a 6-quart capacity. A commercial household 6-quart stainless steel pressure cooker capable of developing 15 psi pressure (the 15 psi pressure set at the location of the test) may be used if equipped with a properly calibrated pressure gauge to maintain 15 psi ± 0.5 psi pressure.

5.2 A laboratory solder pot capable of maintaining a solder bath (SN 60) at 500°F –0° + 10°F.

5.3 Stop watch.

5.4 Solder pot containing SN 60/40 solder.

6.0 Test

6.1 Preparation

6.1.1 Cut test coupons only by sawing, and sand the edges of the specimens so they are smooth.

6.1.2 Etch specimens to remove metal foil except in any areas which may have identification codes.

6.1.3 Apply permanent identification markings on specimens on the end that will not be immersed in the solder pot.

6.1.4 The specimens will be placed in a suitable rack for suspending in the pressure vessel. The specimens should not be drilled for suspension as this creates a path for moisture incursion, giving false results.

6.1.5 Pour water into pressure vessel to approximately 1.0 inch depth. Cover and bring to a boil without pressurizing.

6.2 Test

6.2.1 When steam is observed at the vent, uncover and suspend specimens vertically over boiling water, being careful not to allow specimens to touch each other or the walls of the pressure vessel. This step must be done rapidly to avoid undue cooling of the water and pressure vessel.

6.2.2 The heat-up time should be controlled at 7 minutes ± 1 minute.

6.2.3 After reaching 15 psi. maintain this condition for 30 minutes + 2 – 0 minutes.

Note: Other pressure vessel dwell times may be agreed upon between user and vendor.

6.2.4 At the end of the exposure time, cool and vent the pressure vessel as recommended by the manufacturer.

6.2.5 Carefully remove the hot specimens from the pressure vessel and blot dry with paper towel (see caution notes).

6.2.6 The specimens shall be maintained at ambient temperature, and within 10 minutes it shall be immersed vertically (with the edge parallel to the solder surface) into the solder bath which is maintained at either 500°F –0° + 10°F for 20
seconds. Immersion and withdrawal rates should not exceed 2 seconds. Do not allow test coupons to touch bottom of solder bath.

Note: Other solder bath temperatures maybe agreed upon by user and vendor.

6.3 Evaluation

6.3.1 Do not evaluate areas within 1/8 inch from all edges, including solder line.

6.3.2 Grading Grade specimens on the evaluation scale of 5 through 1 (below) according to degree of severity of the attack. In order for the grading to be more meaningful, the tester should also provide comments on the overall specimen appearance. For additional description and illustrations of measles, blisters, weave texture, delamination, etc., refer to IPC-A-600, Acceptability Guidelines for Printed Wiring.

<table>
<thead>
<tr>
<th>Value</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>The samples have no measles, blisters, or surface erosion.</td>
</tr>
<tr>
<td>4</td>
<td>Occasional minute (1/32 inch or less) measles.</td>
</tr>
<tr>
<td>3</td>
<td>Minute measles scattered across the specimen.</td>
</tr>
<tr>
<td>2</td>
<td>Occasional minor blisters (two to four adjacent weave intersections).</td>
</tr>
<tr>
<td>1</td>
<td>Large blisters, delamination, or convolution.</td>
</tr>
</tbody>
</table>

If five test coupons are evaluated, the test may use a total performance points-rating (e.g., 5 x 5 = 25).

7.0 Notes

7.1 This test method is developed for 1/16 inch thick material. Different results are to be expected for other thicknesses. Therefore, the time of exposure and grading values may change for different thicknesses and must be agreed upon between user and vendor.

7.2 Warning Pressure vessel must always be opened with extreme caution to be certain pressure has been released.

7.3 Warning Samples could retain some moisture. Therefore, care should be taken in immersing the sample in the solder bath. It is recommended that the operator work behind a suitable protective screen and use a glove to protect the hand holding the sample. The wet specimens will react violently during the immersion into the solder pot, splaying and sputtering bits of molten solder about the fume hood. Proper precautionary measures must be taken.
CONDITION 3

CONDITION 4

CONDITION 5
1 Scope
This test method is designed to determine the capability of HDI materials and other dielectrics to withstand moisture induced stress as applied by extended time in a pressure vessel. For laminated constructions, the results may be affected by the process conditions.

2 Applicable Documents
IPC-A-600 Acceptability of Printed Boards
2.1.1 Microsectioning
2.1.1.2 Microsectioning—Semi or Automatic Technique Microsection Equipment (Alternate)
2.3.6 Etching, Ammonium Persulfate Method
2.3.7 Etching, Ferric Chloride Method
2.3.7.1 Cupric Chloride Etching Method
2.3.7.2 Alkaline Etching Method

3 Test Specimen
3.1 Samples shall be prepared as appropriate for the type of material. All samples shall be 10 cm x 10 cm ± 0.5 cm, with the thickness determined by the type of material (see 3.1.1 to 3.1.3). Three samples shall be prepared. Control samples are required for all samples where the dielectric layer is applied to an etched laminate. One control sample of the etched laminate (with no added dielectric) is required for samples prepared according to 3.1.2.2 or 3.1.3.

3.1.1 Copper-Clad Laminate The laminate shall have all copper removed in accordance with IPC-TM-650, Method 2.3.6, 2.3.7, 2.3.7.1 or 2.3.7.2, then cut to dimensions of 10 cm x 10 cm ± 0.65 cm.

3.1.2 Semi-Cured Prepreg The prepreg shall be laminated to a cured sheet configuration, with 35 micron copper foil, using the supplier’s recommended lamination cycle. The laminate shall be etched of all copper, then cut to dimensions of 10 cm x 10 cm ± 0.65 cm.

3.1.2.1 Semi-Cured Prepreg or Dielectric Material, Method A Sufficient plies of prepreg shall be used to result in a composite base thickness of 0.4 mm ± 0.1 mm. If the prepreg is of a nature that does not allow for lamination of a single sample of the thickness specified, then a thinner sample shall be laminated, noting the thickness as part of the report, see 5.5.

3.1.2.2 Semi-Cured Prepreg or Dielectric Material, Alternate Method B The prepreg or dielectric layer shall be laminated to both sides of an etched laminate that has a thickness of 0.4 mm ± 0.1 mm. The prepreg or dielectric layer shall be applied, laminated and cured according to the manufacturer’s recommendations. Unless otherwise specified, the resulting prepreg or dielectric layer thickness shall be a nominal of 0.05 mm on each side of the core laminate. Optionally, the actual thickness may be measured by mechanical or cross-sectional methods and reported, see 5.5. Control samples shall be the etched laminate core with no prepreg or dielectric layer.

3.1.3 Coated Dielectrics The coated dielectrics (i.e., resins, adhesives, dry films) shall be applied to both sides of an etched laminate that has a thickness of 0.4 mm ± 0.1 mm. The coated dielectrics shall be applied and cured according to the manufacturer’s recommendations. Unless otherwise specified, the resulting coated dielectric thickness shall be a nominal of 0.05 mm on each side of the core laminate. Optionally, the actual thickness may be measured by mechanical or cross-sectional methods and reported, see 5.5. Control samples shall be the etched laminate core with no coated dielectric.

4 Test Equipment
4.1 Pressure vessel capable of maintaining a constant pressure of 2 ATM (14 psig), and a temperature of 121°C ± 2°C, with water content maintained for a minimum of six hours before needing replenishment.

4.2 Oven, air circulating, capable of holding a temperature of 105°C ± 2°C

4.3 Microsectioning equipment, including slug cutter, mounting, grinding, and polishing equipment (see IPC-TM-650, Method 2.1.1 or 2.1.1.2)

4.4 Microscope capable of 200X magnification, with optional photographic equipment
5 Procedure

5.1 Prepare specimens as required, depending on the configuration of the material under test (see 3.1).

5.2 Preconditioning  The samples and controls shall be dried by baking at 105°C ± 2°C for a minimum of two hours to remove moisture.

5.3 Expose to Moisture Under Pressure

5.3.1 Place three pieces of each type of material to be tested in the pressure vessel, such that they are vertical by use of a rack or grooved block, which does not cover more than 5% of the surface area of the specimen. If samples have been prepared as per 3.1.2.2 and 3.1.3, place one piece of the base laminate in the vessel along with the specimens.

5.3.2 Fill the pressure vessel with water such that the specimens are not sitting in the water.

5.3.3 Close the lid of the pressure vessel and seal the chamber.

5.3.4 Apply heat to the pressure vessel until the temperature and pressure specified are attained and held constant.

5.3.5 Water must be replenished during the pressure vessel test to maintain the prescribed pressure level. The interval of replenishment should not be less than six hours.

5.3.6 After the required time, which shall be 96 hours unless otherwise specified, remove the pressure cooker from the heat source and open the chamber. Remove the specimens and lay on a countertop to stabilize at room temperature.

5.4 Evaluation

5.4.1 Inspect the surface area of the specimens using 20/20 vision. When applicable, refer to IPC-A-600 to assess degradation, such as measling or crazing.

5.4.1.1 Determine and grade the presence of any degradation (see 5.5.1.1 through 5.5.1.5) or other defects, such as measling, dryness, loss of surface resin, etc. Use the unconditioned specimen from each sample as a control to contrast with the conditioned specimens. For samples prepared as per 3.1.2.2 or 3.1.3, use the base laminate as control.

5.4.1.2 Record any defects or degradation of the material. Note the presence of any defects in the unconditioned control. Include the approximate number and size of defects and the total area of the specimen surface that is afflicted with the defect(s).

5.4.2 When required by the procurement documentation, microsectioning shall be conducted as stated in 5.4.2.1 through 5.4.2.3.

5.4.2.1 Cross section at least one specimen in the center of the specimen in accordance with Method 2.1.7. Mount a section of the control of that material beside the conditioned section.

5.4.2.2 After polishing the sections, examine under 100 - 200X.

5.4.2.3 Determine the presence of voids, resin-to-reinforcement separation, or other defects in both the control and the conditioned specimen.

5.5 Report  Report the base thickness of the laminate. For prepregs or coating et al, if a composite sample is fabricated, include the final thickness of the material in question and the thickness of the core laminate.

5.5.1 Report the condition of the specimens according to the following grade system. If significant differences are noted between specimens of one material, note the worse condition. Exclude the outer 7 mm.

5.5.1.1 Grade 5  No measling, delamination, dryness, voiding or other degradation in excess of that observed on the unconditioned sample.

5.5.1.2 Grade 4  Very slight measling; or slight dryness.

5.5.1.3 Grade 3  Slight measling or dryness; or maximum, of three voids no greater than 0.25 mm.

5.5.1.4 Grade 2  Moderate measling or dryness; moderate dryness; or more than three voids no greater than 0.5 mm.

5.5.1.5 Grade 1  Heavy measling and dryness; or voids greater than 0.5 mm; blisters or delamination.

5.5.2 Optional Microsectioning Evaluation  Report the presence of defects in both control and conditioned specimens.
1 Scope  This test method defines the procedure for determining the hydrolytic stability of a copper foil-clad or unclad flexible dielectric material.

2 Applicable Documents  None

3 Test Specimens

3.1 Three 10 cm x 10 cm x thickness sheets

4 Apparatus

4.1 Reagent grade potassium sulfate

4.2 Desiccator, 25 cm diameter minimum

4.3 Cotton swabs

4.4 Test chamber (oven) capable of maintaining up to 100°C ± 10°C

5 Procedure

5.1 Preparation

5.1.1 Prepare a saturated solution of distilled water and potassium sulfate (35 grams per 100 cc) at the temperature of the test, as indicated in Table 1. Pour the solution into the desiccator to a level just below the ceramic plate. Crystals of potassium sulfate should remain visible in the saturated solution at the chamber operating temperature.

5.1.2 Clean the test specimen thoroughly, using the coating supplier’s recommended solutions and procedures.

5.1.3 Place the test specimen in the desiccator in a vertical position on the ceramic plate (specimens shall not touch one another), seal the desiccator lid with silicone grease, and close the desiccator.

5.1.4 Place the desiccator in the test chamber (oven), presetting to the conditions of Table 1.

5.2 Evaluation

5.2.1 After the required time exposure, remove the test specimens and visually examine for chalking, blistering, cracking, and general degradation.

5.2.2 Touch the surface of the coating with a swab of absorbent cotton and observe for particles of the cotton adhering to the coating.

6 Notes

6.1 Examination and testing may be done at intervals between the test chamber time requirements, if there is suspicion of an early failure and evaluation time is critical.

Table 1 Test Conditions

<table>
<thead>
<tr>
<th>Class</th>
<th>Temperature</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35°C ± 1°C</td>
<td>Four</td>
</tr>
<tr>
<td>2</td>
<td>85°C ± 2°C</td>
<td>Seven</td>
</tr>
<tr>
<td>3</td>
<td>85°C ± 2°C</td>
<td>120</td>
</tr>
</tbody>
</table>

5.1.2 Clean the test specimen thoroughly, using the coating supplier’s recommended solutions and procedures.

5.1.3 Place the test specimen in the desiccator in a vertical position on the ceramic plate (specimens shall not touch one another), seal the desiccator lid with silicone grease, and close the desiccator.

5.1.4 Place the desiccator in the test chamber (oven), presetting to the conditions of Table 1.

5.2 Evaluation

5.2.1 After the required time exposure, remove the test specimens and visually examine for chalking, blistering, cracking, and general degradation.

5.2.2 Touch the surface of the coating with a swab of absorbent cotton and observe for particles of the cotton adhering to the coating.

6 Notes

6.1 Examination and testing may be done at intervals between the test chamber time requirements, if there is suspicion of an early failure and evaluation time is critical.
1.0 Scope  This test method defines the procedure for determining the low temperature flexibility of flexible printed wiring materials by flexing while immersed in a solution mixed from dry ice (solid carbon dioxide) and isopropyl alcohol.

2.0 Applicable Documents  None

3.0 Test Specimen  The test specimen shall consist of an etched conductor pattern in accordance with Figure 1.

4.0 Test Equipment

4.1 Flexing fixture similar to Photo 1, with 1 inch diameter mandrel.

4.2 Insulated container, approximately 20 quart capacity.

4.3 Two lbs. dry ice (solid carbon dioxide).

4.4 Three gallons reagent grade isopropyl alcohol.

4.5 Thermometer capable of measuring at least -65°C.

4.6 Safety gloves.

5.0 Procedure

5.1 Prepared a minimum of two test specimens per Figure 1 using good commercial practices.

5.2 Prepare a bath by mixing two lbs. of solid carbon dioxide with three gallons of isopropyl alcohol. Caution: use adequate safety precautions, as bath will produce extreme cold (approximately -65°C).

5.3 Mount the test specimen in the test fixture such that it is wrapped 180° around the 1 inch diameter mandrel.

5.4 Submerge the test specimen end of the flexing fixture into the cold bath and flex 5 times.

5.5 Remove the specimen from the bath and examine for cracking, delaminations, splits, and/or any other viable defect.

6.0 Notes

6.1 All safety precautions must be exercised when working with a mixture of dry ice and alcohol.

6.1.1 Dry ice has a temperature of -110°F, passes directly to the gaseous state, and is used as a refrigerant. Therefore, it is dangerous if not handled carefully.

6.1.2 Isopropyl alcohol is flammable and toxic; should not be ingested, and should also be handled properly.

6.2 Detailed drawings of the suggested flexing fixture are available from the IPC office.
1.0 Scope  This test method is to evaluate the insulation resistance of ceramic plated-through hole multilayer printed wiring boards before, during and after the deteriorative effects of the high humidity heat conditions, and low temperature thermal shock exposures. Hybrid ceramic multilayer boards are employed as the dimensionally stable interconnection media between conventional printed boards and a variety of hybrid packages.

Tropical degradation results from absorption of moisture vapors by vulnerable insulating materials and surface wetting of both metal conductors and the insulating laminate material. These phenomena may produce corrosion of metals, distortion of the boards, leaching, and detrimental changes in electrical properties.

This method by virtue of the temperature cycling provides alternate cycles of condensation and temperature changes which is essential to the development of the corrosion process, and in addition produces a “breathing” action of moisture.

The low temperature thermal shock phase of the test reveals otherwise undiscernible deterioration. The stresses caused by freezing moisture tends to widen cracks and fissures. As a result the deterioration can be detected by insulation resistance or interconnection resistance of the plated-through hole barrels.

2.0 Applicable Documents

IPC-HM-860  Performance Specification for Hybrid Multilayers

3.0 Test Specimens  Qualification test board of design approved by the customer or a randomly selected production board.

4.0 Test Equipment/Apparatus

4.1 Condition Chamber  An oven capable of continually maintaining 120°C ± 2°C drying conditions.

4.2 Humidity Chamber  A test capable of programming and recording temperatures from 25°C ± 2°C to 65°C ± 2°C and capable of delivering a minimum of 90% relative humidity continuously (see Figure 1).

4.3 Low Temperature Chamber  A test chamber capable of maintaining a constant ambient temperature of -10°C ± 2°C. The low temperature may be achieved by mechanical refrigeration or with the use of gasses such as carbon dioxide (CO₂) or liquid nitrogen (LN₂).

4.4 A DC power supply unit capable of producing a standing bias potential of 100 Vdc with a tolerance of ± 10%.

4.5 An electrical resistance meter capable of reading high resistance, 10¹² or greater, with a voltage range of up to 500 Vdc or greater.

4.6 Scotchbrite very fine pads, pumice, or equivalent

4.7 Two 3500 ml. beakers

4.8 Electric hot plate

4.9 Exhaust ventilation hood

4.10 Metal tongs

4.11 Alkaline cleaning detergent (i.e., 40% alkanolamine, 20% 2-butoxyethanol, glycol ether and the remainder water with a pH factor of 13 or less)

4.12 Soft bristle brush

4.13 Deionized water, 2 megohm/cm minimum resistivity

4.14 Isopropyl alcohol

4.15 Black light (ultraviolet)

4.16 A microscope capable of 10x to 30x magnification

4.17 Silica gel desiccant

5.0 Test

5.1 Specimen Preparation
5.1.1 Identify Specimen  Positive and permanent identification of test specimen is of paramount importance, i.e., serial number, date code, part number, etc.

5.1.2 Visually inspect the test specimens for any obvious defects. If there is any doubt about the overall quality of any test specimen, the test specimen should be discarded.

5.1.3 Solder single strand teflon coated test leads in place and remove flux.

5.1.4 Scrub the test specimen for 15 to 20 seconds by hand using a Scotchbrite very fine pad or equivalent under running tap water, or for one normal cycle through an industrial quality circuit board scrubber. See note 6.1. Handle boards with clean metal tongs for the remainder of the specimen preparation.

5.1.4.1 Clean board in vapor degreaser.
(a) Pour a sufficient amount of solvent (Freon TMS or 1,1,1, trichloroethane) into a 3500 ml. beaker to vapor degrease the number of test boards on hand.
(b) Place the 3500 ml. beaker on an electric hot plate and heat the solvent to the boiling point (under a hood or in a well ventilated area).
(c) Using metal tongs, hold the board suspended over the solvent until the vapor condenses on the board and drips off freely.
(d) Remove the board from the solvent vapor and allow to dry for approximately 5 minutes.

5.1.4.2 Mix a solution of clean, warm deionized water and the alkaline cleaning detergent in a 3500 ml. beaker (approximately 3 oz. per gallon of water). The board shall not be allowed to dry prior to proceeding.
(a) Scrub both sides of the board with a soft bristle brush in the warm (120°F - 130°F) solution (see note 6.1).
(b) Immerse the board in warm, running deionized water and agitate for 30 seconds minimum.
(c) Immerse board in clean deionized water and agitate for a minimum of 30 seconds to remove detergent solution. Handle board by the edges using metal tongs.
(d) Spray rinse thoroughly with deionized water. Hold board at an approximate 30° angle and spray from top to bottom.

5.1.4.3 Immerse board in clean isopropyl alcohol and agitate for a minimum of 30 seconds. Scrub with a soft bristle brush to remove flux residue. Handle board by the edges using metal tongs. Be sure to use a brush that does not leave loose bristles on the specimen.

5.1.4.4 Rinse board and components thoroughly with a second isopropyl alcohol bath. Hold board by edges and agitate in the liquid.

5.1.4.5 Examine for cleanliness. Use black light to detect contaminants that will fluoresce.

5.1.4.6 Dry board in drying oven for a minimum of 3 hours at 100°C.

5.1.4.7 Test specimen cleanliness. For the remainder of the test, the surface of the test specimens should not be handled or exposed to any other contaminating influence.

5.2 Test Procedure

5.2.1 Dry specimens at 50°C ± 2° (122°F) for 24 hours.

5.2.2 Allow specimen to cool and take initial insulation reading at laboratory ambient conditions. Apply electrification voltage of 500 Vdc to the test leads with the resistance meter for 1 minute, then take measurement and record as the initial reading (clip meter to test leads).

5.2.3 Place specimen in humidity chamber in a vertical position and under a condensation drip shield. Apply 100 Vdc polarized voltage.

5.2.4 Start humidity exposure with 90% minimum relative humidity at 25°C, and raise temperature to 65°C over a time span of 2 1/2 hours ± 3/4 hours.

5.2.5 Maintain temperature at 65°C and 90% minimum relative humidity for 3 hours ± 1/4 hour.

5.2.6 Lower temperature from 65°C to 25°C over a time span of 2 1/2 hours ± 1/4 hours while maintaining 80% minimum relative humidity.

5.2.7 Three humidity cycles constitute one 24-hour exposure. Repeat for 10 days.

5.2.8 Subcycle of step 5.2.7. During at least five of the ten cycles a low temperature subcycle shall be performed.

5.2.8.1 Disconnect the 100 Vdc polarized voltage during steps 5.2.7 exposure. At least 1 hour but not more than 4 hours after step 5.2.7 begins, the specimens shall be either removed from the humidity chamber, or the temperature of the chamber shall be reduced, for performance of the subcycle.

5.2.8.2 Specimens during the subcycle shall be conditioned at -10° ± 2°C, with humidity not controlled, for 3 hours minimum as indicated in Figure 1. When a separate cold chamber is not used, care should be taken to assure that the specimens are held at -10° ± 2°C for the full period.

5.2.8.3 After step 5.2.7, the specimens shall be returned to 25°C at 90% relative humidity (RH) minimum and kept there until the next cycle begins.

5.3 Measurements

5.3.1 After the 10 day exposures, disconnect 100 Vdc polarized voltage before taking insulation resistance measurements.

5.3.2 Measure insulation resistance once every 24 hours during the high temperature phase of the humidity exposure. These measurements are to be made without opening the humidity chamber.

5.3.3 The final insulation resistance measurement must be taken 1 to 2 hours after the specimen has stabilized at laboratory ambient conditions.

5.4 Evaluation
5.4.1 All insulation resistance measurements must be compared with the requirements of IPC-HM-860, Performance Specification for Hybrid Multilayers.

5.4.2 Visual examination at 10x to 30x magnification for cracks, fissures, corrosion or other deleterious effects must also be reported.

6.0 Notes

6.1 Documented alternative cleaning procedures may be implemented if there is a concern that scrubbing will adversely affect the test results, i.e., when test specimens have fine spacing and/or are plated with soft metals such as tin/lead, gold, etc.
1 Scope  This test method exists to determine the service temperature of flexible printed wiring.

2 Applicable Documents

2.4.9   Peel Strength, Flexible Printed Wiring Materials
2.4.13  Solder Float Resistance, Flexible Printed Wiring Materials

ASTM-D-149  Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies

3 Test Specimens

3.1  Test specimens shall be constructed in accordance with Figure 1 and shall measure 152 mm long by 12.7 mm wide. Fifteen samples of each construction to be tested shall be prepared.

4 Equipment/Apparatus

4.1  An air-circulating oven capable of maintaining uniform test temperatures as calculated in 5.3

4.2  Equipment capable of performing:
   • Solder float per IPC-TM-650, Method 2.4.13
   • Peel strength per IPC-TM-650, Method 2.4.9
   • Dielectric Strength per ASTM-D-149

5 Procedure

5.1  Three samples of each construction to be tested shall be subjected to initial peel testing per IPC-TM-650, Method 2.4.9. The results shall be recorded and averaged.

5.2  The remaining 12 samples shall have initial dielectric strength measured per ASTM-D-149. The results of these measurements shall be recorded and averaged. These samples shall then be exposed to solder float per IPC-TM-650, Method 2.4.13.

5.3  The samples described in 5.2 shall be aged in the oven described in 4.1 for 10 days (240 hours) or for 56 days (1344 hours). The test temperature will be calculated from the desired service temperature as follows:

   10 day test: $T = 1.076 (t + 288) - 273$
   56 day test: $T = 1.02 (t + 288) - 273$

   where $T$ = test temperature
   $t$ = desired service temperature

5.4  After aging, six samples shall be tested for peel strength per IPC-TM-650, Method 2.4.9, and the results shall be averaged. The remaining six samples shall be tested for dielectric strength per ASTM-D-149, and the results shall be averaged.
Figure 1  Service Temperature Test Samples
1.0 Scope  
This test procedure measures the temperature repeatability inside steam agers used to condition components prior to solderability testing. It should be applied at installation and after any modification to the equipment and/or its location.

2.0 Applicable Documents

IPC-PC-90  General Requirements for Implementation of Statistical Control
MIL-STD-202  Test methods for Electronics and Electrical Components Parts
MIL-STD-750  Test Methods for Semiconductor Devices
MIL-STD-883  Test Methods of Microelectronics
MIL-STD-45662  Calibration Systems Requirements
ANSI/ASQC Z1.1  Guide for Quality Control Charts
ANSI/ASQC Z1.2  Control Chart Method of Analyzing Data
ANSI/ASQC Z1.3  Control Chart Method of Controlling Quality During Production
ANSI/J-STD-002  Solderability Tests for Components Leads, Terminations, Lugs, Terminals and Wires

3.0 Test Specimens  None required

4.0 Apparatus  The following test equipment shall be used during the tests:

4.1 Type T copper-constantan thermocouple wire, 24 AWG, ±0.5°C [±0.9°F] accuracy minimum, premium grade.

Note: PTFE insulation is preferred.

4.2 Thermocouple Temperature Indicator, with an accuracy of ±0.5°C [±0.9°F] minimum, with capability for type T thermocouples, and be calibrated in accordance with MIL-STD-45662 or the equivalent.

It is recommended that the thermocouple indicator have capability to log data and be able to take all readings within 2 minutes.

Since readings must be taken periodically, it is recommended that the indicator have capability for pre-settable time delay between measurements.

Note: Although the specific equipment used to develop this method was as specified above, other thermocouple types and temperature indicators may be used provided the requirements of 5.1 are met.

4.3 Hot plate with 500 ml glass beaker

4.4 The steam ager as used to perform component solderability testing per MIL-STD-202, Method 208; MIL-STD-883, Method 2003; or MIL-STD-750, Method 2026; or ANSI/J-STD-002 as applicable.

5.0 Test Procedure

5.1 Thermocouple Calibration  All thermocouples to be used during the steam ager test shall first be checked. Loosely bundle the thermocouples and place in a 500 ml glass beaker of vigorously boiling water, heated by a hot plate.

Measure the temperature indicated by each thermocouple. All thermocouples should indicate the same temperature ±0.5°C [±0.9°F] to the local boiling point of water. If any thermocouple differs by more this amount, the weld bead shall be reworked (and all thermocouples reverified), or the thermocouple shall be discarded for the purpose of this test.

5.2 Install Thermocouples  Install the thermocouples in the ager at the component level. All thermocouple weld beads shall be at the same height ±6.35 mm [±0.25 in]. The distance from the weld to the water shall be measured prior to the test.

All thermocouples shall be at least 25.4 mm [1 in] away from any wall or bulkhead. The thermocouples should be distributed evenly around the normal working area inside the ager, and the location shall be recorded. Ten thermocouples shall be used in larger agers, eight in smaller agers. For example, if the ager uses five small drawers, a thermocouple centered in the front and back halves of the drawer would be sufficient. If no drawers are used, the thermocouples should be distributed around the areas where parts are usually placed.
Each thermocouple shall be secured using positive mechanical means. For example, the thermocouple wire could be wound around a piano wire secured across the width of the ager.

The natural airflow within the ager should be preserved. Extra baffles or wire mesh screens should not be included for this test, if not used during regular solderability testing. Venting should be preserved as it is during normal testing.

The end of the thermocouple, including the weld bead and exposed wires, should be oriented vertically (pointing upward) to prevent water drops from collecting on them.

5.3 Performing the Test  Turn on the ager and allow to stabilize until measurement procedures used during regular testing indicate stability has been achieved.

Note: Four hours is usually required in most agers to achieve stability, and this “warmup” time should be included in the production part test procedure.

Start the test, logging temperature every 15 minutes for 8 hours. (If the data clearly indicates that the natural variability within the chamber varies more quickly, the sampling frequency can be increased as necessary)

When logging temperatures, all thermocouples should be measured simultaneously, or within 2 minutes maximum. Temperatures shall be recorded in degrees Celsius. Measure temperature to the nearest 0.1 degree.

The steam agers shall not be disturbed during the test, except for routine maintenance or inspection procedures; as used during normal testing. The ager shall be tested without other components inside.

5.4 Test Conditions  Test the temperature stability at the temperature set point used for solderability testing.

5.5 Data Analysis

5.5.1 Record the following data for each test.

a. Ager manufacturer and model number
b. Temperature indicator type, date of calibration
c. Test date
d. Sampling frequency
e. Total vent area on chamber lid [sq.cm]
f. Total chamber cross-sectional surface area [sq.cm] 
g. Total volume of air in chamber [cu.cm] 
h. Set point temperature 
i. Test location

j. Location of room air conditioning vents (include sketch)  
k. Notes on any special conditions during test  
l. Distance from thermocouples to water level  
m. Location of thermocouples inside ager (include sketch)  
n. Room temperature when testing

5.5.2 Test Data  Prepare a matrix of test data, showing temperature of each thermocouple at each sampling interval.

5.5.3 Control Charts  Prepare X-bar and R charts with appropriate control limits. A control limit calculation form is shown in Appendix 1. Further instructions on preparation of control charts can be found in IPC-PC-90 or ANSI/ASQC Z1.1, Z1.2, and Z1.3.

Subgroups shall consist of all thermocouples placed in the ager (8 or 10), and which are measured simultaneously during the test.

The charts shall be considered out of control if any of the following applies:

a. any one data point is beyond the control limits  
b. any 2 or 3 consecutive points are near a control limit (outer third) 
c. a run of 8 or more points is above or below the center line  
d. a run of 6 or more points is increasing or decreasing

5.5.4 Process Capability Histogram  Prepare a process capability histogram, using data ranges of 1/2°C or less.

Estimate the mean and standard deviation of the data.

5.5.5 Process Capability Index  Calculate the process capability index, Cp using the equation shown below (from IPC-PC-90 example 7.5.6.2) for specification limits of ±1°C [±1.8°F], ±2°C [±3.6°F], ±3°C[±5.4°F] and ±4°C[±7.2°F].

$$C_p = \frac{USL-LSL}{6S}$$

Where,

Cp = capability index
USL = upper specification limit
LSL = lower specification limit
S = process standard deviation

Include a plot of Cp against specification tolerance range.
6.0 Notes

6.1 Care should be exercised when interpreting analysis results. Cp may not be meaningful if the X-bar or R charts are out of control, or the process capability histogram is grossly non-normal. Consult IPC-PC-90 or ANSI/ASQC Z1.1, Z1.2 and Z1.3 for further details.
1 Scope  The purpose of these tests is to characterize changes in individual interconnection resistances as a function of exposure time in various environmental aging conditions for both flex to PWB and flex to indium-tin-oxide (ITO) coated glass bonds.

2 Applicable Documents

IPC-3408 General Requirements for Anisotropically Conductive Adhesive Films

3 Test Specimens

3.1  0.2 mm line/space test boards
     0.2 mm line/space flex test circuits

4 Apparatus

4.1  ITO coated soda-lime glass test slides, 20 ohms/sq. mm

4.2  Polypropylene trays for sample storage in chamber

4.3  Instrumentation to permit four-probe resistance measurement

4.5  Required environmental test chamber(s):
     a) Thermal aging, 100°C
     b) Thermal cycling, -55°C to >125°C, five hour period
     c) Humidity aging, 60°C/95% RH

5 Procedure

5.1  Sample Preparation

5.1.1  Cut the flex test circuits to the appropriate length (see Figure 1 and Figure 2). If flex board samples are being prepared, all traces on the flex should be shorted together on one end.

5.1.2  Use of new PCB is recommended. If new boards are being used, there should be no need for any special cleaning procedure. If used boards are to be used, they should be inspected to ensure that:

a) Protective metalization (Au or Pb-Sn) is intact.

b) FR-4 isn’t significantly discolored from prior high temperature exposure.

c) The board is free of any residue from previous tests.

5.1.3  Refer to 5.2 for proper bonding procedure.

5.2  Sample Procedure

5.2.1  Prepare at least three test samples for each test condition to be run. For the flex board case, it is possible to mount two test samples on each board. Refer to IPC-3408 for proper bonding procedure.

5.2.2  After bonding is completed, each sample should be identified by a test number. Test numbers should be written on the test substrate using an indelible marker.

5.2.3  Clamp the unbonded end of the flexible circuit to the matching board traces to make electrical contact, with an elastomeric compliant layer behind the flex to maintain uniform contact force.

5.2.4  Initial interconnection resistances should be measured and recorded. The recommended measurement technique is illustrated in Figure 3. This technique can be used with either test sample type.

Note: This technique doesn’t allow for the measurement of the first and last circuit trace. There are 15 measurements to be made on each sample.

5.2.5  Samples should be placed in the polypropylene trays, and the trays placed in the appropriate chamber. The time and date should be noted for the purpose of computing elapsed time.

5.2.6  Samples should be removed from the chambers for resistance measurement after 24-hour, one-week, three-week, and six-week time points. All environmental tests are considered complete after six weeks. Samples should be allowed to equilibrate at ambient conditions for at least 30 minutes prior to measurement.

5.2.7  All resistance data should be tabulated and/or graphed to facilitate proper interpretation of the results.
Figure 1  Interconnection Resistance Test Assembly; Flex to ITO Glass
Figure 2  Interconnection Resistance Test Assembly; Flex to PWB

Figure 3  Four Probe Interconnect Resistance Measurement Technique for Flex to PWB and Flex to ITO Glass
IPC-TM-650
TEST METHODS MANUAL

1 Scope
This test method provides a means to assess the propensity for conductive anodic filament (CAF) growth, a form of electrochemical migration within a printed wiring board (PWB). Conductive anodic filaments may be composed of conductive salts, rather than cationic metal ions, however inadequate dielectric for the applied voltage, component failures, and part use exceeding the maximum operating temperature (MOT) of the laminate can contribute to product failures as well. This test method can be used to assess PWB laminate materials, PWB design and application parameters, PWB manufacturing process changes and press-fit connector applications.

2 Applicable Documents

2.1 IPC
IPC-A-47  Composite Test Pattern Ten-Layer Phototool
IPC-2221  Generic Standard On Printed Board Design
IPC-9253  CAF Test Board (Available in the ‘Drafts’ section of the 5-32e Committee Home Page)
IPC-9254  CAF Test Board (Available in the ‘Drafts’ section of the 5-32e Committee Home Page)
IPC/EIA J-STD-001  Requirements for Soldered Electrical and Electronic Assemblies
J-STD-004  Requirements for Soldering Fluxes
IPC/EIA J-STD-006,  Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solder for Electronic Soldering Applications

2.2 American Society for Testing and Materials (ASTM)
ASTM D-257  Standard Test Methods for DC Resistance or Conductance of Insulating Materials

3 Test Specimens
(Recommended that the latest version of the CAF test board be used)

3.1 IPC-9253 and IPC-9254  The IPC-9253 and IPC-9254 have 10 layers and dimensions are approximately 125x175 mm [nominally 5x7 in]. Test board designs for evaluating CAF resistance shall have varying drilled hole wall to drilled hole wall distances for plated holes. These distances can range from as low as 0.15 mm [0.00591 in] separation for alternate laminate materials expected to have very high CAF resistance and minimal copper wicking out from the plated-through hole (PTH), to as high as 0.89 mm [0.0350 in] separation for evaluating press-fit connector applications. The drilled hole size, rather than the finished hole size, is specified in the chart on the bare board fabrication drawing to ensure consistent spacing. Internal layer thieving may be added to plane layers around the perimeter. Test boards should be manufactured so that the machine/grain direction of the woven fiber reinforcement is perpendicular to the rows of same-net daisy chain vias for A1-A4 (machine/grain direction tends to fail first). Test board designs shall have sufficient minimum spacings on outer layers to ensure that surface insulation resistance failures do not occur. Layouts of the IPC-9253 and IPC-9254 test board structures (CAF Test Boards) are shown below (Figure 1).

IPC-9253 and IPC-9254 Test Structures A1 through A4
The four structures A1-A4 each have five rows of connected vias. Within each structure each row has 42 vias with alternating rows being tied to positive or negative electrodes. The via edge to via edge spacing is varied from one structure to the next by using a different drilled hole size on the same 1 mm [0.040 in] pitch between rows of daisy chain vias. The resulting via edge to via edge spacings are: 0.27 mm, 0.38 mm, 0.51 mm, 0.65 mm [0.0106 in, 0.0150 in, 0.0201 in, 0.0256 in]. Other than the use of different drilled hole sizes and a small change in pad sizes, the four structures are identical. The vias in these four test structures A1-A4 are aligned with the glass fibers. Since A1-A4 evaluate susceptibility to CAF in just one direction, test coupons should be manufactured so that the machine direction of the woven fiber laminate reinforcement is perpendicular to the rows of same-net daisy chain vias (machine direction tends to fail first).

For both A and B test structures the inner and outer layer pads are the same, i.e., the same pad size is consistently used within a given test structure, although it does change from structure to structure. All via to electrode connections are made on layer 2 and are repeated on layer 9 so that a single etch-out will not affect results. Traces from via to electrode are routed on internal layers rather than external layers to minimize potential for surface insulation resistance failure.
Design details for each test structure A1-A4 follows in Table 1. Note: "Manhattan Distance" is the shortest orthogonal distance along the X- and/or Y-axes lines between adjacent drilled hole features (corresponds to the orthogonal nature of the laminate material’s woven glass fiber reinforcement (Figure 2).

### Table 1 Test Structures A1 through A4 Design Rules

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer layer pad size</td>
<td>0.86 mm [0.0339 in]</td>
<td>0.81 mm [0.0319 in]</td>
<td>0.75 mm [0.0295 in]</td>
<td>0.69 mm [0.0272 in]</td>
</tr>
<tr>
<td>Inner layer pad size</td>
<td>0.86 mm [0.0339 in]</td>
<td>0.81 mm [0.0319 in]</td>
<td>0.75 mm [0.0295 in]</td>
<td>0.69 mm [0.0272 in]</td>
</tr>
<tr>
<td>Drilled hole size</td>
<td>0.74 mm [0.0291 in]</td>
<td>0.63 mm [0.0248 in]</td>
<td>0.51 mm [0.0201 in]</td>
<td>0.37 mm [0.0146 in]</td>
</tr>
<tr>
<td>Via edge to via edge (shortest distance)</td>
<td>0.27 mm [0.0106 in]</td>
<td>0.38 mm [0.0150 in]</td>
<td>0.51 mm [0.0201 in]</td>
<td>0.65 mm [0.0256 in]</td>
</tr>
<tr>
<td>Via edge to via edge (Manhattan Distance)</td>
<td>0.27 mm [0.0106 in]</td>
<td>0.38 mm [0.0150 in]</td>
<td>0.51 mm [0.0201 in]</td>
<td>0.65 mm [0.0256 in]</td>
</tr>
<tr>
<td>On IPC-9254 only, bias applied between:</td>
<td>J1, J5</td>
<td>J2, J5</td>
<td>J3, J5</td>
<td>J4, J5</td>
</tr>
</tbody>
</table>

**IPC-9253 and IPC-9254 Test Structures B1 through B4**

The four "B" test structures have seven alternating rows of vias. Within each structure, alternating rows have either 27 or 26 vias with the alternating rows being tied to either positive or negative electrodes. The via edge to via edge spacing is...
varied from one structure to the next by using a different drilled hole size on the same 1.52 mm x 1.52 mm [0.05984 in x 0.05984 in] via grid. The 1.52 mm x 1.52 mm [0.05984 in x 0.05984 in] grid has an interstitial via therefore, tipping at a 45° angle results in a square 1.08 mm x 1.08 mm [0.04252 in x 0.04252 in] grid. Note: the sketches do not look square when tipped 45° but, the CAF Test Boards do. The resulting via edge to via edge spacings are: 0.26 mm, 0.37 mm, 0.51 mm, 0.62 mm [0.0102 in, 0.0146 in, 0.0201 in, 0.0244 in]. Other than the use of different drilled hole sizes and a small change in pad sizes, the four structures are identical. The vias in the “B” test structure are not aligned with the glass fibers. If the failure mode is along glass bundles it is reasonable to expect the “B” test structure to perform better than the “A” structure for equivalent via edge to via edge spacings. Within a given test structure, the inner and outer layer pads for all 10 layers are the same, i.e., the same pad size is consistently used within a given test structure although, it does change from structure to structure. All via to electrode connections are made on layer 1 and are repeated on layer 10 so that a single etch-out will not affect results.

A conceptual representation of the “B” test structure is shown to the upper right (Figure 3). Design details on each of the four “B” test structures follows in Table 2.

### 3.2 Other Structures
Section C is designed to evaluate plated-through hole (PTH)-to-plane layer spacings. It is recommended to use the registration coupon F from either test artwork IPC-A-47 or IPC-2221 when CAF testing includes this region. Section D in the IPC-9254 design is for layer-to-layer Z-axis CAF testing. Section D in the IPC-9253 is for evaluating CAF resistance in a press-fit compliant pin connector application. The feature in the D region is an optional feature that is present automatically with the design. However, the A, B and C regions shall remain as designed in order to provide a standard basis of comparison.

The CAF test board with 10 layers is designated to evaluate thin single-ply constructions typically used on high performance boards. This board construction stackup can be reduced down to: (a) four layers by eliminating layers 3 through 8 and (b) only test structures A and B, when just evaluating differences between laminate materials.

### 3.3 CAF Test Board Design
This 10-layer CAF test board for evaluating the insulation resistance between internal conductors within a printed wiring board has the following key features for evaluating hole-hole CAF resistance (Figure 3).

**Table 2 Test Structures B1 through B4 Design Rules**

<table>
<thead>
<tr>
<th></th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer layer pad size</td>
<td>0.94 mm [0.0370 in]</td>
<td>0.89 mm [0.0350 in]</td>
<td>0.84 mm [0.0330 in]</td>
<td>0.75 mm [0.0300 in]</td>
</tr>
<tr>
<td>Inner layer pad size</td>
<td>0.94 mm [0.0370 in]</td>
<td>0.89 mm [0.0350 in]</td>
<td>0.84 mm [0.0331 in]</td>
<td>0.75 mm [0.0295 in]</td>
</tr>
<tr>
<td>Drilled hole size</td>
<td>0.81 mm [0.0319 in]</td>
<td>0.71 mm [0.0280 in]</td>
<td>0.57 mm [0.0224 in]</td>
<td>0.46 mm [0.0181 in]</td>
</tr>
<tr>
<td>Via edge to via edge (shortest distance)</td>
<td>0.26 mm [0.0102 in]</td>
<td>0.37 mm [0.0146 in]</td>
<td>0.51 mm [0.0201 in]</td>
<td>0.62 mm [0.0244 in]</td>
</tr>
<tr>
<td>Via edge to via edge (Manhattan Distance)</td>
<td>0.37 mm [0.0146 in]</td>
<td>0.52 mm [0.0205 in]</td>
<td>0.72 mm [0.0283 in]</td>
<td>0.88 mm [0.0346 in]</td>
</tr>
</tbody>
</table>

On IPC-9254 only, bias applied between: J7, J11 J8, J11 J9, J11 J10, J11

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IPA-2625-2

"Manhattan Distance" = \( a+b \)
Holes In-Line (in-line with glass fiber direction): There are two rows of 42 signal-1 vias intermeshed with three rows of 42 signal-2 vias; for a total of 168 potential in-line PTH-PTH failures for each spacing distance.

Holes Staggered (closest PTH-PTH spacing in diagonal direction): There are three rows of 26 signal-1 vias intermeshed with four rows of 27 signal-2 vias; for a total of 312 potential diagonal PTH-PTH failures for each spacing distance.

3.4 CAF Test Coupon/Board Quantity The CAF testing data analysis technique recommended for either of these CAF test coupon/board designs requires a minimum 25 CAF test boards to be run per sample lot per bias level for statistical significance. This provides a total of 4,200 potential in-line hole-hole CAF failure sites and 7,800 potential diagonal hole-hole CAF failure sites for each unique sample/condition set.

For comparison, on a 1,428 I/O BGA device (Figure 4) there are about 500 power/ground pins. So with an average of slightly less than two adjacent power/ground pin spacings per pin there are about 1,000 potential in-line hole-hole CAF failure sites per BGA device. For a production board with the equivalent of three of these BGA devices and about 1200 passives or other components with close power/ground pin spacings, the total number of opportunities for in-line CAF failure would then be about 4,200 (about the same as the entire CAF test board sample lot of 25 pieces).

As a general rule, there should be enough CAF test boards run within each sample test lot to have at least the equivalent number of potential CAF failure sites as on a single targeted specific application PWB.

4 Equipment/Apparatus or Material

4.1 Environmental Test Chamber A clean test chamber capable of producing and recording an environment of 65 ± 2 °C [149 ± 3.6 °F] or 85 ± 2 °C [185 ± 3.6 °F] and 87 ± 3% relative humidity, and that is equipped with cable access to facilitate measurement cables to be attached to the specimens under test.

4.2 Measuring Equipment A high resistance meter equivalent to that described in ASTM D-257, with a range up to $10^{12}$ ohms and capable of yielding an accuracy of ± 5% at $10^{10}$ ohms with an applied voltage of 100 ± 2 VDC, or an ammeter capable of reading 10⁻¹⁰ amps and capable of yielding an accuracy of ± 5% in combination with 100 ± 2 VDC power supply. The values of resistors used shall be verified by reference resistors traceable to known industry or national standards such as NIST.

4.3 Power Supply A power supply capable of producing a standing bias potential of 10 VDC up to 100 VDC with a
tolerance of ± 2 VDC, and current supply capacity of at least 1 Ampere (Amp).

4.4 Current Limiting Resistors  Tight control of the total current limiting resistance value is critical for this test method. One $10^6$ ohm resistor in series shall be used for each current path. Insert the current limiting resistors in series with the terminating leads going to each test pattern. Note that some test equipment has current limiting resistors built into the testing systems. For the purposes of this standard test, excluding the current limiting resistor and for each CAF test circuit, the total series resistance of the measuring equipment and wires shall not be more than 200 ohms. A lower total resistance value will increase potential for damage to the test board when a CAF failure occurs. A higher total current limiting resistance value for each test net removes test conditions further from actual field conditions and is not recommended.

4.5 Connecting Wire  Use PTFE- or PFE-insulated copper wires and solder the copper wire directly to the board to connect test points for each test board to the measurement apparatus.

4.6 Other Dedicated Fixtures  Hard-wiring is the default connection method. Other dedicated fixtures may be used, provided that the fixture does not change the resistance by more than 0.1 decade compared to a comparable hard-wired system when measured at the test conditions. These fixtures should be checked for their resistance values frequently.

5 Procedure

5.1 Test Specimen Preparation

5.1.1 Sample Identification  Use a method for identifying each test board that does not cause contamination, such as a scribe, making marks away from the biased area(s) of the specimen. Test boards shall be handled by the edges of the board only, and the use of noncontaminating gloves is recommended.

5.1.2 Prescreen for Opens and Shorts  Perform as-received insulation resistance measurements using a multimeter to make connection to each net, and check for gross defects. Check for shorts at a 1.0 megohm setting. No opens are allowed in connected nets.

5.1.3 Cleaning  Entirely clean each sample (CAF test board) per IPC Test Method 2.3.25 (Resistivity of Solvent Extract) by immersion washing until the level of ionic contamination is reduced to less than 1.0 microgram NaCl equivalent per square centimeter and for a maximum of 20 minutes. Boards not achieving this level of cleanliness within 20 minutes shall be scrapped for the purposes of this test.

5.1.4 Connecting Wire  Plated-through holes near one edge of the board may be used for connecting wire to each test circuit. Cover the test board with noncontaminating film to prevent flux spattering during the wire attach process. After stripping back the wire insulation, use water white rosin (per J-STD-004, Type B) and best soldering technique (per J-STD-001, Class 1 or 2) to solder (per J-STD-006, Type Sn63) PTFE- or PFE-insulated wires to the connection points on each test board. Ensure against damaging PWB laminate material adjacent to the plated holes during soldering by using appropriate time/temperature parameters for the soldering iron.

5.1.5 Cleaning After Attachment  Perform appropriate local cleaning and rinsing after the attachment of the connecting wires. Isolation resistance between connecting wire attachment sites should remain excellent through 96 hours conditioning. Note: Each CAF test failure that does occur during subsequent testing should be checked to determine whether the connecting wire attach area is the low resistance site. If the connecting wire attach area rather than the daisy chain area is the low insulation resistance site, then that test sample is no longer valid for data analysis.

5.1.6 Dry  Bake sample boards for six hours in a clean oven at $105 \pm 2 \, ^\circ C \ [221.0 \pm 3.6 \, ^\circ F]$.

5.1.7 Precondition  Precondition test board samples in a bias-free state (no electrical potential applied to any test pattern) for 24 hours minimum at $23 \pm 2 \, ^\circ C \ [73.4 \pm 3.6 \, ^\circ F]$ and $50 \pm 5\%$ relative humidity prior to any initial insulation resistance measurements [measuring insulation resistance of each daisy-chain net on each test board before starting the first 96 hours (± 30 minutes) of bias-free temperature and humidity conditioning].

5.1.8 Temperature/Humidity/Bias (T/H/B) Chamber  Place the specimens in the environmental test chamber in a vertical position such that the air flow is parallel to the direction of all test boards in the chamber. Allow at least approximately 2.5 cm [nominally 1.0 in] between each test board. Place the test boards, as much as possible, toward the center of the chamber to help ensure against nonoptimum air flow and/or drops.
of condensation falling onto the test boards. Dress all wiring away from the test patterns, keeping the wires away from the test patterns as they are routed to the outside of the chamber. Also, wire should not impede airflow around the samples. Set the chamber temperature and humidity with a ramp rate of one hour.

5.2 Test Procedures

5.2.1 Environmental Test Chamber Controls  Tight control of the test humidity is critical for this test method. A difference of 5% relative humidity can result in a 0.5 to 1.0 decade difference in measured resistance. If condensation occurs on the test specimens within the environmental chamber while the samples are under voltage, other dendritic growth can occur. Water spotting may also be observed in some ovens where the air flow in the chamber is from back to front, when water condensation on a cooler oven window can be blown around the oven as very small droplets that deposit on test specimens. This contributes to dendritic growth. These conditions should be eliminated to ensure meaningful test results. Although the environmental test chamber should be capable of producing and recording an environment of 65±2 °C [149±3.6 °F] or 85±2 °C [185±3.6 °F] with 87±3/-2% relative humidity. A range of ± 5% relative humidity may be permitted for short periods, not to exceed five minutes.

5.2.2 Resistance Measurements  Measure the insulation resistance of each test board daisy-chain net using 50 VDC per second rate of rise and minimum hold time of 60 seconds at 100 VDC test voltage. The polarity of the bias (conditioning) voltage and the polarity of the test (measurement) voltage must always be the same. 100 VDC applied voltage is used as the test voltage for insulation resistance measurements.

5.2.3 After initial insulation resistance measurements are taken, close the environmental test chamber and allow the test boards to stabilize for 96 hours (± 30 minutes) at the specified 65 ± 2 °C [149 ± 3.6 °F] or 85 ± 2 °C [185 ± 3.6 °F] with 87 +3/-2% relative humidity and no bias applied. After the 96 hour (± 30 minutes) stabilization period, insulation resistance measurements shall be made between each daisy-chain net and ground.

5.2.4 Ensure that all test board samples are connected and that the appropriate current limiting resistor is in series with each corresponding test circuit. Then, connect the test boards to the power supply to begin the T/H/B portion of the CAF testing.

5.2.5 Verify that the appropriate voltage bias is being applied for the duration of the test. For comparing the CAF resistance of different laminate materials and processes, use the CAF test standard of 100 VDC bias condition. For correlating test results to expected life in the field, the second bias voltage condition selected should be two times the maximum operating voltage differential for a given application. While a lower voltage may not discriminate between more CAF-resistant materials and processes, a higher voltage, which almost linearly affects time to failure, should also be avoided. This is because a higher voltage may offset the impact of humidity, a key part of the failure mechanism, due to localized heating.

5.2.6 The bias polarity should always be the same as the polarity used when measuring the insulation resistance after the 96-hour stabilization period.

5.2.7 It is recommended that additional resistance monitoring measurements be taken every 24 to 100 hours of bias (conditioning) voltage during the duration of the test, ensuring that the polarity of the insulation measurement voltage and the bias voltage are always the same. Decade drops in resistance, observed when these intermediate measurements are taken, also count as failures and improve the accuracy of the test since CAF filaments are very thin and are easily destroyed. Also when over 50% of the parts have failed, the test can be stopped. As CAF forms, the voltage delivered across the CAF failure site will drop as the resistance decreases. This becomes significant as the resistance of the net approaches the resistance of the current-limiting resistor, so adjustments to the voltage during the test are not required.

5.2.8 After 500 hours of applied bias (596 hours total), perform the insulation resistance measurements, as before.

5.2.9 Additional temperature/humidity/bias conditioning may be performed after 500 hours of bias, sometimes up to 1000 hours or more. However, the 500 hours bias testing results shall provide a minimum standard for reporting CAF testing results when using this procedure.

5.2.10 Suspect CAF test failures may be checked to determine whether the connecting wire attach area is the low resistance site rather than the daisy-chain area. This requires cutting the trace near the daisy chain (destructive). After all testing is completed, if the connecting wire attach area rather
than the daisy chain area is then found to be the low insulation resistance site, then that test sample is no longer valid for data analysis.

5.3 Data Handling and Analysis

5.3.1 Lognormal plots are recommended for plotting percent of samples above an insulation resistance value, versus insulation resistance. Use the log value of the insulation resistance.

5.3.2 If lognormal plots are not used, a test circuit failure shall be determined by more than a decade drop in insulation resistance as a result of the applied bias. The baseline for the decade drop shall be the average insulation resistance at 96 hours for each coupon (A-1, A-2, etc.).

5.3.3 Test board nets with less than 10 megohms insulation resistance (high resistance short) after the 96-hour stabilization shall be excluded, since these failures are due to poor PTH hole quality or laminate capability.

5.3.4 The insulation resistance baseline (before bias conditioning) value for a given daisy-chain net (same design spacing) shall be the average resistance of those un-shorted daisy-chain nets on all test boards in the valid sample group as measured after the 96-hours stabilization period.

5.3.5 The percent failure rate for a given sample group and subsequent test condition is the percent of test boards that show more than a decade drop in resistance compared with the baseline value for daisy-chain nets with the same design spacing.

5.3.6 For a given sample lot, there may be binomial failure distributions where assignable causes exist along with different levels of capability.

5.4 Visual Examination After completion of the test, the test boards shall be removed from the environmental chamber and examined at 10X magnification for evidence of surface insulation resistance failure (i.e., discoloration, corrosion), handling or processing defects other than CAF.

5.4.1 Assignable Cause Where an assignable cause of low insulation resistance can be properly attributed to a handling or processing defect other than CAF (i.e., contamination on the insulating surface of the board, scratches, cracks, or other obvious damage affecting the insulation resistance between the conductors), then such a value should be excluded.

5.4.2 CAF Microsections Since CAF filaments form along the interface between resin and the woven reinforcement, these filaments can be very small and easily disrupted by a relatively low current flow or other causes. Microsectioning to observe CAF filaments can be a tedious process with a low success rate.

5.5 Reporting Results

5.5.1 The percent failure rate at 500 hours for each spacing in sections A and B are the results of interest. Generally PWB processing has the greatest impact on reduced CAF resistance at smaller plated-through hole-to-plated-through hole (PTH-PTH) spacings, while the laminate material has the greatest impact at larger PTH-PTH spacings. However, the laminate material used can also affect the extent of fracturing and copper wicking near a PTH.

5.5.2 There are several additional factors that can affect CAF resistance. See APPENDIX A for the list of PCB manufacturing parameters that may affect CAF resistance and that should be documented.

6 Notes

6.1 Definitions [Only those terms not already included in IPC-T-50.]

a) Conductive Anodic Filament (CAF) Formation:
The growth of metallic conductive salt filaments by means of an electrochemical migration process involving the transport of conductive chemistries across a nonmetallic substrate under the influence of an applied electric field, thus producing Conductive Anodic Filaments.

b) Electrochemical Migration (ECM):
The growth of conductive metal filaments across or through a dielectric material in the presence of moisture and under the influence of voltage bias.

c) Electroless Nickel / Immersion Gold (ENIG):
This is a multi-functional surface finish wherein the electroless nickel layer is capped with a thin layer of immersion gold. It is applicable to soldering, aluminum wire bonding, press fit connections and as a contact surface. The immersion gold protects the underlying nickel from oxidation/passivation over its intended life.
d) **Maximum Operating Temperature (MOT):**
   An underwriters Laboratories Inc. (UL) requirement value of laminate materials as determined by the results of tests performed by UL.

e) **Organic Solderability Preservative (OSP):**
   A surface finish for fine pitch featured PCBs that are often assembled using surface mount components (SMCs). The OSP surface finish provides very flat/co-planar land areas for the placement and attachment of SMC devices.

f) **Printed Circuit Board Fabrication (PCB Fab):**
   This phrase alludes to the manufacturing of a bare printed circuit board that is not populated (assembled) with any discrete components.

### 6.2 Reference Documents

- **IPC-TR-476**  Electrochemical Migration: Electrically Induced Failures in Printed Wiring Assemblies
- **IPC-TM-650, Method 2.6.14.1**  Electrochemical Migration Resistance Test (note: covers only surface electrochemical migration)
- **IPC-9201**  Surface Insulation Resistance Handbook
APPENDIX A
Additional CAF Resistance Factors Checklist

Document for every CAF resistance test the several additional factors that can affect CAF resistance. These critical factors include:

<table>
<thead>
<tr>
<th>Needed Parameters</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test board revision level used.</td>
<td></td>
</tr>
<tr>
<td>Drilled Hole Size for each Hole-Hole and Hole-Plane spacing tested (also recommend drilling feed rate, speed of rotation, chip loading data, backup material type, etc.).</td>
<td></td>
</tr>
<tr>
<td>Type of desmear (permanganate, plasma, or ?).</td>
<td></td>
</tr>
<tr>
<td>Whether glass microetch was used (and if so, the controlling process parameters).</td>
<td></td>
</tr>
<tr>
<td>Board finish type (HASL or specific OSP, immersion silver, immersion tin, ENIG, etc.).</td>
<td></td>
</tr>
<tr>
<td>Laminate material type that was used (manufacturer and material name or number).</td>
<td></td>
</tr>
<tr>
<td>Type of soldermask (if used).</td>
<td></td>
</tr>
<tr>
<td>PCB Fab manufacturer and facility.</td>
<td></td>
</tr>
<tr>
<td>Method of separating test board from working panel.</td>
<td></td>
</tr>
<tr>
<td>Number of circuit layers in test board.</td>
<td></td>
</tr>
<tr>
<td>Copper thickness in plated through holes in test board.</td>
<td></td>
</tr>
</tbody>
</table>
1 Scope  This test measures changes in resistance of plated-through hole barrels and internal layer connections as holes are subjected to thermal cycling. Thermal cycling is produced by the application of a current through a specific coupon configuration.

In this technique, the test coupon is resistance heated by passing DC current through the internal layer connection to the barrel for three minutes to bring the temperature of the copper to a designated temperature. Switching the current on and off creates thermal cycles between room temperature and the designated temperature within the sample. This thermal cycling induces cyclic fatigue strain in the plated-through hole barrels and internal layer interconnects and accelerates any latent defects.

The number of cycles achieved permits a quantitative assessment of the performance of the entire interconnect.

Detailed information regarding the test is found in Section 6.

2 Applicable Documents


2.1.1 Microsectioning

2.1.1.2 Microsectioning - Semi or Automatic Technique

3 Test Specimens  A typical daisy chain test coupon is shown in Figure 1.

Figure 1

3.1 IST Coupon  Certain design rules must be applied to achieve thermal uniformity. Electronic design files for coupon construction are available from the IST test system provider. The coupon resistance should measure between 150 milliohms and 2.0 ohms when measured at elevated temperatures. Two resistance values (voltage drops) for each coupon are monitored independently, using a four wire measurement technique.

The test coupon(s) is incorporated on the panel to monitor or quality design, materials or processes and provide risk assessment of product and/or reliability assurance.

4 Apparatus or Material

4.1 Interconnect Stress Test System (IST) or equivalent.

IST SYSTEM DETAILS

This equipment is available from:

PWB Interconnect Solutions Inc.
195 Stafford Rd W Unit 105
Nepean, Ontario Canada K2H 9C1
(613)-596-4244
URL: www.pwbcorp.com

4.2 Two (2) four-pin, 2.54 mm [0.1 in] pitch male connectors (MOLEX 2241-4042 or equivalent)

4.3 Sn60Pb40 or Sn63Pb37 Solder

4.4 Solder Flux

4.5 Soldering Iron

4.6 Multimeter - optional

4.7 Thermal Imaging equipment - optional

5 Procedure

5.1 Sample preparation

5.1.1 Solder two four-pin male connectors in the 1.02 mm [0.040 in] holes at left and right edges of side one (1). A solder fillet must be apparent on both sides of the coupon.

5.1.2 Allow coupons to come to room temperature (approximately 10 minutes), prior to installation onto IST system.

5.2 IST Procedure

5.2.1 Position coupons at each test head by attaching male to female connectors.
5.2.2 Provide system software with specific test conditions. The available ranges and typical conditions are as follows:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>IST Range</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of samples</td>
<td>1-6 6</td>
<td></td>
</tr>
<tr>
<td>Test Temp</td>
<td>50°C to 250°C</td>
<td>150°C</td>
</tr>
<tr>
<td></td>
<td>[122°F to 422°F]</td>
<td></td>
</tr>
<tr>
<td>Max. Res. Chng</td>
<td>1-100% 10%</td>
<td></td>
</tr>
<tr>
<td>Max. No. Cycles</td>
<td>1-4000 250 (1 day)</td>
<td></td>
</tr>
<tr>
<td>Data Coll. Freq.</td>
<td>1-100 cycles 10 cycles</td>
<td></td>
</tr>
<tr>
<td>Cooling Ratio</td>
<td>0.5-2X heat time 0.66</td>
<td></td>
</tr>
<tr>
<td>Table Selection</td>
<td>system/custom system</td>
<td></td>
</tr>
</tbody>
</table>

5.2.3 Pre-Cycling Test Sequence The following paragraphs detail the sequence for a single coupon, however this sequence is done at all test heads simultaneously. The ambient resistance, target temperature resistance, rejection resistance and current is calculated for each coupon and displayed on the PC monitor.

CAUTION: Handling the coupons will raise the temperature of the coupon and may affect the ambient resistance calculation during the pre-cycling sequence. If the ambient temperature of the coupons is in question, cool the coupons with the fans on the IST equipment for one to two minutes.

5.2.3.1 Ambient Resistance The auto ranging multimeter measures the ambient resistance (voltage drop) of the coupon. This is the circuit that heats the coupon with DC current.

5.2.3.2 Target Temperature Resistance The system software calculates and displays the required “target” resistance (temperature). The available stress testing range is from 50°C - 250°C [122°F - 422°F]. The equation used to calculate the target resistance is as follows:

\[
\text{Target Resistance} = R_{\text{rm}} \left(1 + \alpha_T \left[T_n - T_{\text{rm}}\right]\right)
\]

where:

- \(\alpha_T\) = Estimated thermal coefficient of resistance for the interconnect
- \(R_{\text{rm}}\) = Resistance of coupon at room temp (approximately 25°C [77°F])
- \(T_n\) = Specified temperature to be achieved.
- \(T_{\text{rm}}\) = Room Temperature

5.2.3.3 Rejection Resistance The rejection resistance is calculated and displayed. This is adjustable from a 1% to a 100% increase. If 10% is selected, 10% of the target resistance is calculated and added to the original resistance to establish the rejection criteria.

5.2.3.4 Current The system selects an initial current based on the ambient resistance of the coupon and the current table. The current tables are derived from software libraries on the IST equipment. During the pre-cycling sequence, the initial current is adjusted for each coupon to assure the test temperature resistance is achieved in three minutes ± three seconds (see paragraph 5.2.3.5).

NOTE: Additional equations/algorithms used by IST that establish the initial current selection for pre-cycling, relative to the relationship of coupon interconnect resistance \(\alpha_T\), coupon construction and stress test temperature to be achieved are considered proprietary at this time.

5.2.3.5 Pre-cycling is initiated by the application of the selected current to the coupon, the computer monitors and records the coupon’s performance throughout this first cycle. If at the end of the first pre-cycle, the coupon achieves the specified resistance level in three minutes ± three seconds, it will be accepted for subsequent stress testing. If the resistance level was not achieved in this time frame, the coupon will automatically be pre-cycled again with a revised or compensated current. The system will re-test using revised conditions until all coupons are accepted or rejected for stress testing.

NOTE: The equation/algorithms used by IST to compensate the DC current is considered proprietary at this time.

5.2.3.6 Forced air cooling is commenced after each pre-cycle to cool the coupons. (Requires three minutes.)

5.2.3.7 The system automatically records and saves all information regarding conditions for subsequent stress testing.

5.2.4 When the pre-cycle sequence is complete, the IST system begins the thermal cycling of the coupons. The IST system continuously monitors the coupons and records the relative changes in resistance of both the barrel and the internal layer connections. Data is compiled for each coupon’s performance throughout IST stress testing. The system software provides a download file to graph the coupon’s performance. Data is compiled to create graphs of each coupon’s performance throughout IST stress testing.
5.3 Microsection Evaluation - Optional  If detailed failure analysis is desired to determine exact location of separations and/or cracks, then a multimeter or a thermal imaging system can aid in identifying the failure location. Microsection of failed coupons shall be performed in accordance with IPC-TM-650, Method 2.1.1 or 2.1.1.2.

6 Notes

6.1 Stress Cycle Test Sequence

6.1.2 The stress test is initiated by re-applying the same DC current level established for each individual coupon during the pre-cycle operation. Three minutes of heating is followed by two to three minutes of cooling. Cooling time is a function of overall thickness and construction of the coupon.

6.1.3 Individual coupons are continually recycled using their customized heating and cooling conditions until one of the rejection criteria is achieved or the maximum number of cycles is completed.

6.1.4 The coupon’s resistance “delta” (variance from initial calculated resistance) increases (positively) as failure inception occurs. The rate of change in the delta is indicative of the mechanical change (failure) within the interconnects.

6.1.5 When each coupon delta reaches the maximum resistance rejection criteria, IST stress testing is stopped. The rejection criteria prevents thermal runaway (burnout) plus allows for early intervention for failure analysis to be completed effectively.

6.2 Graphing and Data Analysis

6.2.1 The IST system continuously monitors the two independent circuits of each coupon, recording multiple points of each cycle until the coupon exceeds one of the rejection criteria. The data is compiled to create graphs of each or all coupon’s performance throughout IST stress testing. Figures 2, 3 and 4 are typical graphs.

6.3 The Test Methods Subcommittee is aware of other test systems that operate on principles similar to those used by IST. The subcommittee encourages their submission along with relevant test data. This test method will be revised as necessary to include these test systems as this information becomes available.