Performance and Reliability Test Methods for Flip Chip, Chip Scale, BGA and other Surface Mount Array Package Applications

Working Draft

5-21g Task Group

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Performance and Reliability Test Methods for Flip Chip, Chip Scale, BGA and other Surface Mount Array Package Applications

About this Document

This document is intended to report on the work being done by several organizations concerned with the design of bare die in flip chip or chip scale configurations. Details were developed by companies who have implemented the processes described herein and have agreed to share their experiences. Readers are encouraged to communicate to the appropriate trade associations or societies any comments or observations regarding details published in this document, or ideas for additional details that would serve the industry.

Users of this standard are encouraged to participate in the development of future revisions.

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Members of the EIA Soldering Technology Committee (STC) and the IPC Device Manufacturers Interface Committee (A-10) have worked together to develop this document.

We would like to thank them for their dedication to this effort. Any Standard involving a complex technology draws material from a vast number of sources. While the principal members of the Flip Chip Task Group are shown below, it is not possible

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J-STD-029

Performance and Reliability Test Methods for Flip Chip, Chip Scale, BGA and other Surface Mount Array Package Application

1 Scope

The scope of this standard is to provide identification and details of test methods required to ensure the quality and reliability of flip chip, chip scale, BGA and other surface mount array package products. The purpose is to establish test methods and acceptance criteria, to facilitate test data correlation between suppliers and users.

1.1 Presentation

All dimensions and tolerances in this standard are expressed in metric units with millimeters being the main form of dimensional expression. Inches may be shown in brackets as appropriate and are not always a direct conversion depending on the round-off or the required precision. Users are cautioned to employ a single dimensioning system, and not intermix millimeters and inches. Reference information is shown in parentheses ( ).

1.2 Interpretation

Shall, the emphatic form of the verb, is used throughout this standard whenever a requirement is intended to express a provision that is mandatory. Deviation from a shall requirement may be considered if sufficient data is supplied to justify the exception.

The words should and may are used whenever it is necessary to express non-mandatory provision.

Will is used to express a declaration of purpose.

To assist the reader, the word shall is presented in bold characters.

2 Applicable Documents

J-STD 030 Qualification and performance of Underfill Materials for Flip Chip and other micropackages

IPC-SM-785 Guidelines for Accelerated reliability testing of surface mount solder attachments

IPC-TM-650 Test methods: Microsectioning, General

3 General Approach to test for Performance and Reliability

Testing is done to confirm materials selection, to optimize production processes, to ruggedize products, and to predict the long term reliability of assemblies. It is critical that such testing include careful planning, design, and manufacturing of appropriate test vehicles, so that meaningful information can be derived from the results. Additionally, it is important to use good laboratory practices, when conducting testing, so that correct and accurate results are generated. The steps to consider, when planning for testing are covered in the following clauses. These include designing test vehicles as well as typical testing techniques such as event detection, temperature cycling, power cycling, vibration, etc.
3.1 Design and manufacturing of test vehicles

3.1.1 Test Planning

While planning for testing, attention is not only focused on evaluating the reliability of the solder joint connection to the substrate, rather the reliability evaluation of the entire interconnect is considered. This involves the total assembly such as plated through holes, blind and buried vias, sockets, packages, modules, motherboard, laminates, etc. The testing of the total interconnection system approach has proved to be very effective in identifying weak links in the overall interconnect reliability.

Typically, test vehicles are designed for Mechanical Deflection Testing (MDS), Accelerated Thermal Cycling Tests (ATC) and Power Cycling tests. Depending on specific requirements, designs are also developed to accommodate other testing and test conditioning. The most important characteristics of the test vehicle is that the resulting data is easy to derive and that it can be correlated to real life conditions.

3.1.2 Component Test Vehicles

Component Test vehicles come in two varieties: packaged die in the form of a BGA, Fine Pitch BGA or similar package structure or un-packaged die intended for flip chip or wire bonding applications. Test packages can be prepared with different kinds of die in them; namely (1) mechanical or dummy die, (2) Daisy Chained die (DC) or (3) thermal die. A typical test package may have both the DC and thermal die structure built inside. The interconnect method between the chip and the mounting substrate used within a package, if intended to represent an actual product, should be replicated and monitored during testing.

When a bare die is used as a component test vehicle the characteristics of the die should represent the process used to produce the semiconductor device. Thus tests performed on the bare die test vehicle can be correlated to data that will be used in final production of the Semiconductor, the semiconductor packaging, or the mounting of the completed component.

3.1.2.1 Daisy Chain Packages

Depending on the number of I/O on the target BGA and the total number of pins and the package type, the daisy chain structure is usually designed such that internal daisy chains on the test die cover the corner balls, balls along the periphery, along the sides, etc... As many sites as possible should be tested. Typically designs representing high IO count (>400) product have 70%-80% of the balls connected to the daisy chains. Lower IO count product (40 to 80) usually have 100% of the balls connected to the daisy chain. The most important parameter is to test the mechanical stresses on the balls at the corners of the package.

3.1.2.2 Thermal packages

Thermal packages consist of heater elements and thermal diodes built on to the test die. The resistance of the heater element and the number of such heater elements is a function of the rated power dissipation of the package. During operation, a calculated amount of power is fed to these heater elements and the junction temperature of the package is monitored via the thermal diodes.

There are test packages which have both daisy chain structure and thermal structure built on the same test package, and these are the choice packages to use for power cycling tests. For instance, daisy chain nets are used to monitor the reliability of the interconnect, while power cycling tests are conducted.
3.1.3 Test Boards

In order to evaluate the total interconnect, test boards are designed to mirror the real boards onto which the BGA packages are placed; i.e., number of layers, conductor width, conductor thickness, etc. The test board will have a similar construction as the production board, except the BGA sites would be designed for test packages, rather than for real packages, and fan out would allow probing of the test board in order to obtain interconnection reliability data.

Daisy chain nets are formed to cover the different regions of the package. Typically on high IO packages daisy chain nets group a number of solder balls together from sections that are likely to have different failure characteristics. These DC nets are brought out to a connector or probing sites on the test board. The connector design is done considering the type of monitoring to be accomplished, the stress environment and the type of monitoring equipment to be used. Typically, a company wide standard for these connectors are defined, so that test boards can be used anywhere. Daisy chain designs are part of all the boards that go through ATC and MDS tests.

Another consideration during the design process of the DC nets is fault isolation to the individual "via" or "ball", in case failures are detected during or after the test. The goal here is to trace the failure connector to an isolated ball or to a test board via. This aids the failure analysis process.

If test packages have both thermal and daisy chain features on them, the above rules apply in terms of doing the daisy chain net design. For the thermal side, to feed the right amount of power to the test package, normal considerations are given in terms of current and voltage levels that the conductors need to carry. Again, company wide standards are used to define the connectors that carry the power to the package. As an option, the thermal diodes in the package are also brought out to a separate connector, if Tj junction temperature monitoring is planned. Also, when the test vehicle has multiple packages of different types, care is exercised in making provisions to feed the required power to each test package.

3.1.4 Test Vehicle Preparation

After the test vehicle is designed and built, but prior to starting the tests, the integrity of the package assembly is verified via x-ray analysis. Also, time zero values of daisy chain net resistance from the connector are measured and recorded for each net. Similarly, the integrity of the heater chains and thermal diodes are manually verified and quantitative data is recorded. Prior to starting tests, the sensitivity of the test set-up and the monitoring equipment is verified. After all prep work and verification, the vehicles are ready for testing.

3.2 Typical testing techniques

Once appropriate and representative test vehicles are assembled, it is informative to learn more about the robustness and reliability of the assemblies, and whether or not the assemblies will be suitable for their intended application. Event detection, temperature cycling, power cycling, vibration, and other typical tests, which are used to evaluate ball grid array (BGA) and direct chip attach (DCA) assemblies, are presented in the following paragraphs.

3.2.1 Event Detection/Continuity Monitoring

Event detection is used to identify the point at which an electrical continuous circuit (or connection) increases to a predefined resistance threshold for a predetermined period of time. In the case of BGA and DCA assemblies, event detection is used to identify whether or not daisy chains (sometimes called nets, channels, circuits, or current paths) exhibit any intermittent operation during the application of adverse environments, i.e. temperature cycling, power cycling, vibration, and others.

Event detection equipment is commercially available and enables the simultaneous, real time monitoring of multiple channels. Each channel might consist of a series connection of several
solder balls. Such a connection permits monitoring the integrity of each solder ball to both the package and the substrate on which the package is mounted.

Electrical transients and other noise signals are sometimes inadvertently detected as events by the event detection equipment. Proper wiring, grounding, and shielding are important and help to minimize such unwanted false triggers of the event detection equipment. Control channels, which are shorted, electrically continuous channels can help to identify when the event is false.

Control channels can indicate false fails but use up nets and reduce equipment utilization. In case of certain board designs that cannot utilize all of the nets, the unused nets should be shorted and considered control channels.

As an example the IEEE test board is shown in Figure 1. The test specimen contains conductors and plated-through holes and parts connected in a single daisy chain. One end of the daisy chain is connected to a common ground while the other end of the chain is connected to land patterns, then to a plated-through hole in which a wire may be soldered for test purposes. The standard board contains eight position which can accommodate different land pattern designs.

![Figure 1 – General description of process validation contact pattern and interconnect](image)

Figure 2 shows an example of test circuits for various surface mount packages. During the cycling processes, daisy-chained plated-through holes and daisy-chained solder joints are measured during the initial phase as to their resistance, and then monitored for increased resistance during the thermal cycling. Increased resistance of 30 $\mu\Omega$ in most instances constitutes a failure of either the plated-through hole, or the solder joint.
3.2.1.1 Non Encapsulated Solder Joint Testing

A common misconception among some involved with event detection monitoring is that extremely low resistance thresholds are essential for effective detection of non encapsulated solder joint degradation. Figure 3 shows why solder joints can be monitored by using resistance thresholds as high as 100 or even 1000 ohms. This is, because the resistivity of solder is sufficiently low to maintain a low resistance path, regardless of the cross sectional area of the joint, as long as there is a solder connection. Even as the cross sectional area of a solder joint decreases, a low resistance path remains. It is typically only a few extra thermal cycles, or just a little more mechanical stress, that will cause a joint to go completely open, at which time its circuit will exhibit a high resistance spike, and at which time the defective joint can be detected as a failure by the event detection equipment.

\[ R = \rho \frac{\ell}{A} \]

\( \rho = \text{resistivity of solder (63/37)} \)
\( \rho = 145 \times 10^{-7} \ \Omega \cdot \text{cm} \)

A 1000x reduction in cross sectional area \((A)\) is not detectable by sensitive event

When first detected, a non encapsulated solder joint failure (event) is characterized by high resistance spikes (100 ohms +). These resistance spikes occur for brief periods of time, i.e.
nanoseconds, as a cracked joint makes and breaks upon itself; usually as a result of some externally applied stress. The intermittent failure or event is sometimes called a "soft" failure. A "hard" failure is a joint that consistently measures open circuit. The application of an adverse stimulus, i.e. temperature cycling, power cycling, mechanical stress, vibration, etc..., is typically required to accelerate and precipitate failures (events). This is why event detection monitoring is frequently, if not always, conducted in conjunction with the application of adverse environments and/or stimuli.

3.2.1.2 Encapsulated Solder Joint Testing

Encapsulated solder joints can crack and the cracked surfaces still be held tightly together by the encapsulation. The resistance can slowly increase over many cycles. Experience has shown slowly increasing resistance (20 to 100 ohms over several hundred cycles) can occur on encapsulated solder connections. These occurrences have been noted on flip chip solder bumps attaching chip to laminate, encapsulated with underfill materials (see J-STD-030). The monitoring equipment should be capable of detecting small increases (>5 ohms) and constantly chart the resistance along with time and cycle number for several cycles before a hard fail of an encapsulated solder joint is declared.

It should be pointed out that event detection equipment with low resistance monitoring thresholds is also important for use, when monitoring the integrity of electrical connections, like connectors. Electrical connectors have distinct contact interfaces, which can be compromised, and which can exhibit gradual increases in contact resistance. Such failure modes are different than the spiked increases in resistance typically observed, when solder joints fail.

The time domain, at which event detection monitoring is done is very important. This is especially true, when one considers the increased emphasis on today's high speed circuitry. An intermittency as brief as one nanosecond can disturb the proper transmission of a 1 gigahertz signal.

Event detection monitoring is usually used in conjunction with the application of some adverse environment and/or stimuli, to accelerate and precipitate defects. Any form of conditioning which is intended to simulate field or service life should be capable of being used with event detection equipment. The important thing to note about conducting accelerated life/reliability testing is that test results will have more meaning, if effective planning, good test design, sound laboratory practices, and proper interpretation of the results occur. Results can be particularly meaningful, if assumptions made about the acceleration factors of the testing are accurate and realistic.

3.2.2 Accelerated Life/Temperature Cycling

Temperature cycling and intermittent monitor can be conducted in a variety of ways. Usually cyclic tests are run between a low and high temperature with fifteen minute excursions between temperatures and fifteen minute dwells at each temperature extreme. If the package has more thermal resistance the dwell times may be longer. During the temperature cycling, dedicated monitoring equipment is used to monitor daisy chains or nets for intermittent operation. Monitoring equipment must be capable of automatically recording each failure/event by daisy chain net number, temperature cycle number, temperature at which it occurred, and the time and date of occurrence.

Typical details that need to be specified for conducting accelerated life/temperature cycling include but is not limited to the following:

- The physical size of the samples
- The number of samples to be tested
- The number of daisy chains (nets or channels) that will be monitored
• The time domain and resistance threshold settings for the monitoring (event detection) equipment
• The type of monitoring equipment to be used
• The harnessing requirements
• The temperature cycling profile

Other details that are helpful include the acceleration factor assumed for the applied environment, the type of reporting/data analysis that is required, and any pre or post test inspections that might be required. IPC SM 785 provides excellent guidance in the area of accelerated life/temperature cycling.

A typical temperature cycling testing procedure might start with samples being received, unpackaged, visually inspected, and numbered for traceability purposes. Photographs of any obvious anomalies are taken.

While it is not always a part of the procedure, some manufacturers prefer to subject their samples to an xray inspection, an ultrasonic inspection, an infrared inspection, initial microsectioning, or some other preliminary screening, to verify that the samples are manufactured properly and that they are adequate for testing purposes.

A four point resistance measurement may be made on each of the daisy chains that are to be monitored. This accomplishes three things. First, it provides a base line (initial resistance value), to which subsequent results can be compared. Second, it verifies that the daisy chains that are going to be monitored are electrically continuous. Third, it also helps the test operator familiarize himself with the configuration of the test board.

The samples should be harnessed in a logical, efficient fashion. The harnessing of the samples is done in a way that permits clear identification and traceability of the samples via the monitoring equipment (computer screen) display. High temperature, Teflon coated ribbon wire is typically used for harn essing. Harnesses consisting of a ribbon cable and connector are usually connected to the samples through the gold edge contacts on the test board. The samples are also instrumented with thermocouples. Care must be taken to assure that the thermocouples are in intimate contact with substrate, the package or near the solder joints on the test boards, so that an accurate measurement of the temperature response of the test samples can be made.

The samples are placed in a temperature cycling chamber such that there is room for sufficient air flow in and around the samples. The harnesses and thermocouples are routed from the chamber and they are connected to appropriate monitoring equipment, i.e. a datalogger, an event detector, a bit error rate detector, or some other suitable piece of monitoring equipment, which satisfies the particular objectives of the testing. Care is taken to ground and electrically shield the test setup, to minimize the unwanted effects of transients and other electrical noise. Event detection equipment is typically set to record events that exhibit a 100 ohm resistance, or greater, for a period of 200 nanoseconds or greater. A block diagram of the test set up appears in Figure 4.
The samples are subjected to a thermal mapping process, which is conducted to optimize the temperature cycling profile. The thermal cycling profile is optimized by verifying that all thermocouples mounted on the samples are actually reaching the desired temperature extremes and that the samples, and not just the chamber air temperature, are thermally tracking with respect to the desired temperature profile. If samples are not tracking well with respect to the desired temperature profile, then adjustments are made.

Repositioning samples in the chamber, adjusting the chamber air temperature profile, increasing the air flow, baffling the air flow, etc., are all techniques that can be used to optimize the temperature profile. The thermal mapping process is completed and the optimum temperature cycling profile is determined. Temperature cycling/event detection monitoring begins per the profile determined during the thermal mapping process. A typical temperature profile, which depicts the chamber program and the thermal response of the test samples, is depicted in Figure 5.
As temperature cycling is conducted, the event detection equipment is checked frequently. The definition of a failure should be agreed upon. A failure might be defined as the first confirmed event followed by at least nine additional such events within the next 20 cycles. A determination is made regarding the validity of any events detected. A careful study is made, to determine if events were caused by an actual failure of the device being tested, or if they were an artifact of the testing, i.e. a loose or disconnected harness, a transient signal, etc. Confirmed events are recorded on a spreadsheet, which tracks each event by daisy chain number, the temperature cycle (time) and the temperature at which it occurred, and whether the event is a soft or hard failure.

The temperature cycling, which allows for creep and stress relaxation of the solder joints, continues until a satisfactory number of cycles are completed, or until a certain percentage of the population fails.

Failure analysis and inspections can consist of electrical checks, x-ray inspection, ultrasonic, infrared, microsectioning, etc. The post test measurements and inspections are compared to the corresponding initial results, and they are also compared to the results obtained from the event detection equipment during temperature cycling testing/monitoring.

All data is recorded. The recorded data, which may consists of large computer data files from the monitoring equipment. Most data can be reduced into a spreadsheet format for analysis. Statistical calculations can be made on the data, to make predictions about the long term reliability of the samples. These predictions can be made with a fair degree of accuracy, provided that a realistic, legitimate assumption about the acceleration factor of the test can be made, and provided that a sufficient number of failures (events) are precipitated during the course of testing.

### 3.2.3 Power Cycling

Power cycling, like temperature cycling, involves cycling the temperature, so that the sample is exposed to rapid temperature excursions. However, unlike temperature cycling, power cycling does not use a temperature chamber to cycle the temperature. Temperature cycling is
accomplished by means of heater chains (electrical circuits) embedded in special power cycling test vehicles. These heater chains can be powered on and off to simulate and/or accelerate normal operation, and to achieve the desired thermal response for the test samples.

For IC component testing power cycling usually is conducted by running the rated voltage and current through a heater chain in the die. The power to the die is applied until the junction temperature is verified to reach 95° to 100°C. Then, power is turned off and the die is allowed to return to room ambient temperature conditions. A typical cycle usually takes one to two minutes for the samples to reach a junction temperature of 100°C and another 10 to 15 minutes for the samples to cool to room temperature. Numerous cycles are conducted. During the power cycling test, daisy chains are monitored for evidence of intermittent operation.

The thermal response of the test samples to the power cycling can be mapped by means of diodes that are built into the special power cycling test vehicles. The output of these diodes can be calibrated, so that the junction temperatures can be mapped, and so that the desired, optimum thermal response can be obtained during each cycle of power cycling.

During power cycling, daisy chains of solder joints are monitored by utilizing event detection equipment in very much the same way monitoring is done during temperature cycling testing. The important difference between power cycling and temperature cycling is that the heat is generated from within the package, not from the outside of the package, as with thermal cycling. Power cycling can be accomplished with timer relays, to cycle a power source On/Off, and it can be performed on a bench with laminar air flow. A block diagram, which shows a typical power cycling test set up, is included in Figure 6. Typical power cycling operating parameters and a profile are depicted in Figure 7. Data that is generated from the power cycling testing card be treated in much the same manner in which data for temperature cycling is handled.
3.2.4 VIBRATION

Vibration testing combined with intermittent monitoring is also conducted occasionally, to determine the potential for cold solder joints. This particular test is a mechanical forcing function that will precipitate latent manufacturing defects. Typically, a random vibration of approximately 6 G's RMS is applied and the samples are monitored for evidence of intermittent operation.

Vibration testing is usually applied in an axis that is perpendicular to the plane of the test boards. This is typically the worst case axis. A broadband random vibration spectrum is recommended to excite as many modes as possible in the test boards. A typical random vibration spectrum, which depicts typical test levels and duration, is included as Figure 8. The test boards are typically fixtured in a manner, which simulates the way in which they are mounted in the equipment or in the field. An improper fixture, which does not simulate a typical field installation, could produce invalid results.
1.1.1 Typical Random Vibration Spectrum
Applied in Axis Perpendicular to plane of Test

As is the case with temperature cycling and power cycling, daisy chains of solder joints are monitored for intermittent operation. A block diagram of a typical vibration test set up appears in Figure 9. One interesting thing to note about vibration testing is that it can be conducted with temperature cycling or power cycling to precipitate defects more rapidly.

3.2.5 Humidity/surface insulation resistance (biased and non-biased)

Humidity/surface insulation resistance (SIR) testing is conducted occasionally, to determine whether or not there is potential for dendritic growth underneath Flip Chip/BGA packages between conductors. This test is a measure of the cleanability underneath the package. This test can also be used to measure the compatibility of the various materials used in manufacturing the Flip Chip/BGA package or assembly. Biased temperature/Humidity test can be done on a test board to determine if there is potential for dendritic growth under power conditions in the real world.
3.2.6 Drop testing

Drop testing is a very transient event and a variation of the vibration testing indicated in 3.2.4. The test is a mechanical forcing function designed to precipitate catastrophic failures that might be encountered during mishandling of the package. Typically, the board fixture is in a card cage (rail) mounting configuration. This mounting configuration is then placed in some sort of chassis, to simulate the end assembly. The entire chassis is then dropped from a height of three to four feet onto a concrete surface, while daisy chains are monitored for intermittent operation.

3.2.7 Microsectioning

Before and after testing, microsectioning is done on test samples, to determine more about the metallurgy, registration, integrity of attachments, coplanarity, etc.. Microsections are evaluated under a metallographic microscope (standard light microscope with magnification capability from 400x up to 1,500x magnification). The higher magnification is adequate for evaluating BGA packages and some of the typical gross features that need to be checked.

3.2.8 Coefficient of thermal expansion

Coefficient of thermal expansion can be measured on packages by utilizing a thermal mechanical analyzer (TMA), microstrain gages or Moire Fringe Interferometry. When TMA is not appropriate, strain gages or Moire Fringe Interferometry can measure CTE. Many manufacturers want to know the CTE's of the materials used in the construction of their packages. By using microstrain gages, evaluating the CTE's of entire packages can be done as well as measuring the CTE's of individual pads on the component or lands on the substrate.

3.2.9 Other test and evaluation procedures

Scanning electron microscopy or photographs can be used to document before and after testing of samples. Sems can also be used to evaluate fine structure details like solder grain structures. Xray pictures can be used to document samples with before and after subjecting them to adverse environmental conditions. Scanning acoustic Microscopy is useful in evaluating any voids that may exist in the package. It is not able to identify fine line separation or microcracks at the package/board interface. However, many manufacturers find it useful 'as a technique to evaluate voids in epoxies. Shear testing is a mechanical test that measures the strength of solder joints. Pull testing is similar to shear testing.

4 ACCURACY, PRECISION, and RESOLUTION

Errors and uncertainties are inherent in all measurement processes. One needs to determine valid estimates of the amount of error and uncertainty to be taken into account.

Test data serves a number of purposes which include:

- to monitor a process.
- to enhance confidence in quality conformance.
- to arbitrate between customer and supplier.

In any of these circumstances, it is essential that confidence can be placed upon the test data in terms of:

- Accuracy: calibration of the test instrument and/or system.
- Precision: the repeatability and uncertainty of the measurement.
- Resolution: the suitability of the instrument(s) and/or system for the test
4.1 Accuracy (Calibration)

The regime by which routine calibration of the test equipment is undertaken shall be clearly stated in the quality documentation of the supplier or agency conducting the test. The calibration should be conducted by an agency having accreditation to a national or international measurement standard. There should be an uninterrupted chain of calibration to a national or international standard. Where calibration to a national or international standard is not possible, "round robin" techniques may be used, and documented, to enhance confidence in measurement accuracy.

The calibration interval shall normally be once a year. Equipment consistently found to be outside acceptable limits of accuracy shall be subject to shortened calibration intervals. Equipment consistently found to be well within acceptable limits may be subject to relaxed calibration intervals. A record of the calibration and maintenance history should be maintained for each instrument. These records should state the uncertainty of the calibration technique (in +/- % deviation) in order that uncertainties of measurement can be aggregated and determined. A procedure shall be implemented to resolve any situation where an instrument is found to be outside calibration limits.

4.2 Precision

The uncertainty budget of any measurement technique is made up of both systematic and random uncertainties. All estimates shall be based upon a single confidence level, the minimum being 95%. Systematic uncertainties are usually the predominant contributor, and will include all uncertainties not subject to random fluctuation. These include:

- Calibration uncertainties.
- Errors due to the use of an instrument under conditions which differ from those under which it was calibrated.
- Errors in the graduation of a scale of an analogue meter (scaleshape error).

Random uncertainties result from numerous sources but can be deduced from repeated measurement of a standard item. Therefore, it is not necessary to isolate the individual contributions. These may include:

- Random fluctuations such as those due to the variation of an influence parameter. Typically, changes in atmospheric conditions reduce the repeatability of a measurement.
- Uncertainty in discrimination, such as setting a pointer to a fiducial mark, or interpolating between graduations on an analogue scale.

Geometric addition (root-sum-square) of uncertainties may be used in most cases. Interpolation error is normally added separately and may be accepted as being 20% of the difference between the finest graduations of the scale of the instrument. Random uncertainty can be determined by repeated measurement of a parameter, and subsequent statistical manipulation of the measured data. The technique assumes that the data exhibits a Normal (Guassian) Distribution.

4.3 Resolution

It is paramount that the test equipment used is capable of sufficient resolution. Measurement systems used should be capable of resolving 10% (or better) of the test limit tolerance.

It is accepted that some technologies will place a physical limitation upon resolution. (eg: optical resolution)

In addition to requirements detailed in the test specification, the report shall detail:

- The test method used.
- The identity of the sample(s).
- The test instrumentation.
- The specified limit.
- An estimate of measurement uncertainty, and resultant working limit for the test.
- The detailed test results.
- The test date, and operators signature.

4.4 STUDENT’S "t" DISTRIBUTION

Table 1 gives values of the factor "t" for 95% and 99% confidence levels, as a function of the number of measurements. It is usually sufficient to use 95% limits.

<table>
<thead>
<tr>
<th>Sample Size</th>
<th>t value 95%</th>
<th>t value 99%</th>
<th>Sample Size</th>
<th>t value 95%</th>
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<td>4.3</td>
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<td>2.14</td>
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<tr>
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<td>3.18</td>
<td>5.84</td>
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<td>2.13</td>
<td>2.95</td>
</tr>
<tr>
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<td>2.78</td>
<td>4.6</td>
<td>17</td>
<td>2.12</td>
<td>2.92</td>
</tr>
<tr>
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<td>2.57</td>
<td>4.03</td>
<td>18</td>
<td>2.11</td>
<td>2.9</td>
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<tr>
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<tr>
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<td>3.36</td>
<td>21</td>
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<tr>
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<td>2.2</td>
<td>3.11</td>
<td>24</td>
<td>2.065</td>
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</tr>
<tr>
<td>13</td>
<td>2.18</td>
<td>3.05</td>
<td>25</td>
<td>2.06</td>
<td>2.79</td>
</tr>
</tbody>
</table>

4.5 Suggested Uncertainty Limits

The following target uncertainties are suggested:

a) Voltage <1kV : +/- 1.5%

b) Voltage >1kV : +/- 2.5%

c) Current <20A : +/- 1.5%
d) Current >20A : +/- 2.5%

Resistance
e) Earth & Continuity : +/- 10%
f) Insulation : +/- 10%
g) Frequency : +/- 0.2%

Time
h) Interval <60seconds : +/- 1 second
i) Interval >60seconds : +/- 2%

j) Mass <10g : +/- 0.5%
k) Mass 10g - 100g : +/- 1%
l) Mass >100g : +/- 2%
m) Force : +/- 2%
n) Length <25mm : +/- 0.1mm
o) Length >25mm : +/- 0.5%
p) Temperature <100 °C : +/- 1.5%
q) Temperature >100 °C : +/- 3.5%
r) Humidity 30 - 75% RH : +/- 5% RH

**Plating Thicknesses**
s) Backscatter Method : +/- 10%
t) Microsection : +/- 2 microns
u) Ionic Contamination : +/- 10%

### 5 Catalog of Approved Test Methods

There are numerous tests that can be conducted to verify the robustness of direct chip attach, CSP or BGA assemblies and the manufacturing processes used to make them. For instance, mechanical deflection, die shear, pull testing, humidity/SIR, ultrasonic inspections, xray evaluations, infrared analyses, computer modeling, microsectioning, and other tests can be done, to evaluate BGA and/or direct chip attach assemblies.

Frequency of testing depends on type of test and purpose.
- Design Process/Package verification may only need to be done first time
- Process control tests are done on a lot by lot or daily basis
- Reliability tests may be done on a lot by lot or audit basis

The objective of this standard is to provide specific test methods in complete detail with to permit implementation with minimal cross referencing to other specific procedures. The use of generic conditioning exposures is accomplished in the methods by reference to test methods already in use and documented in IPC-TM-650. When referenced as applicable methods is a mandatory part of the test method standard.

Each method has its own title, number and revision status to accommodate updating and improving the methods as industry requirements change or demand new methodology. The methods are organized in test method groups and individual tests. The tests are grouped according to the following principles.

P: Preparation/Conditioning Test Methods
V: Visual Test Methods
D: Dimensional Test Methods
C: Chemical Test Method
M: Mechanical Test Methods
E: Electrical Test Methods
N: Environmental Test Methods
X: Miscellaneous Test Methods

To facilitate reference to the tests, to retain consistency of presentation, and to provide for future expansion, each test is identified by a number (assigned sequentially) added to the prefix letter showing the group to which the test method belongs.
The test method numbers have no significance with respect to an eventual test sequence; that responsibility rests with the relevant specification that calls for the method being performed. The relevant specification, in most instances, also describes pass/fail criterion.

The letter and number combinations are for reference purposes, to be used by the relevant specification. Thus "D02" represents the second dimensional test method described in this J standard. i.e. J-STD-029 method D02.

6 P: Preparation/Conditioning Test Methods

Under consideration

7 V: Visual Test Methods
7.1 Test V01: Visual workmanship assessment at magnification (non-measurement)

7.1.1 Scope

This test method is for the visual assessment of the flip chip physical attributes. This is a visual assessment and not an actual measurement.

7.1.2 Applicable documents

None.

7.1.3 Test Specimen

This is a final flip chip wafer visual inspection. No wafer preparation is necessary. A low volume process sample size should be 100 die per wafer/every wafer in a lot. A high volume mature process sample size is 10 die per wafer/10 wafers a lot.

7.1.4 Test Apparatus and materials

A metallurgical type microscope with an automatic cassette to cassette wafer handler is used. Visual inspection of flip chip bumps is done at 50x magnification. (i.e. 10x objectives and 5x magnification lens) Higher magnifications may be used to verify that a rejected defect really exists.

7.1.5 Procedure for visual inspection

1. Turn on microscope. Make sure illuminator light is on.
2. Place cassette of wafers on microscope wafer loader handler.
3. Verify microscope wafer magnification 5x for (50x magnification)
4. Push LOAD button to move wafer in position for inspection.
5. Move wafer to 5 designated areas of the wafer (4 quadrants and center)
6. Visual specified amount of die in each area.
7. Visual for flip chip bump non-conformances (see section 7.0)
8. Verification that a defect is present may be done at higher magnifications.
9. Record all non-conformances by category on a record sheet.
10. Push LOAD button to remove inspected wafer and load next wafer.

7.1.6 Report

Record all none conformances on the visual log sheet. Summarize the log sheet and record summary information on the Q. C. lot summary sheet.

7.1.7 Additional Information - Non-conformance definitions

1. Missing bump - Any bump where the underlying metal (UBM) is exposed.
2. Bump shorts - Any two bumps that are unintentionally connected or shorted.
3. Damaged bump - Any bump which has been damaged by a certain percent (usually 25% or 50% depending on the type bump and/or process).
4. Oversize bumps - A non-measurement gross visual assessment (typically 50% oversize)
5. Bump Alignment - Bump alignment should not be more than 25% off center from the underlying bump metal (UBM).
6. Edge Cracks- Die edge cracks should not go into the active area (diffusion area) of the die.
7. Contamination/Residue - Any discoloration or residue on the bump.
8. Bump consistency - Repetitive characteristics of the bump which can be visualized. (i.e. height, size, shape, texture) This depends on the type bump and/or process.
7.2 Test V02: Physical Assessment at Magnification (Bump Diameter)

7.2.1 Scope
This test method is for the physical assessment of the flip chip physical attributes of bump shape at magnification.

7.2.2 Applicable documents
None

7.2.3 Test Specimen
This is a final flip chip wafer bump diameter measurement inspection. No wafer preparation is necessary. A low volume process sample size should be 10 die per wafer/every wafer in a lot. A high volume mature process sample size is 5 die per wafer/10 wafers a lot.

7.2.4 Test apparatus and materials
A metallurgical type microscope with an automatic cassette to cassette wafer handler with a measurement system to determine table travel is used. Bump diameter measurement of flip chip bumps is done at 40x magnification. (i.e. 10x objectives and 4x magnification lens) Laser scanning systems may also be used to determine bump diameter.

7.2.5 Procedure for visual
1. Turn on microscope. Make sure illuminator light is on.
2. Place cassette of wafers on microscope wafer loader handler.
3. Verify microscope wafer magnification 4x for (40x magnification)
4. Push LOAD button to move wafer in position for measurement.
5. Move wafer to 5 designated areas of the wafer (4 quadrants and center)
6. 10x magnification can be used to locate the bump to be measured.
7. If not at 40x magnification go to 40x. The bump should fill the viewing area.
8. Align cross hair on one side of the bump.
10. Move cross hair to other side of the bump by turning thumbscrew dial.
11. Record digital reading from display to the QC log sheet.
12. Measure bump diameter on specified amount of die in each area.
13. Record all bump diameter data on a record sheet.
14. Push LOAD button to remove wafer and load next wafer.

7.2.6 Report
Record all data in the bump diameter log sheet. Summarize the log sheet and record summary information on the Q. C. lot summary sheet.
7.3 Test V03: Physical Assessment at Magnification (Bump Height measurement)

7.3.1 Scope
This test method is for the characterization of the physical bump height of flip chips using a microscope with measurement capability.

7.3.2 Applicable Documents
None

7.3.3 Test Specimen
This is a final flip chip wafer bump height measurement test. No wafer preparation is necessary. A low volume process sample size should be 10 die per wafer/every wafer in a lot. A high volume mature process sample size is 2 die per wafer/every wafer in a lot.

Note - Inspection equipment is being developed to use laser scanners for 100% wafer bump height measurement. This bump height inspection will be a pass/fail inspection and not actual bump height measurements.

7.3.4 Test Apparatus and materials
A bump height measuring system that incorporates a metallurgical microscope and an automatic cassette to cassette wafer handler is used. Laser scanning systems may also be used to determine bump height.

7.3.5 Procedure for visual
1. Turn on power for microscope system, computer and, wafer handler.
2. On the computer display, select proper bump measurement program.
3. Press 'run' on keyboard.
4. Select device type in the program and press 'load' key (F-10).
5. Place cassette of wafers on the first wafer loader elevator.
6. Press 'start' key (F-10).
7. The Zeiss system optics will move across the wafer in predetermined areas and measure bump height automatically. The whole cassette of wafers will be automatically measured. Accept wafers will be loaded on a second cassette. Reject wafers will be loaded on a third cassette.
8. When the cassette is finished, it will ask you if you have another cassette. Press F1 key to end or 'enter' key to load another cassette. If 'enter' key is pressed, load another cassette of wafers and press 'enter' again.
9. When finished with lot inspection, rerun reject wafers to verify the wafers are bad.
10. Remove good wafer cassette and bad wafer cassette if necessary.
11. Press end inspection key (F1).
12. The end inspection screen will now appear. Press 'Store' data (F7).
13. The program now asks for a file name. Enter the lot number.
7.3.6 Report
Record all non-conformance's on the Q.C. log sheet. Record data summary information from the computer display to the Q.C. bump height log sheet.

8 D: Dimensional Test Methods
Under consideration

9 C: Chemical Test Method
Under consideration

10 M: Mechanical Test Methods
10.1 Test M01: Bump Shear Test - Final Wafer Test

10.1.1 Scope

This Test Method is for the Flip Chip Wafer Bump Shear Test.

10.1.2 Applicable documents

None

10.1.3 Test Specimen

This is a final flip chip wafer bump shear test. No wafer preparation is necessary. Shear testing is a destructive bump test. The shear should be done on test pattern die on the wafer. A low volume process sample size should be 2 bumps per wafer/every wafer in a lot. A high volume mature process sample size is 1 bump per wafer/10 wafers a lot.

10.1.4 Test Apparatus and materials

There are several bump shear machines available. A typical machine is a Kellar Technology Shear Machine Model 80. A second shear machine is manufactured by Dage Inc.

10.1.5 Procedure for Bump Shear

1. Machine setup. Set bump shear speed to be a minimum of 0.1mm per second.
2. Power up machine if not already on. Make sure red ready light is on.
3. Make sure test frame is up, vacuum is off, and illuminated lights on.
4. Place wafer on the vacuum chuck centering the test pattern die under the shear tool.
5. Turn on vacuum switch. Using the tilt frame adjustment knob and joystick, position the shear tool behind the bump.
6. Focus the microscope so the bumps in the center of field are well defined.
7. If the shear tool appears too high or low behind the bump, use the height adjustment switch to raise or lower it. The ideal shear tool height is half way up the bump, unless the bump is a mini-bump copper bump in the solder jacket. In this instance the shear height is above the internal copper bump. It is important that the shear tool not be too low and drag on the surface of the slice as it shears the bump. Also, if the shear tool is too high, it will ride over the bump. Both situations will result in inaccurate readings.
8. Check readout meter for 0 gram reading. If not, hit reset button.
9. Push the shear button.
10. Record the shear value from the display on the appropriate log sheet.
11. Tilt test frame up, turn off vacuum, and remove the wafer.

10.1.6 Report

Record all readings on the Q. C. lot summary sheet. If any bump shear readings are below the statistically determined process limit. reject the lot.
10.2 Test M02: Bump Resistance Test

10.2.1 Scope
This is a test method for checking the resistance of bumps through a prescribed bump test pattern on a wafer.

10.2.2 Applicable documents
None

10.2.3 Test Specimen
This test method is a final flip chip wafer bump resistance test. No wafer preparation is necessary. Bump resistance testing is a non-destructive bump test. The bump resistance test is to be done in a bump test pattern on the wafer. A low volume process sample size should be 2 bump test sites per wafer/every wafer in a lot. A high volume mature process sample size is 1 bump test site per wafer/10 wafers a lot. A typical bump test pattern is a two bump test structure with an aluminum metalization interconnect. The two bump test structure is probed for the bump resistance test. Another choice is to use a three bump test pattern with an aluminum interconnect. The three probe/bump sites are used for Kelvin probes.

10.2.4 Test Apparatus and materials
Any manual or semi-automatic wafer prober can be used to perform the bump resistance test. The Probe card uses two probes per bump for probing on the two bump test pattern. This allows for a Kelvin connection to be made to top of the bumps. A low resistance Kelvin ohm meter is used. Any multimeter with force and sense connectors can be used for bump resistance measurements.

10.2.5 Procedure for Bump Resistance Test
1. Power up machine if not already on. Make sure red ready light is on.
2. Center microscope and illuminator beam on probes, focus if necessary.
3. Depress the PROBE RING button to raise the stage.
4. Release the vacuum and move the chuck out away from the probe for wafer loading.
5. Place wafer on the vacuum chuck with the correct wafer flat orientation.
6. Depress the VACUUM switch.
7. Depress the side button on the arm and move the wafer under the probes until the test pattern die is in position under the probes.
8. Lower the probe into proximity position by depressing the PROBE RING button.
9. Focus the microscope on the bump test pattern in the center of field.
10. Fine align test pattern bumps to the probe card probes by using the joystick.
11. Depress the TEST button. This lowers the probes to the top of the bumps.
12. Observe bump resistance reading. If it is not steady, use the micrometer dial to slowly lower the probes until the reading is steady.
13. Record bump resistance reading.
14. Depress the PROBE RING button to raise the ring.
15. Depress the side button and move out the chuck.
15. Depress the VACUUM button to release the wafer.
16. Take wafer off the chuck.

10.2.6 Report

Record all readings on the Q. C. lot summary sheet. If any bump resistance readings are below the statistically determined process limit, reject the lot.
10.3 Test M03: Test Ua₂ - Thrust

10.3.1 Scope

The purpose of this test is to verify that the terminations and attachment of the terminations to the body of the component will withstand such thrusts as are likely to be applied during normal assembly or handling operations. This test applies only to specimens of small dimensions and of low mass, to the exclusion of equipment and assemblies.

Note: This test does not apply to flexible terminations.

10.3.2 General description

With the termination in its normal position and the component held by its body, thrust is applied to the termination as close to the body of the component, but leaving a clear 2 mm of wire between the body of the component and the nearest point of the device applying the force. The force shall be applied progressively (without any shock) and then maintained for a period of 10 s ± 1 s.

10.3.3 Preconditioning

The method of preconditioning shall be as prescribed in the relevant specification.

10.3.4 Initial measurements

The specimen shall be visually inspected and electrically and mechanically checked, as required by the relevant specification.

10.3.5 Test method

Refer to figure 2b.

10.3.5.1 Application

The relevant specification shall state whether this test is applicable. When applicable, it shall be carried out on all the terminations, except where a component has more than three terminations, in which case the specification shall state the number of terminations per component to be tested. The test shall be carried out in such a manner that all the terminations of the component have an equal probability of being subjected to test. The relevant specification shall define the direction of applied force.

10.3.5.2 Procedure

With the termination in its normal position and the component held by its body, thrust shall be applied to the termination as close as possible to the body of the component, but leaving a clear 2 mm of wire between the body of the component and the nearest point of the device applying the force. The force shall be applied progressively (without any shock) and then maintained for a period of 10 s ± 1 s.

The value of the applied force is as follows:

1. Wire terminations (circular section or strip) or pins
   The value of the force applied shall be as given in table 3.
Table 3  Value of applied force for test Ua₂

<table>
<thead>
<tr>
<th>Nominal cross-sectional area (S)* mm²</th>
<th>Corresponding diameter (d) for circular section wire mm</th>
<th>Force with tolerance of ± 10% N</th>
</tr>
</thead>
<tbody>
<tr>
<td>S ≤ 0.05</td>
<td>d ≤ 0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>0.05 &lt; S ≤ 0.10</td>
<td>0.25 &lt; d ≤ 0.35</td>
<td>0.5</td>
</tr>
<tr>
<td>0.10 &lt; S ≤ 0.20</td>
<td>0.35 &lt; d ≤ 0.50</td>
<td>1</td>
</tr>
<tr>
<td>0.20 &lt; S ≤ 0.50</td>
<td>0.50 &lt; d ≤ 0.80</td>
<td>2</td>
</tr>
<tr>
<td>0.50 &lt; S ≤ 1.20</td>
<td>0.80 &lt; d ≤ 1.25</td>
<td>4</td>
</tr>
<tr>
<td>S &gt; 1.20</td>
<td>d &gt; 1.25</td>
<td>8</td>
</tr>
</tbody>
</table>

Insulated wires shall be stripped of the insulation at the point at which the load is applied. Where the technical features of insulated wires may give rise to difficulties during the stripping, and be liable to cause dispute for the test results, such operations shall be in accordance with the relevant specification or, where necessary, with the instructions of the component manufacturer.

2. Other terminations (tag terminations, threaded studs, screws, terminals, etc.)

   The value of the force to be applied shall be given in the relevant specification.

10.3.5.3 Final measurements

The specimen shall be visually inspected and electrically and mechanically checked, as required by the relevant specification.

10.3.5.4 Information to be given in the relevant specification

1. Method of preconditioning
2. Initial measurements
3. Indication as to whether the test is applicable.
4. Number of terminations to be tested, if more than three
5. Direction of applied force
6. Details of stripping, if necessary
7. Force, for other than wire terminations or pins
8. Final measurements
10.4 Test M04: Test Ue1 - Substrate bending test

10.4.1 Scope
The purpose of this test is to assess the mechanical robustness of surface mounting device (SMD) terminations mounted on a substrate using a specified method. The terminations consist of metallized portions on non-conductive parts of the component or of short, partly flattened metallic parts.

10.4.2 General description
Epoxide woven glass fabric copper-clad laminated sheet, general purpose grade with foil bonded to one side and a nominal thickness of the sheet, including the metal foil, of 1.6mm with a tolerance of ± 0.010mm.

The substrate pattern of figures 5, 6 or 8 is preferred but not required.

Note: These patterns are basically applicable to two-terminal device.

The relevant specification shall prescribe all additional details, including whether the specimen may be a non-operative device.

The test shall be made under the standard atmospheric conditions for measurement and tests as given in 5.3 of IEC 60068-1.

The tests are destructive because mounted specimens are required and cannot be reused. Different specimens will be required for each test.

10.4.3 Mounting
The dimensions for the soldering lands on the substrate shall be prescribed by the relevant specifications.

For the mounting of the specimen on the test substrate, the relevant specification shall prescribe the method to be selected, preferably from the following list, with all the necessary details (see 8.3.3):

1. solder bath;
2. solder wave, single or double;
3. reflow soldering with heating by one of the following means:
   - solder bath
   - hot plate
   - oven or conveyor oven (including infra-red radiation)
   - hot gas jet
   - vapor phase condensation
4. microweld/bonding

10.4.4 Mounting method for pull-off, push-off and shear
When the details of mounting are not prescribed by the relevant specification, the method of mounting shall be as follows:

1. Choice of solder paste
a) A solder paste, made from solder as specified in annex B of IEC 60068-2-20 (see note 1 below) or 63% tin and 37% lead may be used and mildly activated flux (see note 2 below) as specified in annex C of IEC 60068-2-20. Silver (2 weight % or more) can be added in accordance with the relevant specification. The contamination limits of the solder shall comply with ISO 9453.

Note 1: The solder has the following composition: tin 59% to 61%; antimony 0.5% maximum; copper 0.1% maximum; arsenic 0.05% maximum; iron 0.02% maximum; remainder lead.

Note 2: The activated flux has the following composition: colophony 25 g; 2 propanol (iso-propanol) or ethyl alcohol 75 g; diethylammonium chloride 0.39 g.

b) The viscosity of the solder paste shall be in accordance with the relevant specification.

c) The particle mesh size of the solder paste shall be 160 or finer.

d) The footprints shall be covered with solder deposit. The thickness of the solder deposit shall be between 100 µm and 250 µm; the thickness shall be specified in the relevant specification.

2. Preparation of the specimen

a) The specimen surface to be tested shall be in the "as received" condition and shall not be touched by fingers or otherwise contaminated.

b) The specification shall not be cleaned prior to the test. If required by the relevant specification, the specimen may be immersed in an organic solvent at room temperature for preconditioning.

c) Preconditioning

d) Specimens which need preconditioning shall be pretreated in accordance with the relevant specification.

3. Positioning of the specimen

a) The specimen shall be placed symmetrically on its footprint.

4. Preheating

a) Soldering shall be performed immediately after preheating.

b) As long as the soldering conditions do not lead to a thermal load, which exceeds the SMD specification, any kind of reflow oven or vapor phase soldering oven may be used.

c) The solder temperature shall be between 215°C and 235°C and the time at the peak temperature shall not exceed 10 s. During soldering the total time above 185°C shall be 45 s minimum.

d) Care should be taken that complete wetting is achieved.

e) The soldered area of the substrate shall be cleaned using 2-propanol (iso-propanol) or water to remove surplus flux. If necessary, the details of the cleaning method shall be specified in the relevant specification.

f) The solder fillet shall comply with the minimum requirements for the relevant joint given in IEC 61191-2.

10.4.5 Initial measurements

Visual inspection of the specimen shall be made with a magnification of at least 10x under adequate light (e.g., 2 000 lx). If specified in the relevant specification, electrical and/or mechanical characteristics shall be measured. The strength of the solder weakens with time and this will influence the test results.
Unless otherwise specified in the relevant component specification, the test shall be performed after 24 h ± 6 h.

10.4.6 Test Ue6: Substrate bending test

This test is suitable for all devices except those intended for mounting on rigid substrates only.

Note: It is the responsibility of the manufacturer or supplier of the device to indicate whether it is intended for mounting on rigid substrates only.

10.4.6.1 Object

The purpose of this test is to verify that pliable terminations and attachment of these terminations to the body of the component shall withstand such bending loads as are likely to be applied during normal assembly or handling operations.

10.4.6.2 Test

The specimen shall be mounted on the test substrate (see figure 5) according to 8.3. The geometry of the specimen should be taken into account when selecting its position on the substrate and, therefore, when defining the dimensions of the solder lands.

The test substrate with the specimen is placed in the bending jig (see figure 7) and gradually bent to a depth, D, of 1mm, 2mm, 3mm, or 4mm. The value of D and its tolerance shall be prescribed in the relevant specification. The substrate shall be maintained in the bent state for 5 s ± 1 s, unless another time is prescribed in the relevant specification. The bending force shall then be released. The relevant specification shall prescribe, where necessary, a critical (electrical) parameter to be monitored throughout the period during which the specimen remains bent under test.

10.4.7 Final measurements

10.4.7.1 Recovery

Components which need recovery treatment shall be treated in accordance with the relevant specification.

10.4.7.2 Visual examination of terminations

Visual inspection of the specimen shall be made under adequate light (e.g., 2 000 lx), with a magnification of at least 10x. The joints between the specimen terminations and the specimen body shall be inspected. There shall be no visible evidence of rupture or cracking. The termination shall remain secured to the specimen. Defects of the substrate shall not be considered in assessing the specimen.

10.4.7.3 Electrical characteristics

Electrical measurements shall be performed in accordance with the relevant specification. The relevant specification shall provide the criteria upon which the acceptance or rejection of the specimen is to be based.

10.4.7.4 Hidden defect

In many cases the damage caused by testing cannot be assessed by visual inspection or electrical measurements. In order to develop and reveal hidden faults, it is recommended that the test should be immediately followed by the climatic sequence in IEC 60068-2-61 or by other appropriate mechanical and/or electrical conditioning as prescribed by the relevant specification.
10.4.8 Information to be given in the relevant specification

When this test is included in a relevant specification, it shall be stated which elements are applicable as well as which are mandatory.

a) Applicable test method
b) Indication as to whether the tested specimen is operative or non-operative
c) Type and dimensions of the substrate
d) Shape and dimensions of the solder lands on the substrate
e) Method of mounting if other than given in 8.3
f) Type of solder alloy
g) Use of solder paste with the addition of silver
h) Viscosity and the method of measurement
i) Conditions of preconditioning the specimen
j) Soldering method and condition of soldering if other than as specified in 8.3.3e
k) Method of cleaning
l) Initial measurements
m) Dwell time between soldering and testing
n) If the bending test (Ue1) is specified, the depth of the bend and time of remaining bent, if other than 5 s and any required monitoring
o) Test method for test Ue2 (pull-off or push-off)
p) Method of attachment of the wire for test Ue2 (push-off)
q) Loading condition (pulling or pushing force and direction) if other than as specified in 8.5.2.2.1 and 8.5.2.2.2
r) Radius of pushing tool, if other than 0.5 mm, for test Ue2 (shear test)
s) The pushing tool, point of contact between the specimen and pushing tool and the type of contact, for test Ue3 (shear test)
t) Pushing force if other than 10 N, for test Ue3 (shear test)
u) Critical parameter to be monitored during application of force, for test Ue3 (shear test)
v) Recovery condition
w) Final measurement
x) Types of defect
y) Acceptance/rejection criteria
z) Indication as to whether the climatic sequence test should be used
10.5 Test M05: Test Ue2 - Pull-off and push-off test

10.5.1 Scope
The purpose of this test is to assess the mechanical robustness of surface mounting device (SMD) terminations mounted on a substrate using a specified method. The terminations consist of metallized portions on non-conductive parts of the component or of short, partly flattened metallic parts.

10.5.2 General description
Alumina ceramic, with a purity of 90% to 98%, a thickness of 0.635mm ± 0.05 mm or more with fired-on metallized pads of a material which is difficult to peel off (e.g., copper or silver palladium) or epoxide glass board as for test Ue1. Where the push-off method of Ue2 is to be applied, a hole shall be made in the substrate with dimensions as given in figure 8, as an example. Where the pull-off method of Ue2 is to be applied, a substrate without holes may be used.

The substrate pattern of figures 5, 6 or 8 is preferred but not required.

Note: These patterns are basically applicable to two-terminal device.

The relevant specification shall prescribe all additional details, including whether the specimen may be a non-operative device.

The test shall be made under the standard atmospheric conditions for measurement and tests as given in 5.3 of IEC 60068-1.

The tests are destructive because mounted specimens are required and cannot be reused. Different specimens will be required for each test.

10.5.3 Mounting
The dimensions for the soldering lands on the substrate shall be prescribed by the relevant specifications.

For the mounting of the specimen on the test substrate, the relevant specification shall prescribe the method to be selected, preferably from the following list, with all the necessary details (see 8.3.3):

1. solder bath;
2. solder wave, single or double;
3. reflow soldering with heating by one of the following means:
   - solder bath
   - hot plate
   - oven or conveyor oven (including infra-red radiation)
   - hot gas jet
   - vapor phase condensation
4. microweld/bonding
10.5.4 Mounting method for pull-off, push-off and shear

When the details of mounting are not prescribed by the relevant specification, the method of mounting shall be as follows:

1. Choice of solder paste
   a) A solder paste, made from solder as specified in annex B of IEC 60068-2-20 (see note 1 below) or 63% tine and 37% lead may be used and mildly activated flux (see note 2 below) as specified in annex C of IEC 60068-2-20. Silver (2 weight % or more) can be added in accordance with the relevant specification. The contamination limits of the solder shall comply with ISO 9453.

   Note 1: The solder has the following composition: tin 59% to 61%; antimony 0.5% maximum; copper 0.1% maximum; arsenic 0.05% maximum; iron 0.02% maximum; remainder lead.

   Note 2: The activated flux has the following composition: colophony 25 g; 2 propanol (iso-propanol) or ethyl alcohol 75 g; diethylammonium chloride 0.39 g.

   b) The viscosity of the solder paste shall be in accordance with the relevant specification.
   c) The particle mesh size of the solder paste shall be 160 or finer.
   d) The footprints shall be covered with solder deposit. The thickness of the solder deposit shall be between 100 µm and 250 µm; the thickness shall be specified in the relevant specification.

2. Preparation of the specimen
   a) The specimen surface to be tested shall be in the "as received" condition and shall not be touched by fingers or otherwise contaminated.
   b) The specification shall not be cleaned prior to the test. If required by the relevant specification, the specimen may be immersed in an organic solvent at room temperature for preconditioning.
   c) Preconditioning
   d) Specimens which need preconditioning shall be pretreated in accordance with the relevant specification.

3. Positioning of the specimen
   a) The specimen shall be placed symmetrically on its footprint.

4. Preheating
   a) Soldering shall be performed immediately after preheating.
   b) As long as the soldering conditions do not lead to a thermal load, which exceeds the SMD specification, any kind of reflow oven or vapor phase soldering oven may be used.
   c) The solder temperature shall be between 215°C and 235°C and the time at the peak temperature shall not exceed 10 s. During soldering the total time above 185°C shall be 45 s minimum.
   d) Care should be taken that complete wetting is achieved.
   e) The soldered area of the substrate shall be cleaned using 2-propanol (iso-propanol) or water to remove surplus flux. If necessary, the details of the cleaning method shall be specified in the relevant specification.
   f) The solder fillet shall comply with the minimum requirements for the relevant joint given in IEC 61191-2.
10.5.5 Initial measurements

Visual inspection of the specimen shall be made with a magnification of at least 10x under adequate light (e.g., 2 000 lx). If specified in the relevant specification, electrical and/or mechanical characteristics shall be measured. The strength of the solder weakens with time and this will influence the test results.

Unless otherwise specified in the relevant component specification, the test shall be performed

10.5.6 Test Ue₂ - Pull-off and push-off test

This test is suitable for SMDs intended for mounting on rigid substrates.

10.5.6.1 Object

The purpose of this test is to evaluate the adhesion strength at the interface between the terminations of an SMD and its body.

10.5.6.2 Test methods

The specimen shall be mounted on the substrate, as shown in figure 8.

Either a pull-off or push-off test method may be used. The choice of the method shall be prescribed in the relevant component specification. In general, the pull-off method is used as the first choice. The push-off method is used when it is too difficult to attach a pulling wire to the specimen. When required by the relevant specification, the time between soldering and testing shall be specified. The strength of the solder weakens with time and this will influence the test results. Unless otherwise specified in the relevant component specification, the test shall be performed after 24 h ± 6 h.

10.5.6.2.1 Pull-off test

A suitable pulling tool shall be attached to the center of the specimen by clamping or by means of a wire fastened perpendicularly to the top of the specimen mounted on its substrate, as shown in figure 9.

Note: If necessary, the clamping and adhesion methods of the specimen shall be prescribed in the relevant specification.

With the substrate firmly held, a pulling force of 10 N (unless otherwise specified in the relevant component specification) shall be applied to the specimen. The force shall be applied gradually at a constant rate, but in all cases the maximum force shall be reached within 5 s and maintained constant for 10 s ± 1 s. Unless otherwise specified, the force shall be applied along an axis within 5° to the normal (see figure 9).

10.5.6.2.2 Push-off test

Fix the substrate and apply the push load through the hole in the substrate on the center of the specimen by means of a pushing tool, as shown in figure 10. Unless otherwise specified in the relevant specification, the pushing tool shall be chamfered with a radius of 0.5mm. The pushing tool shall be brought, without shock, into contact with the lateral surface of the specimen. A pushing force of 10 N (unless otherwise specified in the relevant component specification) shall be applied to the specimen. The force shall be applied gradually at a constant rate, but in all cases the maximum force shall be reached within 5 s and maintained constant for 10 s ± 1 s. Unless otherwise specified, the force shall be applied along an axis within 5° to the normal.
10.5.7 Final measurements

10.5.7.1 Recovery

Components which need recovery treatment shall be treated in accordance with the relevant specification.

10.5.7.2 Visual examination of terminations

Visual inspection of the specimen shall be made under adequate light (e.g., 2 000 lx), with a magnification of at least 10x. The joints between the specimen terminations and the specimen body shall be inspected. There shall be no visible evidence of rupture or cracking. The termination shall remain secured to the specimen. Defects of the substrate shall not be considered in assessing the specimen.

10.5.7.3 Electrical characteristics

Electrical measurements shall be performed in accordance with the relevant specification. The relevant specification shall provide the criteria upon which the acceptance or rejection of the specimen is to be based.

10.5.7.4 Hidden defect

In many cases the damage caused by testing cannot be assessed by visual inspection or electrical measurements. In order to develop and reveal hidden faults, it is recommended that the test should be immediately followed by the climatic sequence in IEC 60068-2-61 or by other appropriate mechanical and/or electrical conditioning as prescribed by the relevant specification.

10.5.8 Information to be given in the relevant specification

When this test is included in a relevant specification, it shall be stated which elements are applicable as well as which are mandatory.

<table>
<thead>
<tr>
<th>Subclause</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>a)</td>
<td>Applicable test method</td>
</tr>
<tr>
<td>b)</td>
<td>Indication as to whether the tested specimen is operative or non-operative</td>
</tr>
<tr>
<td>c)</td>
<td>Type and dimensions of the substrate</td>
</tr>
<tr>
<td>d)</td>
<td>Shape and dimensions of the solder lands on the substrate</td>
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<tr>
<td>e)</td>
<td>Method of mounting if other than given in 8.3</td>
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<tr>
<td>f)</td>
<td>Type of solder alloy</td>
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<td>g)</td>
<td>Use of solder paste with the addition of silver</td>
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<td>h)</td>
<td>Viscosity and the method of measurement</td>
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<tr>
<td>i)</td>
<td>Conditions of preconditioning the specimen</td>
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<td>j)</td>
<td>Soldering method and condition of soldering if other than as specified in 8.3.3e</td>
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<td>m)</td>
<td>Dwell time between soldering and testing</td>
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<tr>
<td>n)</td>
<td>If the bending test (Ue1) is specified, the depth of the bend and time of remaining bent, if other than 5 s and any required monitoring</td>
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</table>
o) Test method for test Ue$_2$ (pull-off or push-off) 8.5.2.2
p) Method of attachment of the wire for test Ue$_2$ (push-off) 8.5.2.2.1
q) Loading condition (pulling or pushing force and direction) if other than as specified in 8.5.2.2.1 and 8.5.2.2.2 8.5.2.2.1, 8.5.2.2.2
r) Radius of pushing tool, if other than 0.5 mm, for test Ue$_2$ (shear test) 8.5.2.2.2
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x) Types of defect 8.6.2
y) Acceptance/rejection criteria 8.6.3
z) Indication as to whether the climatic sequence test should be used 8.6.4
10.6 Test M06: Test Ue₃ - Shear (adhesion) test

10.6.1 Scope
The purpose of this test is to assess the mechanical robustness of surface mounting device (SMD) terminations mounted on a substrate using a specified method. The terminations consist of metallized portions on non-conductive parts of the component or of short, partly flattened metallic parts.

10.6.2 General description
Alumina ceramic, with a purity of 90% to 98%, a thickness of 0.635 mm ± 0.05 mm or more with fired-on metallized pads of a material which is difficult to peel off (e.g., copper or silver palladium) or epoxide glass board as for test Ue₁. Where the push-off method of Ue₂ is to be applied, a hole shall be made in the substrate with dimensions as given in figure 8, as an example. Where the pull-off method of Ue₂ is to be applied, a substrate without holes may be used.

The substrate pattern of figures 5, 6 or 8 is preferred but not required.

Note: These patterns are basically applicable to two-terminal device.

The relevant specification shall prescribe all additional details, including whether the specimen may be a non-operative device.

The test shall be made under the standard atmospheric conditions for measurement and tests as given in 5.3 of IEC 60068-1.

The tests are destructive because mounted specimens are required and cannot be reused. Different specimens will be required for each test.

10.6.3 Mounting
The dimensions for the soldering lands on the substrate shall be prescribed by the relevant specifications.

For the mounting of the specimen on the test substrate, the relevant specification shall prescribe the method to be selected, preferably from the following list, with all the necessary details (see 8.3.3):

1. solder bath;
2. solder wave, single or double;
3. reflow soldering with heating by one of the following means:
   - solder bath
   - hot plate
   - oven or conveyor oven (including infra-red radiation)
   - hot gas jet
   - vapor phase condensation
4. microweld/bonding
10.6.4 Mounting method for pull-off, push-off and shear

When the details of mounting are not prescribed by the relevant specification, the method of mounting shall be as follows:

1. Choice of solder paste
   a) A solder paste, made from solder as specified in annex B of IEC 60068-2-20 (see note 1 below) or 63% tin and 37% lead may be used and mildly activated flux (see note 2 below) as specified in annex C of IEC 60068-2-20. Silver (2 weight % or more) can be added in accordance with the relevant specification. The contamination limits of the solder shall comply with ISO 9453.

   Note 1: The solder has the following composition: tin 59% to 61%; antimony 0.5% maximum; copper 0.1% maximum; arsenic 0.05% maximum; iron 0.02% maximum; remainder lead.

   Note 2: The activated flux has the following composition: colophony 25 g; 2 propanol (iso-propanol) or ethyl alcohol 75 g; diethylammonium chloride 0.39 g.

   b) The viscosity of the solder paste shall be in accordance with the relevant specification.
   c) The particle mesh size of the solder paste shall be 160 or finer.
   d) The footprints shall be covered with solder deposit. The thickness of the solder deposit shall be between 100 µm and 250 µm; the thickness shall be specified in the relevant specification.

2. Preparation of the specimen
   a) The specimen surface to be tested shall be in the "as received" condition and shall not be touched by fingers or otherwise contaminated.
   b) The specification shall not be cleaned prior to the test. If required by the relevant specification, the specimen may be immersed in an organic solvent at room temperature for preconditioning.
   c) Preconditioning
   d) Specimens which need preconditioning shall be pretreated in accordance with the relevant specification.

3. Positioning of the specimen
   a) The specimen shall be placed symmetrically on its footprint.

4. Preheating
   a) Soldering shall be performed immediately after preheating.
   b) As long as the soldering conditions do not lead to a thermal load, which exceeds the SMD specification, any kind of reflow oven or vapor phase soldering oven may be used.
   c) The solder temperature shall be between 215°C and 235°C and the time at the peak temperature shall not exceed 10 s. During soldering the total time above 185°C shall be 45 s minimum.
   d) Care should be taken that complete wetting is achieved.
   e) The soldered area of the substrate shall be cleaned using 2-propanol (iso-propanol) or water to remove surplus flux. If necessary, the details of the cleaning method shall be specified in the relevant specification.
   f) The solder fillet shall comply with the minimum requirements for the relevant joint given in IEC 61191-2.
10.6.5 Initial measurements

Visual inspection of the specimen shall be made with a magnification of at least 10x under adequate light (e.g., 2 000 lx). If specified in the relevant specification, electrical and/or mechanical characteristics shall be measured. The strength of the solder weakens with time and this will influence the test results.

Unless otherwise specified in the relevant component specification, the test shall be performed.

10.6.6 Test Ue3: Shear test

This test is suitable for SMDs intended for mounting on rigid substrates.

10.6.6.1 Object

The purpose of this test is to evaluate the shear strength at the interface between the terminations of an SMD and its body.

10.6.6.2 Test method

The method is used for SMDs with comparatively large heights, such as electrolytic capacitors, connectors, switches and ceramic-based SMDs. When permitted by the type and geometry of the specimen, a force shall be applied by means of an appropriate pushing tool. Unless otherwise specified in the relevant specification, a pushing tool chamfered with a radius of 0.5mm shall be used. The thickness of the pushing tool shall be larger than the height of the relevant contact surface of the specimen to be tested; however, the width of the pushing tool is not specified (see figure 11). The force shall be applied parallel to the substrate and perpendicular to the specimen lateral surface, as shown in figure 11. The point of contact between the specimen and the pushing tool shall be prescribed by the relevant specification.

Unless otherwise specified in the relevant specification, the pushing tool shall be brought, without shock, into contact with the lateral surface of the specimen. A pushing force of 10 N (unless otherwise specified in the relevant component specification) shall be applied to the specimen. The force shall be applied gradually at a constant rate, but in all cases the maximum force shall be reached within 5 s and maintained constant for 10 s ± 1 s. When required by the relevant specification, the time between soldering and testing shall be specified. The strength of the solder weakens with time and this will influence the test results. Unless otherwise specified in the relevant component specification, the test shall be performed after 24 h ± 6 h.

If prescribed by the relevant specification, a suitable critical parameter shall be monitored throughout the period during which the force is applied.

10.6.7 Final measurements

10.6.7.1 Recovery

Components which need recovery treatment shall be treated in accordance with the relevant specification.

10.6.7.2 Visual examination of terminations

Visual inspection of the specimen shall be made under adequate light (e.g., 2 000 lx), with a magnification of at least 10x. The joints between the specimen terminations and the specimen body shall be inspected. There shall be no visible evidence of rupture or cracking. The termination shall remain secured to the specimen. Defects of the substrate shall not be considered in assessing the specimen.
10.6.7.3 Electrical characteristics

Electrical measurements shall be performed in accordance with the relevant specification. The relevant specification shall provide the criteria upon which the acceptance or rejection of the specimen is to be based.

10.6.7.4 Hidden defect

In many cases the damage caused by testing cannot be assessed by visual inspection or electrical measurements. In order to develop and reveal hidden faults, it is recommended that the test should be immediately followed by the climatic sequence in IEC 60068-2-61 or by other appropriate mechanical and/or electrical conditioning as prescribed by the relevant specification.

10.6.8 Information to be given in the relevant specification

When this test is included in a relevant specification, it shall be stated which elements are applicable as well as which are mandatory.

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**Subclause**

- a) Applicable test method (8.2)
- b) Indication as to whether the tested specimen is operative or non-operative (8.2)
- c) Type and dimensions of the substrate (8.2)
- d) Shape and dimensions of the solder lands on the substrate (8.2)
- e) Method of mounting if other than given in 8.3 (8.3)
- f) Type of solder alloy (8.3.3)
- g) Use of solder paste with the addition of silver (8.3.3)
- h) Viscosity and the method of measurement (8.3.3)
- i) Conditions of preconditioning the specimen (8.3.3)
- j) Soldering method and condition of soldering if other than as specified in 8.3.3e (8.3.3)
- k) Method of cleaning (8.3.3)
- l) Initial measurements (8.4)
- m) Dwell time between soldering and testing (8.4, 8.5.2.2, 8.5.3.2)
- n) If the bending test (Ue1) is specified, the depth of the bend and time of remaining bent, if other than 5 s and any required monitoring (8.5.1)
- o) Test method for test Ue2 (pull-off or push-off) (8.5.2.2)
- p) Method of attachment of the wire for test Ue2 (push-off) (8.5.2.2.1)
- q) Loading condition (pulling or pushing force and direction) if other than as specified in 8.5.2.2.1 and 8.5.2.2.2 (8.5.2.2.1, 8.5.2.2.2)
- r) Radius of pushing tool, if other than 0.5 mm, for test Ue2 (shear test) (8.5.2.2.2)
- s) The pushing tool, point of contact between the specimen and pushing tool and the type of contact, for test Ue3 (shear test) (8.5.3.2)
- t) Pushing force if other than 10 N, for test Ue3 (shear test) (8.5.3.2)
- u) Critical parameter to be monitored during application of force, for test Ue3 (shear test) (8.5.3.2)
- v) Recovery condition (8.6.1)
w) Final measurement 8.6
x) Types of defect 8.6.2
y) Acceptance/rejection criteria 8.6.3
z) Indication as to whether the climatic sequence test should be used 8.6.4
10.7 Test M07: Body Strength

10.7.1 Scope

This test method is applicable to surface mounting devices (SMDs) made of glass or sintered materials such as capacitors, resistors and inductors incorporating ferrites. Two test methods exist: body strength and shock.

The object of both tests is to evaluate the mechanical stresses applied to SMDs during and after mounting; these tests look at different mechanical stresses. The relevant component specification shall specify which test method or methods are applicable.

10.7.2 Applicable documents

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

10.7.3 Test Method

This test evaluates the strength of the body of the SMD against external static forces which are applied to them during mounting, in the direction perpendicular to the printed board on which the SMDs are mounted.

Note: The test evaluates the sturdiness of the body of the SMDs and not the adhesive strength at the interface between the termination and solder of the body. These latter tests are described in IEC 60068-2-21.

This test simulates the static force applied to SMDs during picking up and centering in a placement process with a rather slow speed mounting machine in which the forces are mainly of a static nature.

A static force can have a different influence on a device from that of a dynamic force whose effects can be evaluated by a test separately described as an impact shock test. This simulates the mechanical stress applied to the SMDs, during and after mounting the SMDs on a printed board. This test shall be referred to in the relevant detail specification.

10.7.4 Test Equipment

The equipment shall be able to apply the specified force to the specimen and maintain the test load for the specified duration. The length (L) of the tip of the pushing tool shall be wider than the width (W) of the specimen under test. Unless otherwise specified in the relevant specification, the shape of the tip of the pushing tool shall be chamfered with a radius of 0.5mm. The thickness of the pushing tool is not specified (see figure 1). If this specification cannot be applied due to the shape or construction of the specimen under test or for any other reason, the shape of the pushing tool shall be specified in the relevant specification.

10.7.4.1 Preconditioning

Specimens which need preconditioning shall be pretreated in accordance with the relevant specification.

10.7.4.2 Initial measurements

Visual inspection of the specimen shall be made with the assistance of a magnification of at least 10x under adequate lighting (e.g., 2 000 lx). If specified in the relevant specification, electrical and/or mechanical characteristics shall be measured.
10.7.5 Test procedure

Testing shall include the following steps:

1. Unless otherwise specified in the relevant specification, the specimen shall be placed on the supporting base, shown in figures 2 and 3, so that both ends of the specimen are symmetrically positioned on the supporting base. The test table shall be placed on a plane, robust platform so that the test results shall not be affected when the load is applied. The angle of the taper of section "A" in figure 2 shall be greater than 70°, but less than 90°.

2. The shapes and supporting base shall be specified in the relevant specification for different types of SMDs. Two typical examples are given in figures 2 and 3.

3. Apply pressure to the center of the specimen, using the pushing tool (shown in figures 2 and 3) to reach the specified load within 5 s and maintain the pressure for (10±1) s. The load shall be 10N unless otherwise specified by the relevant specification.

4. Unless otherwise specified, electrical measurements shall be made during the load application, in accordance with the relevant specification.

10.7.5.1 Recovery

Where a specimen requires recovery treatment, this shall be given in the relevant specification.

10.7.5.2 Final measurement

Inspection of the specimen appearance for any damage, such as cracks or flaws, shall be made with the assistance of a magnification of at least 10x, under adequate light (e.g., 2 000 lx). If the electrical and/or mechanical properties of the specimen require testing, this shall be specified in the relevant specification.

10.7.6 Information to be given in the relevant specification

When this test is included in a relevant specification, it shall be stated which clauses are applicable as well as which are mandatory.

Subclause

a) Method of test: body strength or impact shock or both 4.1, 4.2
b) Shape of pushing tool for body strength 5.1a
c) Construction and dimensions of the specimen holding jig for impact shock 5.1b
d) Method of preconditioning 5.2
e)* Initial measurements 5.3
f) Supporting base 5.4.1a,
   5.4.1b
g)* Load 5.4.1c
h) Measurements to be made during testing 5.4.1d
i) Loads direction and height 5.4.2a
j)* Load weight of the collet and shaft 5.4.2b
k) Additional weight 5.4.2b
l)* Recovery conditions 5.5
m) Final measurements 5.6
n) Acceptance criteria 5.6

Figure 1 Pushing tool

Figure 2 Example of a body strength test (e.g., multilayer ceramic chip capacitor)

Figure 3 Example of a body strength test (for cylindrical ceramic chip capacitors)

Figure 4 Principle of test equipment
10.8 Test M08: Impact shock

10.8.1 Scope

This test method is applicable to surface mounting devices (SMDs) made of glass or sintered materials such as capacitors, resistors and inductors incorporating ferrites. Two test methods exist: body strength and shock.

The object of both tests is to evaluate the mechanical stresses applied to SMDs during and after mounting; these tests look at different mechanical stresses. The relevant component specification shall specify which test method or methods are applicable.

10.8.2 Applicable documents

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

10.8.3 Test Method

This test evaluates the physical resistance of SMDs against impact shock. This test simulates the dynamic forces applied by picking and placing tools on a high speed mounting machine. The influence of a dynamic force on a device can differ from the influence of a static force. This test shall be referred to in the relevant detail specification.

10.8.4 Test Equipment

The equipment shall be able to apply the specified potential energy to the specimen. The principle of the equipment is given in figure 4. The potential energy is given by the following formula:

\[ E_p(J) = m(g) \times g \times h \times 10^{-7} \]

where:

- \( E_p \) is the potential energy;
- \( m \) is the load (weight of collet, shaft and additional weight);
- \( g \) is the gravity;
- \( h \) is the height.

The equipment shall be capable of generating a specified impact energy to a specimen by dropping a load (collet and weight) (see figure 5). No apparent friction shall be experienced when the collet and weight are dropped. The material of the base of the equipment shall be made of metal in excess of 1 cm thick, having a sufficiently larger area than the specimen to be tested and weighing more than 2 kg. There shall be no material under the base which might reduce the impact energy, such as an elastomer sheet. The equipment shall be placed on a concrete floor or equivalent rigid structure. The construction and dimensions of the specimen holding jig shall be given in the relevant specification.

10.8.4.1 Preconditioning

Specimens which need preconditioning shall be pretreated in accordance with the relevant specification.
10.8.4.2 Initial measurements

Visual inspection of the specimen shall be made with the assistance of a magnification of at least 10x under adequate lighting (e.g., 2,000 lx). If specified in the relevant specification, electrical and/or mechanical characteristics shall be measured.

10.8.5 Test procedure

Testing shall include the following steps:

1. The specimen shall be mounted on the apparatus as shown in figure 5. A dropping load shall be applied to the center surface of the specimen from the dropping height, in each of three directions, X, Y, and Z axes, once on each side, as illustrated in figure 6a). If it is difficult to apply a load in all three directions, due to the shape of the specimen or termination construction (see figure 6b), refer to the relevant specification.

2. A load (weight of collet, shaft and additional weight) shall be dropped freely onto a specimen from specified drop height. Additional weight may be added to the shaft, in accordance with the relevant specification. The tip shape of the collet shall be in accordance with figure 7. A tip diameter of 1.8mm shall be used for rectangular specimens where the height or width is between 2.0mm and 4.0mm, or for a cylindrical specimen where the length is between 2.0-mm and 4.0mm. For larger specimens which are 4.0mm or more, the tip diameter shall be 4.0mm. The hardness of the tip shall be suitable for the mechanical property of the specimen to be tested.

10.8.5.1 Recovery

Where a specimen requires recovery treatment, this shall be given in the relevant specification.

10.8.5.2 Final measurement

Inspection of the specimen appearance for any damage, such as cracks or flaws, shall be made with the assistance of a magnification of at least 10x, under adequate light (e.g., 2,000 lx). If the electrical and/or mechanical properties of the specimen require testing, this shall be specified in the relevant specification.

10.8.6 Information to be given in the relevant specification

When this test is included in a relevant specification, it shall be stated which clauses are applicable as well as which are mandatory.

<table>
<thead>
<tr>
<th>Subclause</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Method of test: body strength or impact shock or both</td>
</tr>
<tr>
<td>b) Shape of pushing tool for body strength</td>
</tr>
<tr>
<td>c) Construction and dimensions of the specimen holding jig for impact shock</td>
</tr>
<tr>
<td>d) Method of preconditioning</td>
</tr>
<tr>
<td>e)* Initial measurements</td>
</tr>
<tr>
<td>f) Supporting base</td>
</tr>
<tr>
<td>g)* Load</td>
</tr>
<tr>
<td>h) Measurements to be made during testing</td>
</tr>
<tr>
<td>i) Loads direction and height</td>
</tr>
</tbody>
</table>
j)* Load weight of the collet and shaft  5.4.2b  
k)  Additional weight  5.4.2b  
l)* Recovery conditions  5.5  
m)* Final measurements  5.6  
n) Acceptance criteria  5.6  

Figure 5  Example of impact shock test equipment  
Figure 6  Example of application of impact  
Figure 7  Example of collet  

11 E: Electrical Test Methods
11.1 Test E01: Surface corrosion

11.1.1 Object
To determine any tendency for electrolytic corrosion products to occur when an etched conductive pattern is subjected to a polarizing voltage and high humidity.

11.1.2 Test specimen
Four specimens, 100 mm x 100 mm, shall be taken from the panel or sheet at least 25 mm from the edge. The specimens shall be printed, on one side, with the ring and disk pattern of figure 28.

11.1.3 Test apparatus and materials
a) a test chamber as specified in IEC 61189-3 test method 3N06;
b) a power supply capable of producing a standing bias potential of (100 ± 5)V dc;
c) a limiting resistor, 100 KΩ, to limit the current to 1 mA;
d) wires, teflon-insulated, to connect the specimens to the power supply, which are insulated with a material that will not prejudice the test results;
e) a fixture with spring loaded contacts may be used instead of wire terminations.

11.1.4 Procedure
a) The specimen shall be connected as shown in figure xx or figure xx. The specimens shall be placed in the chamber in a vertical position, and the termination wires of the specimens connected to the power supply.
b) Environmental conditions shall be in accordance with IEC 61189-3 test method 3N06. The duration shall be 21 days.
c) The sample shall be polarized with 100 V dc and the current limited to 1 mA.
d) After environmental conditioning, the specimens shall be removed from the chamber and examined for corrosion.
e) Visual examination may be conducted up to and including 3x magnification.

11.1.5 Report
The report shall include:
a) the test method number, revision, and type of pattern;
b) the date of test;
c) identification of the test material;
d) whether corrosion products have been observed or not;
e) any deviation from this test method.

11.1.6 Additional information
During this test, handling of the specimen shall be kept to a minimum to avoid contamination. The specimen shall be held by the edges, and rubber or polyethylene gloves shall be worn. When connecting the wires, care shall be taken to prevent contamination of the surface of the material by solder flux. The use of solvents to remove contaminants may result in spreading the contaminants over the whole surface.
Figure xx  Ring and disk pattern

Figure xx  Comb Pattern
12 N: Environmental Test Methods

13 X: Miscellaneous Test Methods
13.1 Test X01: Solder bath method

13.1.1 Scope

This method provides standard procedures for determining the solderability, resistance to dissolution of metallization and resistance to soldering heat of array type surface mounting devices (SMD) (hereinafter referred to as specimens).

The procedures use either solder bath (X01) or reflow (X02) method and are applicable only to specimens or products designed to withstand short term immersion in molten solder or limited exposure to reflow systems.

13.1.2 Applicable documents

None

13.1.3 Preconditioning

1. The specimen shall be tested in the "as-received" condition unless otherwise specified by the relevant specification. Care should be taken that no contamination, by contact with the fingers or by other means, occurs.

2. When accelerated aging is prescribed by the relevant specification, one of the methods of 4.5 of IEC 60068-2-20 shall be used.

3. Prior to the resistance to soldering heat test, specimens of semiconductor SMDs in plastic encapsulation shall be soaked and/or baked in accordance with the relevant specification of IEC 60749.

13.1.4 Test method

13.1.4.1 Test apparatus and materials

1. Solder bath - The solder bath dimensions shall comply with the requirements of 4.6.1 of IEC 60068-2-20.

2. Flux - The flux shall comply with the requirements of 4.6.2, 6.6.1, or 6.6.2 of IEC 60068-2-20 as prescribed by the relevant specification.

3. Solder - The solder composition shall be 60% tin and 40% lead according to appendix B of IEC 60068-2-20.

13.1.4.2 Test Procedure

1. Number of specimens

A specimen shall not be used for more than one test.

2. Clamping

The specimen shall be placed in a stainless steel clip as shown in figure 1. No part of the clip jaws shall make contact with the areas to be examined. The specimen shall remain in the clip while being fluxed and dipped in the solder.
3. **Fluxing**

The specimen shall be completely immersed in flux and withdrawn slowly. Any excess flux shall be removed by contact with absorbent paper.

4. **Solder immersion**

When preheating is prescribed by the relevant specification, the specified duration and temperature shall be applied immediately prior to the immersion of the specimen in the solder bath.

---

**Insert figure xx  Examples of immersion**

### 13.1.4.2.1 Severities

The duration and temperature of immersion shall be selected from table 1, unless otherwise prescribed by the relevant specification. Guidance on the choice of severities, including those for lower grades of resistance to soldering heat and dissolution of metallization, is given in annex B.

**Table xx  Severities (duration and temperature)**

<table>
<thead>
<tr>
<th>Property tested</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(215 ± 3) °C</td>
</tr>
<tr>
<td></td>
<td>(235 ± 5) °C</td>
</tr>
<tr>
<td></td>
<td>(260 ± 5) °C</td>
</tr>
<tr>
<td>Wetting</td>
<td>(3±0.3)s (10±1)s (40±1)s</td>
</tr>
<tr>
<td>Dewetting</td>
<td>X</td>
</tr>
<tr>
<td>Resistance to dissolution of metallization</td>
<td></td>
</tr>
<tr>
<td>Resistance to soldering heat</td>
<td>X</td>
</tr>
</tbody>
</table>

The oxide film on the solder bath shall be skimmed off immediately before immersion.

The immersion and withdrawal speed shall be between 20 mm/s and 25 mm/s.

### 13.1.4.2.2 Attitude

Two attitudes of immersion are standardized:

**Attitude A:** For most specimens, the areas to be examined shall be immersed not less than 2 mm below the solder meniscus (but not to a greater depth than necessary (see figure 1) with the seating plane vertical.

**Attitude B:** For certain specimens (see B.3.4), the specimen may be floated on the solder, but only when testing resistance to soldering heat.

If the relevant specification does not mention the attitude, attitude A shall be adopted.
13.1.5 Flux removal

Within 60 min of the test and after the specimen has been allowed to cool to room temperature, the flux residues shall be removed with a suitable solvent.

13.1.5.1 Recovery

The recovery conditions shall be prescribed in the relevant specification.

13.1.6 Evaluation

13.1.6.1 Wetting

The wetting shall be assed visually under adequate light with a binocular microscope of magnification in the range between 10x and 25x, using the photographs of component terminations in figure 3 to assist with the evaluation. The areas to be examined shall be prescribed in the relevant specification.

13.1.6.1.1 Terminations with metallized solder pads

The dipped or reflowed surface shall be covered with a smooth and bright solder coating with no more than small amounts of scattered imperfections, such as pinholes or non-wetted or dewetted areas. These imperfections shall not be concentrated in one area.

13.1.6.1.2 Metallic terminations shorter than 6mm (dimension d in figure xx)

The following criteria apply where the specimen is tested in the "as-received" condition or after accelerated aging.

1. Areas that form the joint:

   a) the underside of the termination foot and the convex side of the lower bend;

   b) the side faces of the foot.

   The highest quality is required in these areas. The dipped or reflowed surface shall be covered with a smooth and bright solder coating with no more than small amounts of scattered imperfections such as pinholes, non-wetted or dewetted areas. These imperfections shall not be concentrated in one area.

2. The upper side of the termination:

   – After the dipping test, the dipped surface shall show visible evidence of being wettable, as indicated by the presence of fresh solder. A homogeneous coating is not necessary here.

3. Non-coated cut edges at the end of the termination and the termination above the lower bend:

   – for these surfaces no criteria are given. These areas are illustrated in figure xx.

13.1.6.2 Dewetting

The criteria for wetting described in 11.2.6.3 shall also apply after dipping at 260°C.

The dewetting shall be assessed visually under adequate light with a binocular microscope of magnification in the range between 10x and 25x.
13.1.6.3 Resistance to soldering heat

After testing for resistance to soldering heat, the specimen shall be checked and visually examined in accordance with the relevant specification.

13.1.6.4 Resistance to dissolution of metallization

1. Areas where metallization is lost during immersion shall not individually exceed 5% of the total electrode area, and collectively shall not exceed 10% of the total electrode area.

2. The functional connection of the electrode to the interior of the specimen shall not be exposed.

3. Where the metallization of the electrode extends over edges onto adjacent surfaces, loss of metallization on the edges shall not exceed 10% of their total length.

13.1.7 Information to be given in the relevant specification

When this test is included in a specification, the following details shall be given as far as they are applicable. Particular attention should be given to items marked with an asterisk (*) as this information is mandatory.

a) Applicable test method
b) Condition of preconditioning (soak and bake)
c) Flux type
d) Solder temperature for bath tests
e) Dwell time for bath tests
f) Attitude to be used for bath tests
g) Viscosity of solder paste
h) Thickness of solder paste
i) Amount and particle mesh size of solder paste
j) Dimensional details of test substrate
k) Placement procedure (depth of penetration)*
l) Pre-heating temperature and time
m) Temperature profile for reflow
n) Temperature measurement point
o) Number of test cycles for resistance to soldering heat
p) Removal procedure
q) Cleaning method
r) Recovery conditions
s) Final inspection requirements and acceptance criteria
t) Areas of the terminations to be examined.
13.2 Test X02: Reflow method

13.2.1 Scope

This method provides standard procedures for determining the solderability, resistance to dissolution of metallization and resistance to soldering heat of array type surface mounting devices (SMD) (hereinafter referred to as specimens).

The procedures use either solder bath (X01) or reflow (X02) method and are applicable only to specimens or products designed to withstand short term immersion in molten solder or limited exposure to reflow systems.

13.2.2 Applicable documents

None

13.2.3 Preconditioning

1. The specimen shall be tested in the "as-received" condition unless otherwise specified by the relevant specification. Care should be taken that no contamination, by contact with the fingers or by other means, occurs.

2. When accelerated aging is prescribed by the relevant specification, one of the methods of 4.5 of IEC 60068-2-20 shall be used.

3. Prior to the resistance to soldering heat test, specimens of semiconductor SMDs in plastic encapsulation shall be soaked and/or baked in accordance with the relevant specification of IEC 60749.

13.2.4 Test method

13.2.4.1 Test apparatus and materials

The following two methods may be used to determine the suitability of SMDs for reflow soldering or when they are only designed for reflow soldering processes and when the solder bath (dipping) method is not appropriate.

Where the characteristics of an SMD are such that both reflow methods are applicable, then infrared, forced gas or vapor phase shall take precedence over hot plate reflow. The applicable test method shall be stated in the relevant specification

13.2.4.1.1 Solder paste

1. The particle mesh size of the solder paste shall be 160 or finer.

2. The metal composition shall be in accordance with the solder specification B.1 of IEC 60068-2-20.

3. The composition of the flux shall comply with the flux specification in annex C of IEC 60068-2-20.

4. The viscosity range and method of measurement shall be specified in the relevant specification.

13.2.4.1.2 Test substrates

1. Test substrates for infrared, forced gas or vapor phase solder reflow
The test substrate shall consist of an unmetallized (no tracks or lands) piece of ceramic (alumina 90% to 98%) or glass epoxy (see IEC 60249-2-4).

Dimensional details shall be given in relevant specification.

2. Test substrates for hot plate solder reflow.

The test substrate shall consist of an unmetallized (no tracks or lands) piece of ceramic (alumina 90% to 98%).

Dimensional details shall be given in the relevant specification.

13.2.4.2 Test Procedure

13.2.4.2.1 Number of specimens

A specimen shall not be used for more than one test.

13.2.4.2.2 Application of solder paste

The solder paste shall be applied to the test substrate by screen or stencil printing, dispensing or pin transfer.

The thickness of the solder deposit shall be between 100 µm and 250 µm and shall be specified in the relevant specification.

The area (size) to be printed, and thus the amount of solder paste deposit, shall be specified in the relevant specification.

When semiconductor SMDs are examined, solder paste shall not be applied as specified in IEC 60759.

13.2.4.2.3 Placement of specimens

After printing, the terminations of the specimen shall be placed on the solder paste.

The placement procedure (for example depth of penetration) shall be prescribed in the relevant specification.

13.2.4.2.4 Preheating

Unless otherwise specified in the relevant specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 10)ºC and maintained for 60 s to 120 s in the reflow system.

13.2.4.2.5 Solder reflow

1. Reflow procedure for wetting

Reflow method 1: infrared, forced gas or vapor phase.

As long as the test conditions prescribed in 8.4 are fulfilled, any suitable infrared, forced gas or vapor phase system may be used.

The temperature of the reflow system shall be quickly raised until the specimen has reached (215±3)ºC and maintained at this temperature for (10±1) s.
The temperature shall be measured at the specimen termination.

The temperature profile shall be specified in the relevant specification. After cooling, the specimen shall be removed from the substrate for inspection. Details of the removal procedure shall be given in the relevant specification.

Reflow method 2: hot plate soldering

As long as the test requirements of 8.4 are fulfilled, any suitable equipment, such as a metallic plate (carrier), floating on a molten solder bath or an electrically heated plate, may be used.

Immediately after preheating, the specimen shall be moved to a second hot plate so that the temperature of the specimen is quickly raised to (215±3)ºC and maintained at this temperature for (10±1) s. The temperature of the substrate shall be maintained above 140ºC between preheating and reflow.

The temperature shall be measured at the specimen termination.

The temperature profile shall be specified in the relevant specification. After cooling, the specimen shall be removed from the substrate for inspection. Details of the removal procedure shall be given in the relevant specification.

2. Reflow procedure for resistance to soldering heat:

The following three methods may be used to determine the suitability of SMDs for reflow soldering or when they are only designed for reflow soldering processes and when the solder bath (dipping) method is not appropriate.

Where the characteristics of an SMD are such that both reflow methods 1 and 2 are applicable, the applicable test method shall be stated in the relevant specification.

Reflow method 1: vapor phase soldering system

As long as the test conditions prescribed in 8.4 are fulfilled, any suitable vapor phase system may be used.

Unless otherwise specified, the number of test cycles shall be a minimum of one and a maximum of three, and shall be specified in the relevant specification. The recovery period between two successive cycles shall be either 60 min minimum or until the temperature of the specimen drops below 50ºC.

The temperature of the reflow system shall be quickly raised until the specimen has reached (215±3)ºC and maintained at this temperature for (40±1) s.

Unless otherwise specified, the temperature shall be measured at the specimen termination. When semiconductor SMDs are examined, the temperature shall be measured at the SMD's body surface, as specified in IEC 60749.

The temperature profile shall be specified in the relevant specification.

The test duration of 40 s is based on only one cycle for the resistance to soldering heat.

The dwell time for more than one cycle shall be given in the relevant specification.
If more than one cycle is specified, both the preheating and the test shall be repeated. After cooling the specimen shall be removed from the substrate for inspection. Details of the removal procedure shall be given in the relevant specification.

Reflow method 2: infrared and forced gas convection soldering systems

As long as the test conditions prescribed in 8.4 are fulfilled, any infrared or forced gas system may be used.

Unless otherwise specified, the number of test cycles shall be a minimum of one and a maximum of three, and shall be specified in the relevant specification. The recovery period between two successive cycles shall be either 60 min minimum or until the temperature of the specimen drops below 50°C.

The temperature of the reflow system shall be quickly raised until the specimen has reached (235±5)°C and maintained at this temperature for (10±1) s.

Unless otherwise specified, the temperature shall be measured at the specimen termination. When semiconductor SMDs are examined, the temperature shall be measured at the SMD's body surface, as specified in IEC 60749.

The temperature profile shall be specified in the relevant specification.

The test duration of 10 s is based on only one cycle for the resistance to soldering heat.

The dwell time for more than one cycle shall be given in the relevant specification.

If more than one cycle is specified, both the preheating and the test shall be repeated. After cooling the specimen shall be removed from the substrate for inspection. Details of the removal procedure shall be given in the relevant specification.

Reflow method 3: hot plate soldering

As long as the test conditions prescribed in 8.4 are fulfilled, any suitable equipment, such as a metallic plate (carrier), floating on a molten solder bath or an electrically heated plate, may be used.

Unless otherwise specified, the number of test cycles shall be a minimum of one and a maximum of three, and shall be specified in the relevant specification. The recovery period between two successive cycles shall be either 60 min minimum or until the temperature of the specimen drops below 50°C.

Immediately after preheating, the specimen shall be moved to a second hot plate so that the temperature of the specimen is quickly raised to (235±5)°C and maintained at this temperature for (30±1) s. The temperature of the substrate shall be maintained above 140°C between preheating and reflow.

Unless otherwise specified, the temperature shall be measured at the specimen termination. When semiconductor SMDs are examined, the temperature shall be measured at the SMD's body surface, as specified in IEC 60749.

The temperature profile shall be specified in the relevant specification.

The test duration of 30 s is based on only one cycle for the resistance to soldering heat.
The dwell time for more than one cycle shall be given in the relevant specification.

If more than one cycle is specified, both the preheating and the test shall be repeated. After cooling the specimen shall be removed from the substrate for inspection. Details of the removal procedure shall be given in the relevant specification.

13.2.5 Flux removal

Within 60 min of the test and after the specimen has been allowed to cool to room temperature, the flux residues shall be removed with a suitable solvent.

13.2.5.1 Recovery

The recovery conditions shall be prescribed in the relevant specification.

13.2.6 Evaluation

13.2.6.1 Wetting

The wetting shall be assessed visually under adequate light with a binocular microscope of magnification in the range between 10x and 25x, using the photographs of component terminations in figure 3 to assist with the evaluation. The areas to be examined shall be prescribed in the relevant specification.

13.2.6.1.1 Terminations with metallized solder pads

The dipped or reflowed surface shall be covered with a smooth and bright solder coating with no more than small amounts of scattered imperfections, such as pinholes or non-wetted or dewetted areas. These imperfections shall not be concentrated in one area.

13.2.6.1.2 Metallic terminations shorter than 6mm (dimension \(d\) in figure 2)

The following criteria apply where the specimen is tested in the "as-received" condition or after accelerated aging.

1. Areas that form the joint:

   a) the underside of the termination foot and the convex side of the lower bend;

   b) the side faces of the foot.

   The highest quality is required in these areas. The dipped or reflowed surface shall be covered with a smooth and bright solder coating with no more than small amounts of scattered imperfections such as pinholes, non-wetted or dewetted areas. These imperfections shall not be concentrated in one area.

2. The upper side of the termination:

   After the dipping test, the dipped surface shall show visible evidence of being wettable, as indicated by the presence of fresh solder. A homogeneous coating is not necessary here.

3. Non-coated cut edges at the end of the termination and the termination above the lower bend:

   for these surfaces no criteria are given. These areas are illustrated in figure 2.
13.2.6.2 Dewetting

The criteria for wetting described in 11.2.6.3 shall also apply after dipping at 260ºC.

The dewetting shall be assessed visually under adequate light with a binocular microscope of magnification in the range between 10x and 25x.

13.2.6.3 Resistance to soldering heat

After testing for resistance to soldering heat, the specimen shall be checked and visually examined in accordance with the relevant specification.

13.2.6.4 Resistance to dissolution of metallization

1. Areas where metallization is lost during immersion shall not individually exceed 5% of the total electrode area, and collectively shall not exceed 10% of the total electrode area.

2. The functional connection of the electrode to the interior of the specimen shall not be exposed.

3. Where the metallization of the electrode extends over edges onto adjacent surfaces, loss of metallization on the edges shall not exceed 10% of their total length.

13.2.7 Information to be given in the relevant specification

When this test is included in a specification, the following details shall be given as far as they are applicable. Particular attention should be given to items marked with an asterisk (*) as this information is mandatory.

a) Applicable test method
b) Condition of preconditioning (soak and bake)
c) Flux type
d) Solder temperature for bath tests
e) Dwell time for bath tests
f) Attitude to be used for bath tests
g) Viscosity of solder paste
h) Thickness of solder paste
i) Amount and particle mesh size of solder paste
j) Dimensional details of test substrate
k) Placement procedure (depth of penetration)*
l) Pre-heating temperature and time
m) Temperature profile for reflow
n) Temperature measurement point
o) Number of test cycles for resistance to soldering heat
p) Removal procedure
q) Cleaning method
r) Recovery conditions
s) Final inspection requirements and acceptance criteria
t) Areas of the terminations to be examined.
Appendix A

**Normative Terminology**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball array</td>
<td>A group of ball arranged in rows and columns</td>
</tr>
<tr>
<td>ball</td>
<td>A raised metal, (or other conductive material) feature on a package substrate used to facilitate bonding to the next level of interconnect.</td>
</tr>
<tr>
<td>coefficient of thermal expansion</td>
<td>The quotient of the fractional increase in length to the increase in temperature expressed in ppm/°C</td>
</tr>
<tr>
<td>creep</td>
<td>Time-dependent strain occurring under stress</td>
</tr>
<tr>
<td>electromigration</td>
<td>An undesirable phenomenon in which metal ions migrate through a suitable medium under the influence of an electrical field.</td>
</tr>
<tr>
<td>electrodeposition, galvanic deposition</td>
<td>The deposition of a conductive material from a plating solution by the application of electrical current</td>
</tr>
<tr>
<td>eutectic composition</td>
<td>The lowest melting-point alloy composition possible for a mixture of two or more elements</td>
</tr>
<tr>
<td>pitch</td>
<td>Center-to-center (true position) distance of adjacent balls</td>
</tr>
<tr>
<td>thermal conductivity</td>
<td>Measure of a material's ability to conduct heat thermal migration - an undesirable phenomenon in which metal ions migrate through a suitable medium under the influence of a thermal gradient</td>
</tr>
<tr>
<td>thermal mismatch</td>
<td>Difference in coefficients of thermal expansion of materials that are bonded together</td>
</tr>
<tr>
<td>thermal resistance</td>
<td>The resistance of a material to the passage of thermal energy usually measured in °C/W</td>
</tr>
<tr>
<td>Under Ball Metallization</td>
<td>The solder-wettable terminal area that defines the metallurgy size and area of a soldered connection, such as a solder ball. Possible acronyms: PLM or BLM</td>
</tr>
<tr>
<td>via</td>
<td>An opening in a dielectric layer(s) through which a conductor passes up or down to a subsequent conductive layer for electrical or thermal interconnection.</td>
</tr>
<tr>
<td>wetting</td>
<td>The spreading of molten solder or glass on a metallic or nonmetallic surface, with proper application of heat and in some cases flux.</td>
</tr>
</tbody>
</table>
## Appendix B

### ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLM</td>
<td>Ball Limiting Metal</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>CSP</td>
<td>Chip Size Packaging</td>
</tr>
<tr>
<td>CTE</td>
<td>Coefficient of Thermal Expansion</td>
</tr>
<tr>
<td>C4</td>
<td>Controlled-Collapse Chip Connection</td>
</tr>
<tr>
<td>DNP</td>
<td>Distance to Neutral Point</td>
</tr>
<tr>
<td>DRC</td>
<td>Design Rule Check</td>
</tr>
<tr>
<td>EBR</td>
<td>Edge Bead Removal</td>
</tr>
<tr>
<td>ESD</td>
<td>Electrostatic Discharge</td>
</tr>
<tr>
<td>FEM</td>
<td>Finite Element Modeling</td>
</tr>
<tr>
<td>FOC</td>
<td>Flex On Cap, term for solder paste deposition on sputtered UBM</td>
</tr>
<tr>
<td>GDSII</td>
<td>A stream format for CAD</td>
</tr>
<tr>
<td>FR-4</td>
<td>A fire-retardant epoxy resin/glass cloth laminate</td>
</tr>
<tr>
<td>IC</td>
<td>Integrated Circuit, also may be referred to in this document as chip</td>
</tr>
<tr>
<td>I/O</td>
<td>Input / Output</td>
</tr>
<tr>
<td>KGD</td>
<td>Known Good Die</td>
</tr>
<tr>
<td>LC</td>
<td>Inductance Capacitance</td>
</tr>
<tr>
<td>PB</td>
<td>Printed Board</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
</tr>
<tr>
<td>PLM</td>
<td>Pad Limiting Metal</td>
</tr>
<tr>
<td>PWB</td>
<td>Printed Wiring Board</td>
</tr>
<tr>
<td>RC</td>
<td>Resistive Capacitance</td>
</tr>
<tr>
<td>SEMI</td>
<td>Semiconductor Equipment and Materials International</td>
</tr>
<tr>
<td>SPICE</td>
<td>Simulated Program for Integrated Circuit Emphasis</td>
</tr>
<tr>
<td>TAB</td>
<td>Tape Automated Bonding</td>
</tr>
<tr>
<td>THB</td>
<td>Temperature Humidity Bias</td>
</tr>
<tr>
<td>UBM</td>
<td>Under Ball Metallurgy: Interchangeable with PLM, BLM</td>
</tr>
</tbody>
</table>