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PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

Electronics assembly technology – Selection guidance of environmental and endurance test methods for solder joints

IEC/PAS 62137-3:2008(E)

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CONTENTS

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ELECTRONICS ASSEMBLY TECHNOLOGY – SELECTION GUIDANCE OF ENVIRONMENTAL AND ENDURANCE TEST METHODS FOR SOLDER JOINTS

FOREWORD

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IEC-PAS 62137-3 was submitted by the JEITA (Japan Electronics and Information Technology Industries Association) and has been processed by IEC technical committee 91: Electronics assembly technology.

The text of this PAS is based on the following documents	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:
Draft PAS	**Report on voting**
91/784/DPAS	91/821/RVD

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

This PAS shall remain valid for an initial maximum period of three years starting from the publication date. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

INTRODUCTION

Tin-Lead eutectic solder had been used for both internal and external joints of electric and electronic equipment for its characteristics and cost for long time. The recent request to reduce burdens to the environment, however, resulted in various types of lead-free solders being developed by many organizations. Now the solders used in production are being switched from tin-lead based solders to lead-free solders in many production lines. The study of the solder joints using lead-free solders has revealed that the reliability of the joints is not the same as that of joints prepared using tin-lead solder. The Japan Electronics & Information Technology Industries Association (JEITA) has been developing test methods to evaluate the performance of the joints based on analysis of various experiments made by member experts. It should be noted that any single test is not necessarily applicable to all the electronic components. There are appropriate tests suitable for the size and shape of a component and also for specific types of leads of components. This series of standards are thus prepared to provide the industry with the necessary evaluation methods to produce reliable products to the society.

ELECTRONICS ASSEMBLY TECHNOLOGY – SELECTION GUIDANCE OF ENVIRONMENTAL AND ENDURANCE TEST METHODS FOR SOLDER JOINTS

1 Scope

This guidance describes the selection of an appropriate test method for reliability test of solder joints for various shapes and types of surface mount devices (SMD) and leaded devices, including various types of solder material.

The regions of the joints to be tested are shown in **Figure 1**. The test methods given here are applicable to evaluate the strength of joints of a component mounted on printed wiring board but not to test the mechanical strength of components themselves.

The test conditions for accelerated tests (rapid temperature change and high temperature tests) may exceed the maximum allowable temperature range for a component.

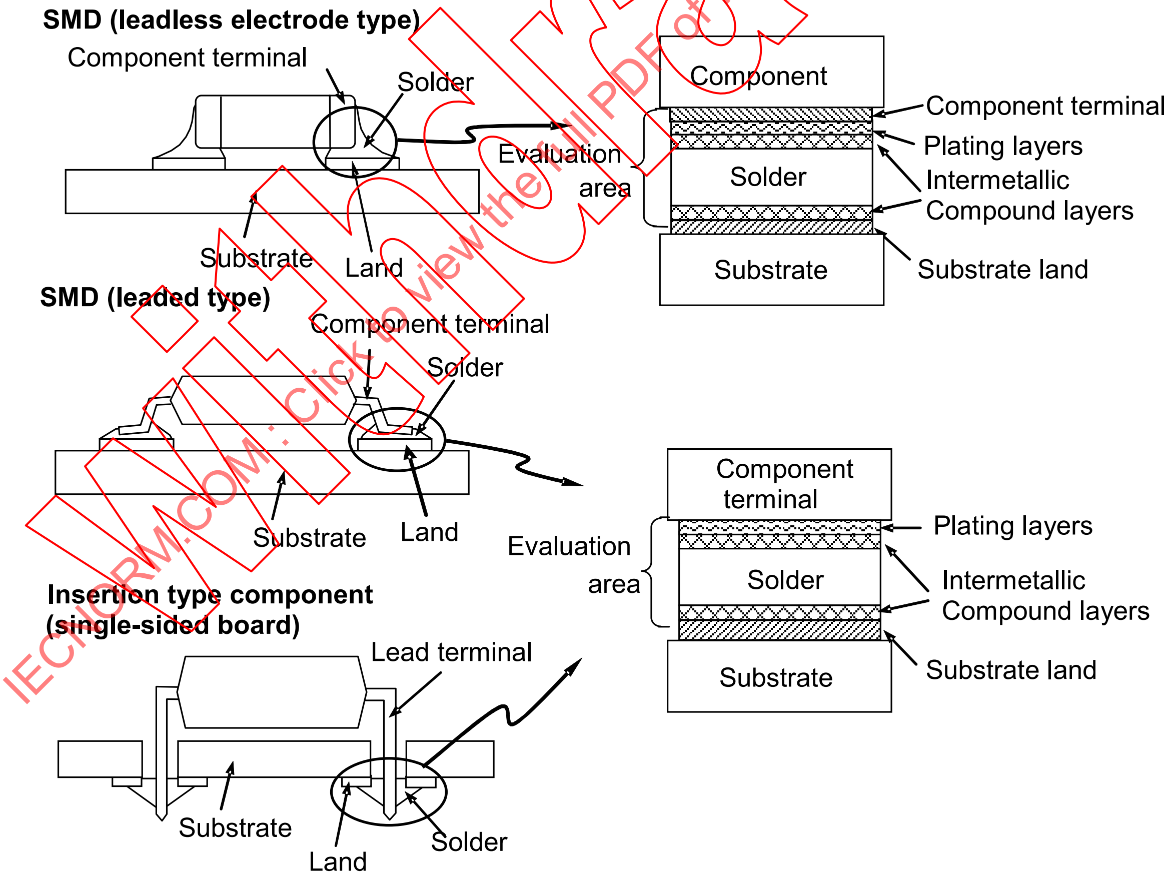


Figure 1 – The joint regions for the reliability tests

The lead-free solders have different properties from those of the conventional tin-lead eutectic solder. The reliability of soldered joints using lead-free solder may be reduced by the composition of the solder used, the shape of terminals and surface treatment.

The factors affecting the joint reliability using Sn96,5Ag3Cu,5 solder are shown in **Figure 2**. This solder has the properties of higher melting temperature and harder than the tin-lead eutectic solder and the solid is not easily deformed. Consequently, the stress induced to the joint becomes higher than the tin-lead eutectic solder.

These properties may induce break of a soldered joint by accelerated temperature changes, or mechanical stress.

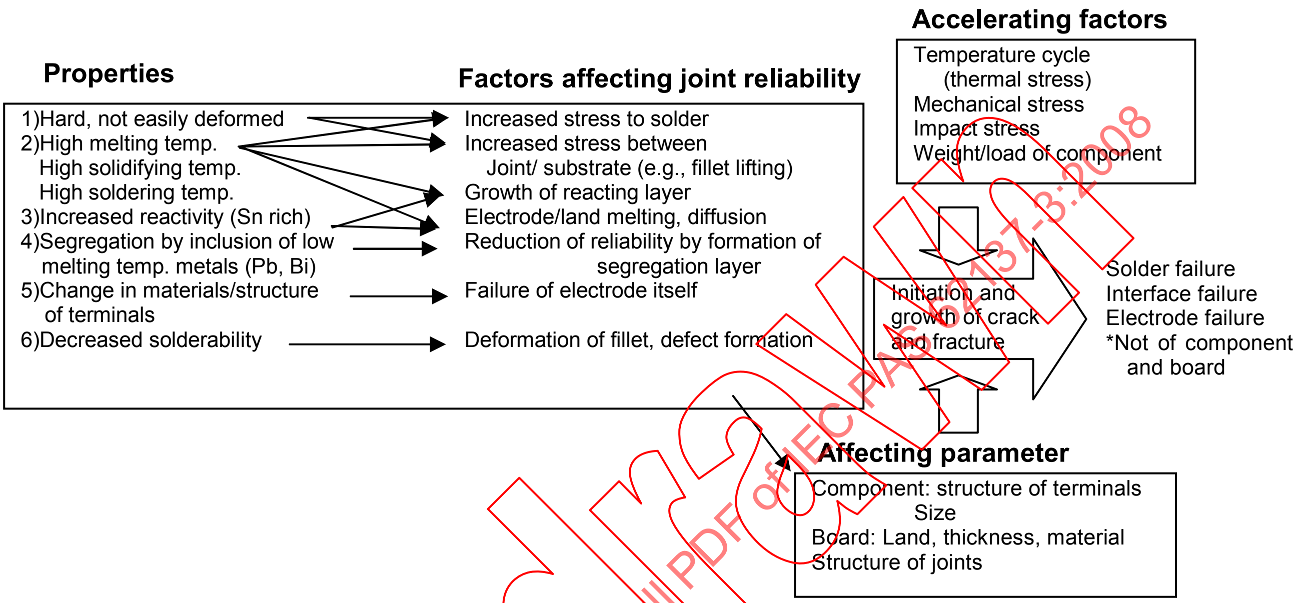


Figure 2 – Factors affecting the joint reliability made by lead-free solder

2 Normative references

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

IEC 60068-1:1988, *Environmental testing. Part 1: General and guidance,*
Amendment 1:1992

IEC 60068-2-2:2007, *Basic environmental testing procedures Part 2:Tests, Test B: Dry heat*

IEC 60068-2-14:1984, *Environmental testing – Part 2: Test N: Change of Temperature*
Amendment 1:1986

IEC 60068-2-78:2001 *Environmental testing – Part:2-78: Tests – Test: Cab: Damp heat, steady state*

IEC 60194:2006, *Printed board design, manufacture and assembly – Terms and definitions*

IEC 61188-5(all parts) :*Printed boards and printed board assemblies – Design and use*

IEC 61190-1-1:2002, *Attachment materials for electronic assembly – Part 1-1 Requirements for soldering fluxes for high-quality interconnections in electronics assembly*

IEC 61190-1-2:2007, *Attachment materials for electronic assembly – Part 1-2 Requirements for solder pastes for high-quality interconnections in electronics assembly*

IEC 61249-2-7:2002, *Materials for printed boards and other interconnecting structure – Part 2-7; Reinforced base materials clad and unclad – Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad*

IEC 62137:2005, *Environmental and endurance testing – Test methods for surface-mount boards of area array type packages FBGA, BGA, FLGA, LGA, SON and QFN*

IEC 62137-1-1:2007, *Surface mounting technology – Environmental and endurance test methods for surface mount solder joint – Part 1-1: Pull strength test*

IEC 62137-1-2:2007, *Surface mounting technology – Environmental and endurance test methods for surface mount solder joint – Part1-2: Shear strength test*

IEC 62137-1-3(91/708/CDV), *Surface-mount technology – Environmental and endurance test methods for surface mount solder joint – Part 1-3: Cyclic drop test*

IEC 62137-1-4(91/746/CDV), *Surface mounting technology – Environmental and endurance test methods for surface mount solder joints – Part 1-4: Cyclic bending test*

IEC 62137-1-5(91/743/CDV), *Surface mounting technology – Environmental and endurance test methods for surface mount solder joints – Part 1-5: Mechanical shear fatigue test*

3 Terms and definitions

For the purposes of this document, the terms and definitions in **IEC 60194**, as well as the following, apply.

3.1
lead-free
the lead content in the objective portion of an electronic components or similar products is equal or less than 0,1 wt%

3.2
pull strength for SMD
applied force to break the joint of the lead of a gull-wing type SMD solder mounted and the copper land of printed wiring board using a jig to pull the lead

3.3
shear strength for SMD
applied force to break the all the joints of leads of an SMD and lands on the printed wiring board when a force is applied parallel to the side of the SMD

3.4
torque shear strength for SMD
applied force to break the soldered joints of leads of an SMD to the lands on printed wiring board when a rotating force is applied to the SMD at the both end with the centre of the moment at the center of the SMD with the rotation moment in parallel to the printed wiring board surface

3.5
monotonic bending strength for SMD
strength of soldered joints of SMD mounted on board when the board is bent convex toward to the mounted SMDs expressed by the maximum bending depth to the break of joints

3.6
cyclic bending strength for SMD

number of bending to the break of soldered joints of SMDs to the copper lands on board which is fixed to a jig when the board is bent convex toward to the mounted SMDs

3.7
mechanical shear fatigue strength for SMD

imposition of cyclic shear deformation on the solder joints by mechanical displacement instead of relative displacement generated by CTE (coefficient of thermal expansion) mismatch in thermal cycling testing

NOTE The mechanical shear fatigue tests continues until the maximum force decreases to a certain value, which corresponds to the appearance of an initial crack, or the electrical resistance-measuring instrument can detect electric continuity interruption, and the number of cycles is recorded as fatigue life

3.8
cyclic drop test for SMD

number of drops to the break of soldered joints of an SMD to the copper lands on a board which is fixed to a jig when the board is dropped from a specified height

3.9
cyclic steel ball drop strength for SMD

number of drops to the break of soldered joints of an SMD to the copper lands on a board when the steel ball is dropped from a specified height on a board

3.10
pull strength for lead terminal type device

maximum applied force to break the soldered joint of a lead of an SMD to a land on board when the lead is pulled using a jig

3.11
creep test for lead terminal type device

strength of a soldered joint expressed by the time to break the joint held in a thermostat when a continuous force is applied to a lead of an SMD soldered to a land

3.12
fillet lifting phenomenon

phenomenon a solder fillet of a lead of an SMD is fillet lifting from a land on a board, or of the land from the board (De-lamination)

3.13
daisy chain

all chain of connections solder joint are connected in series

NOTE Lands on both sides of a board and leads are solder- connected in a chain in the case of a lift off test

4 Procedure of selecting the applicable test method

4.1 Stress to solder joints in the field and test methods

The correlations between the test methods and the actual stress induced to components are shown in Figure 1. The printed wiring board and the shapes of terminals effective to correlate the test results to actual conditions of the component mounting in the filed are also shown as reference. The selection of a test method suitable for a specific shape of terminal is given in 4.2.

Table 1 – Correlations between test methods and actual stresses in the filed

Test method **(Applicable standard)**	**Accelerated stress application**	**Applicable board/** **Components**	**Stress in the field and applicable products**
Conduction test a), b) **IEC 62137:Annex B**	Temperature cycling (rapid temperature change) c)	SMD	Repeated thermal stress caused by the difference in thermal expansion coefficients of component and board at the ON/OFF of equipment and/or temperature changes in the surrounding environment
Pull strength a) **IEC 62137-1-1**		SMD (Gull-wing)	
Shear strength a) **IEC 62137-1-2**		SMD	
Torque shear strength a) **Annex C**		SMD	
Monotonic bending test a) **Annex D**		SMD	
Cyclic bending strength test **IEC 62137-1-4**	Repeated board bending	SMD	Repeated mechanical stress applied to soldered joints and board as in the case of keying, especially for portable equipment
Mechanical shear fatigue test **IEC 62137-1-5**	Cyclic strain	SMD	Repeated thermal stress caused by the difference in thermal expansion coefficients of component and board at the ON/OFF of equipment and/or temperature changes in the surrounding environment
Cyclic drop test d) **IEC 62137-1-3**	Repeated board drop	SMD	Shock induced to soldered joints when equipment is erratically dropped while the equipment is in use
Cyclic steel ball drop strength test d) **Annex E**	Repeated ball drop	SMD	
Pull strength test **Annex F**	Temperature cycling (rapid temperature change) c)	Single-sided TH/Leaded insertion type	Repeated thermal stress caused by the difference in thermal expansion coefficients of component and board at the ON/OFF of equipment and/or temperature changes in the surrounding environment
Creep strength test **Annex G**	Loading + Temperature	Single-sided TH/Leaded insertion type	Degradation of soldered joint when a continuous force is applied
Observe of fillet lifting phenomenon **Annex H**	Evaluation method	Single-sided TH/Leaded insertion type	The external observation method of fillet lifting phenomenon that may occur when soldering an alloy and the terminal plating

NOTE 1

a) This is a test to evaluate degradation of joint strength with repeated thermal stress induced to the joint by means of rapid temperature change for an accelerated test. A proper test should be selected according to the features of the component under test such as the shape of its leads.

b) This is a test to check if there is a failure at a soldered joint by measuring changes of resistance of the joint without applying mechanical stress. This test method is not a new test method developed in this document but referred here as an alternative method as it is a useful test especially for BGA and LGA.

c) Each temperature test is applied in the case of the following alloys.

1) temperature cycling test (Rapid temperature change): Sn-Ag-Cu, Sn-Zn, Sn-Bi and Sn-In

2) High temperature / high humidity test: Sn-Zn

3) High temperature test: Sn-Bi

d) Applicable using Sn-Ag-Cu, Sn-Zn, Sn-Bi and Sn-In alloy

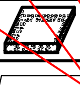
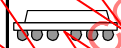
NOTE 2 The vibration test is a test of a durability against the vibration a product may receive while in transportation or in the service in the field. It was not proved that a vibration test, including the most severe random acceleration test, could evaluate degradation of soldered joints. The vibration test is, therefore, not included in this document.

4.2 Selection of test methods based on the shapes and terminals of electronic components

4.2.1 Surface Mount Devices

The recommended test methods suitable for specific shapes and terminals of devices are listed in **Table 2**.

Table 2 – Recommended test methods suitable for specific shapes and terminals of SMDs

	Types and terminals of device				Rapid temperature change test					Cyclic bending test	Cyclic drop test	Mechanical shear fatigue test
	Terminals		Number of terminals	Examples	Pull test	Shear strength test	Torque shear test	Resistance measurement	Monotonic bending limit			
General electronics components	Electrodes on 2 sides (bent leads)		2	Tantalum capacitor, inductor	-	A,B	-	-	-	-	C	-
	Electrodes on 3 sides		2	Rectangular chip resistor/film capacitor	-	A,B	-	-	-	-	C	-
	Electrodes on 5 sides (including cap)		2	Laminated capacitor, thermistor,	-	A,B	-	-	-	-	C	-
	Multi terminals (terminals on sides)		4 or more	Resistor array, capacitor array	-	A,B	-	-	-	C	C	-
	Gull wing – 1		4 or more	Transformer	A,B	C	-	-	C	-	C	-
	Gull wing – 2		Up to 6	Switch	-	B	A,B	-	-	-	C	-
	Gull wing – 3		4 or more	Connector	-	A,B	A,B	-	C	-	C	-
	Electrodes on bottom		2	Inductor, tantalum capacitor	-	A,B	B	-	-	-	C	-
	Round electrode (including cap)		2	MELF capacitor/resistor/fuse	-	A,B	B	-	-	-	C	-
Semiconductor devices	Leads on two sides (bent lead)		2	Diode	-	A,B	C	-	-	-	C	-
	Gull wing leads		3 to 6	Small transistor	C	B	C	-	-	-	C	-
	Gull wing leads		6 or more	QFP, SOP	A,B	-	-	C	C	C	B	B
	Non-lead		6 or more	QFN, SON	-	-	-	A,B	C	B	B	B
	Ball electrodes on bottom		Multiple	BGA, FBGA	-	-	-	A,B	C	B	B	B
	Electrodes on bottom without ball		Multiple	LGA, FLGA	-	-	-	A,B	C	B	B	B

Note1: A: Recommended for accelerated endurance test, B: Applicable, C: Applicable when condition are met, -: Not applicable

Note2: One of the following static mechanical tests is performed before or after the rapid temperature change test according to the shape of the component under test.
a) Pull strength test: SMD with gull wing terminals.
b) Shear strength test: Small rectangular SMD to which a pushing jig can be pressed to a side of the device.
[illegible]

Note3: The conduction test is applicable to devices to which a Daisy-chain can be formed on the mounting board or within the device under test itself. Examples are those semiconductor devices not with leads such as BGA, LGA or QFN.

Note4: The monotonic bending limit test is applicable to those components with height or large size to which the resistance measurement test is available and which are not easily deformed. This test is applicable in case the resistance measurement does not give a good criterion for the durability analysis and a mechanical stress is expected to exist in the service.

Note5: The cyclic bending strength test and cyclic drop test are applicable to those components mainly used in portable equipment.
The use of these tests should be specified in the specification of the product.

Note6: Each temperature test is applied in the case of the following alloys.
a) temperature cycling test (Rapid temperature change): Sn-Ag-Cu, Sn-Zn, Sn-Bi and Sn-In
b) High temperature / high humidity test: Sn-Zn
c) High temperature test: Sn-Bi

4.2.2 Insertion component (leaded component)

The pull strength test is the basic test for such leaded components. The creep test should also be used for components of a large size, or an external force seems to be applied continuously from its structure.

The selection of the test shall be stated in the product specification for the component to be mounted on solely single-side of a board. In many cases, strength of terminal leads in insertion type through-hole mounted components may be inferior as compared to soldered joints. These tests are not appropriate for equipment using this type of boards.

Recommended test methods such as the weight of lead terminal part, the kind of the board and bite of the load are given in **Table 3**.

Table 3 – Test method to recommend from application and weight of the lead terminal part

PWB Type	Application, Component type		Test			
	Application	Weight of a lead terminal	Pull strength test	Creep strength test	Evaluation of fillet lifting phenomenon	Conduction test
Single-sided TH	No continuous load	Light	A	–	–	–
		Heavy	B	A	–	–
	Continuous load	Light	A	–	–	–
		Heavy	B	A	–	–
Both-sided TH	General lead terminal part		–	–	A	B
	Daisy chain type part		–	–	A	A

NOTE 1 A: Applicable, B: Applicable when condition are met, – : Not applicable

NOTE 2 Environment of each test is as follows.

a) Pull strength test: Room temperature

b) Creep strength test: High temperature environment to prescribe in a product standard

c) Lift off test: Room temperature

d) Conduction test: Rapid temperature change test environment to prescribe in a product standard

NOTE 3 For these test, the Sn – Ag – Cu alloy and Sn – Zn alloy are suitable

NOTE 4 In case of using both-sided TH board, the strength of the lead terminal tends to be smaller than the strength of solder joint. Therefore, this type board is not suitable for a joining strength test.

5 Common subjects in each test method

5.1 Mounting device and materials used

a) Solder

The composition of the lead-free solder for interconnection is not specified. The standard solder composition is given in **Table 4**.which shall be used in case the composition is not specified in the product specification.

Table 4 – Solder composition

Solder alloy	Solder composition (Short name)	
Sn-Ag-Cu	Sn96,5Ag3Cu,5(A30C5)	–
Sn-Zn	Sn91Zn9(Z90)	Sn89Zn8Bi3(Z80B30)
Sn-Bi	Bi58Sn42(B580)	–
Sn-In	Sn88In8Ag3,5Bi,5(N80A35B5)	–
Sn-Cu	Sn99,3Cu,7(C7)	–

b) Board used in the tests

The board shall be the copper-clad laminate of glass-cloth epoxy type specified in **IEC 61249-2-7**. When board of other material is used, it is recommended to choose board of fewer thermal degradation, mechanical deformation and board breakage.

The monotonic bending strength test, cyclic bending strength test and cyclic drop test are not applicable to specimens using a substrate made of materials which are hard to be deformed such as ceramics.

Other test conditions are specified in the relevant test method.

c) Mounting of components to board

Mounting of components to board is specified below.

Tests for SMDs are performed by mounting the devices on single-sided or one side of double-sided board.

Tests for leaded components for insertion mounting are for mounting the components on one side of board. Tests for leaded components mount on both sides are not appropriate as the strength of soldered joints in this case is much higher than that of leads themselves to the component.

d) Position of components and land pattern

The SMD to be tested in the monotonic bending strength test, cyclic bending strength test and cyclic drop test shall be mounted on the center of a board as illustrated in Figure 3. The position of the device under test for other tests may be determined in appropriate place on board as agreed between user and supplier. When a product standard does not have a rule, the land pattern is based on standards of IEC 61188-5 series.

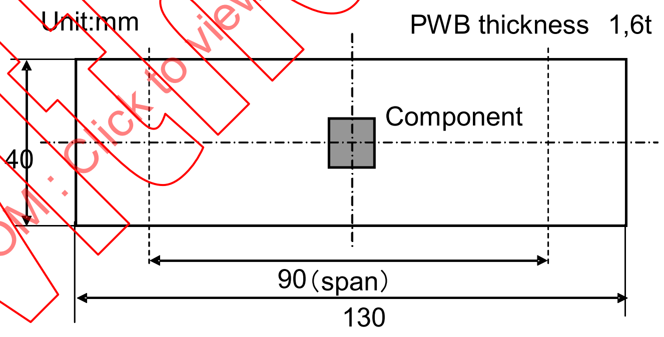
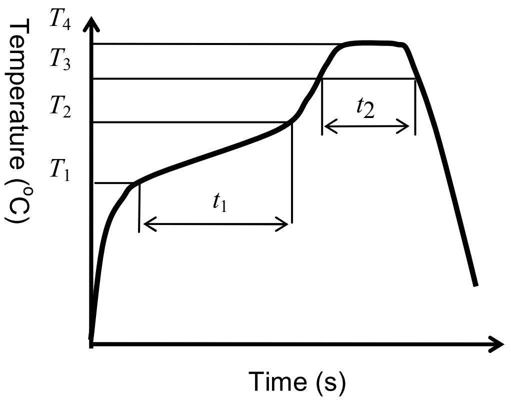


Figure 3 – An example of the mounting position of SMD for monotonic bending, cyclic bending and cyclic drop tests

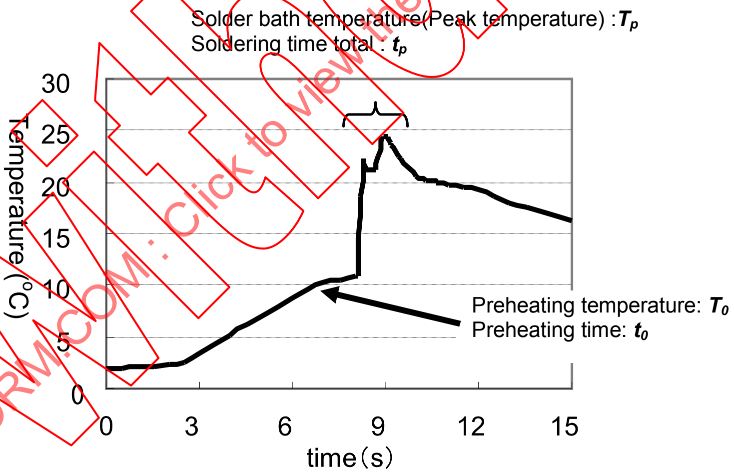
5.2 Soldering condition

A proper soldering condition shall be selected to form appropriate solder fillet. Examples of the temperature profile for the lead free solder for reflow and flow soldering are shown in **Figures 4** and **Figures 5**.



		Solder composition			
		Sn96,5Ag3Cu,5	Sn91Zn9*, Sn89Zn8Bi3	Bi58Sn42	Sn88In8Ag3,5Bi,5
T_1	Minimum preheat temperature	150 °C	130 °C	100 °C	140 °C
T_2	Maximum preheat temperature	180 °C	150 °C	120 °C	160 °C
T_3	Soldering temperature	220 °C	200 °C	150 °C	206 °C
T_4	Peak temperature	250 ± 5 °C	220 ± 5 °C	190 ± 5 °C	220 ± 5 °C
t_1	Preheat time	90 ± 30 s	90 ± 30 s	90 ± 30 s	90 ± 30 s
t_2	Soldering time	20 ~ 60 s	20 ~ 60 s	20 ~ 60 s	20 ~ 60 s
NOTE* Sn91Zn9 is recommended soldering of N2 reflow condition.					

Figure 4 – An example of reflow soldering temperature profile



Solder composition	Preheat		Soldering	
	Preheat temperature T_0 °C	**Preheat time t_0 s**	**Peak temperature Tp °C**	**Soldering time t_p s**
Sn96,5Ag3Cu,5(A30C5)	100 ~ 120	30 ~ 90	250 ± 5	3 ~ 5
Sn99,3Cu,7(C7)	100 ~ 120	30 ~ 90	250 ± 5	3 ~ 5

Figure 5 – An example of flow soldering temperature profile

5.2.1 Other specifications

Details of other specifications are given in relevant test methods.

5.3 Accelerated endurance test

5.3.1 Rapid temperature change test (apply to all solder alloy in this standard)

The rapid temperature change test as specified in **IEC 60068-2-14** (Temperature change tests) shall be performed for pull, shear, torque shear, and monotonic bending tests for SMDs and pull test for leaded components. The temperature condition shall be chosen considering the effect of temperature variation characteristics of a soldered joint to the stress relaxation of the joint when a stress is applied to the joint. The temperature characteristics depend on the size of the specimen (specific heat and heat dissipation of the specimen), size of the board, or the number of boards tested in one measurement (see **Annex A**).

Recommended temperature conditions are given in **Table 5**.

Unless otherwise specified, the number of temperature cycles is 500 and 1000 cycles except for the resistance measurement.

Table 5 – Temperature condition for rapid temperature change test

		Solder composition			
		Sn96,5Ag3Cu,5	Sn91Zn9, Sn89Zn8Bi3	Bi58Sn42	Sn88In8Ag3,5Bi,5
Minimum storage temperature	Temperature	−40 °C	−40 °C	−40 °C	−40 °C
	Hold time	30 min	30 min	30 min	30 min
Maximum storage temperature	Temperature	125 °C	125 °C	85 °C	125 °C
	Hold time	30 min	30 min	30 min	30 min

5.3.2 High temperature test (apply to Bi58Sn42 alloy solder only)

Peel strength test, Shear strength test, Torque shear strength test, and monotonic bending test of SMD and Pull strength test of leaded component in **IEC 60068-2-2**, as well as the follow, apply.

a) Test temperature: 85 °C

b) Test time: 500 h and 1 000 h

5.3.3 High temperature and High humidity test (constant) (apply to Sn91Zn9 and Sn89Zn8Bi3 alloy solder)

Peel strength test, Shear strength test, Torque shear strength test, and monotonic bending test of SMD and Pull strength test of leaded component in **IEC 60068-2-78**, as well as the follow, apply.

a) Test temperature and humidity: 65 °C, 85 %

b) Test time: 500 h and 1 000 h

5.4 Selection of test conditions and analysis of test results

a) Test speed

The test methods and conditions for the evaluation of durability of soldered joints shall be such that the test does not break the specimen itself but damages are induced only to the soldered joints. There is a tendency to increase the break of board and/or specimen in pull, shear, torque shear, and monotonic bending tests for SMDs and pull test for leaded components when the test speed is very high. It is recommended that the slower test speed with which a soldered joint breaks in several tens of seconds to several minutes is chosen by performing a preliminary test of a specimen.

b) Board fixing

The measurement result may be affected if the board floats from the base or is distorted during a test. The board shall be fixed firmly on a base preferably at a position near the testing soldered joint.

The structure and/or size of the board fixing jig or the board supporting jig are specified in each test method to assist reproducibility of the test.

c) Test result

The test result shall be analyzed by confirming and recording not only the strength and time to break of a soldered joint but also the mode of break.

6 Test method

6.1 Body strength test of SMD before and after the rapid temperature change test

The pull, shear, torque shear, and monotonic bending tests for SMDs are to judge the degree of degradation of strength and other characteristics of a joint by the rapid temperature change. Pull strength test.

6.1.1 Pull strength test

The pull strength test is applicable to SMDs with gull-wing type leads. As illustrated in **Figure 6**, a pulling jig is hooked to one of the leads to pull the lead at an angle of 45 ° and to measure the force to break the joint.

The degradation of a joint is analyzed from the changes of the maximum pulling force and mode of break before and after the rapid temperature change test. This test is applicable to both of reflow and flow soldering.

The proper pulling speed for a 0,5 mm pitch QFP is 0,0083 mm/s (0,5 mm/min).

The details of the test are given in **IEC 62137-1-1**.

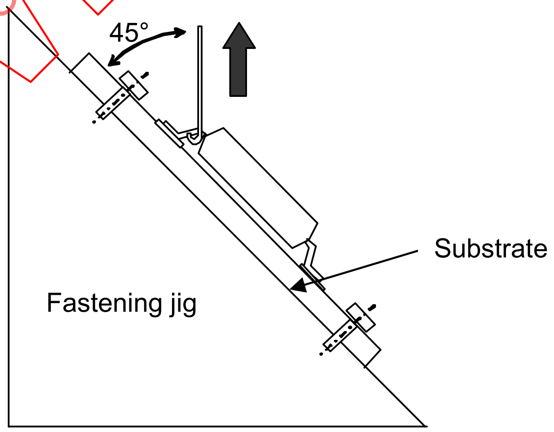


Figure 6 – Pull strength test

6.1.2 Shear strength test for force applied to the side of a specimen

The shear strength test is applicable for SMDs of rather small size. As illustrated in **Figure 7**, the maximum testing force is measured when a force is applied horizontally to a side of a specimen. The specimen is soldered to a board by reflow soldering.

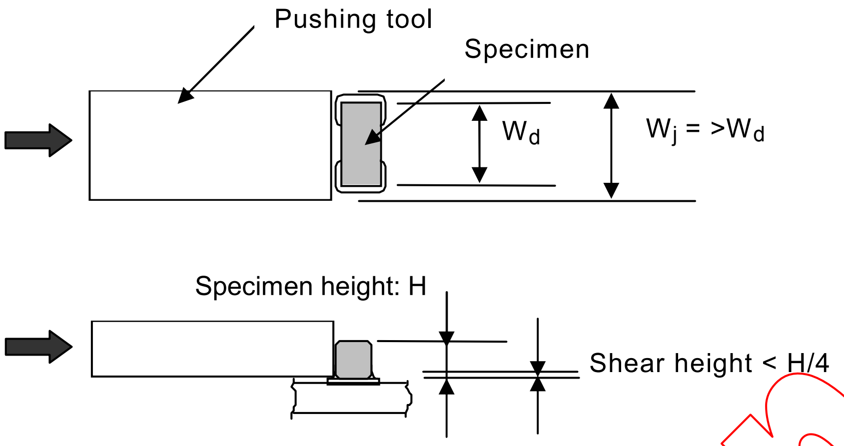


Figure 7 – Shear strength test

It is necessary to keep the constant shear height which is lower than 1/4 of the height of the specimen to obtain accurate measurement. The proper speed of applying the force is 0,0083 to 0,15 mm/s (0,5 to 9 mm/s).

The details of the test are given in **IEC 62137-1-2**.

6.1.3 Torque shear strength test

The torque shear strength test is an alternative test method to the shear strength test for components to which the shear strength test is not easily applicable due to their shapes. This test is also applicable to a rather large component. A concave shaped jig as illustrated in **Figure 8** holds a specimen and a torque force is applied to the jig to rotate the specimen. The maximum torque to shear the specimen is measured when a rotating moment is applied parallel to the board.

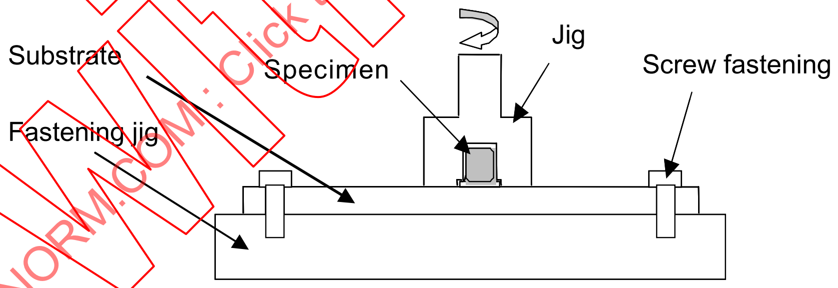


Figure 8 – Torque shear strength test

The depth of the jig should be the same as to the height of the specimen to obtain accurate measurement. The centre of rotation shall be the center of the specimen, and swaying of the rotation axis shall be avoided. The proper rotation speed, if adjustable, is 0,00698 to 0,0175 rad/s (0,4 to 1,0 deg/s).

The details of the test are given in **Annex C.**

6.1.4 Monotonic bending strength test

The monotonic bending strength test is a test appropriate to a component of rather a large size. As illustrated in **Figure 9**, the board with an SMD mounted is placed between two supporting jigs with the mounted face down, and the board is pressed using a indenter on the back side until the soldered joint breaks, and the bending depth is measured. Measurement is made before and after the rapid temperature change to evaluate the degree of degradation of soldered joints.

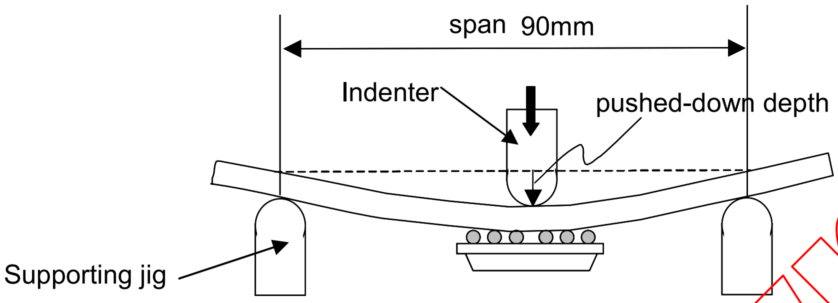


Figure 9 – Monotonic bending strength test

It is desirable that the board is bent with a circular bending. This test is not appropriate for a thin board or a ceramic substrate. The pushed-down depth to break a joint is preferably measured by conduction measurement using a circuit such as the Daisy chain.

The distance between the two supporting jigs shall be 90 mm with the radius of curvature, R, of 2,5 mm. The radius of curvature of the pressing rod shall be 5 mm.

The test condition shall be used such as the relation between the strain induced to the board and the depth of pressing becomes linear. It is desirable to make a preliminary test to check the relation of pressing depth and strain, and also the limit of the depth at a predetermined pressing speed using strain gauge attached near the soldered joint of the device under test.

The proper pressing speed is 0,0083 mm/s (0,5 mm/min) for a glass-epoxy copper-clad laminate board. The limiting depth of pressing is 20 mm.

The details of the test are given in **Annex D**.

6.2 Cyclic bending strength test

The cyclic bending strength test is a test for rather a large leadless SMD used in portable equipment. As illustrated in **Figure 10**, the board with an SMD mounted is placed between two supporting jigs with the mounted face down, similar to the case of the monotonic bending strength test. The board is repeatedly pressed using a pressing rod on the back side to a predetermined depth and the number of bending until the soldered joint breaks is measured by means of a continuous conduction measurement using a circuit such as the Daisy chain as described in **Annex B**.

The test equipment and the structure of the supporting jigs are similar to those of the monotonic bending strength test. The board, however, may not return to the original flatness after many bending cycles and affect the test result. The structure of the jig should be such that the curvature of the board is smooth and kept constant. **Figure 11** illustrates such a specimen supporting jig and indenter scheme to bend back the board compulsively to the original flatness by holding both ends of the board to supporting jigs and the indenter using a bearing supporting structure.

The appropriate speed of bending is 0,5 mm/s (30 mm/min). A preliminary test should be made to determine a proper depth of pressing for each SMD of different size as to the joint breaks at a bending of several thousands. Since the bending depth and the number of bending to break give a roughly straight line on a log-log scale presentation, a proper depth may be determined without much difficulty.

A ceramic substrate is not suitable for this type of the bending test.

The details of the test are given in **IEC 62137-1-4**.

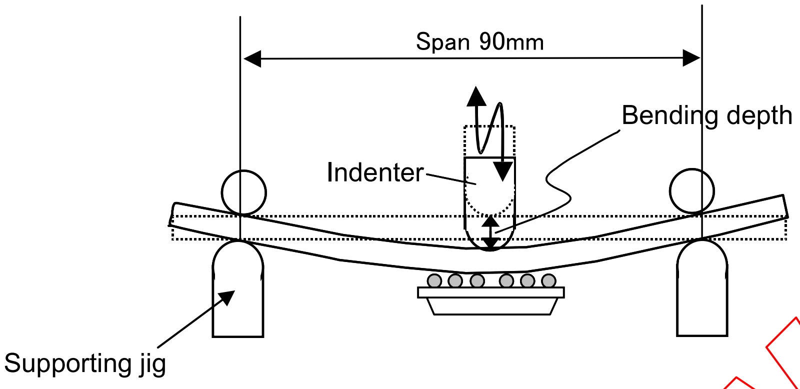


Figure 10 – Cyclic bending strength test

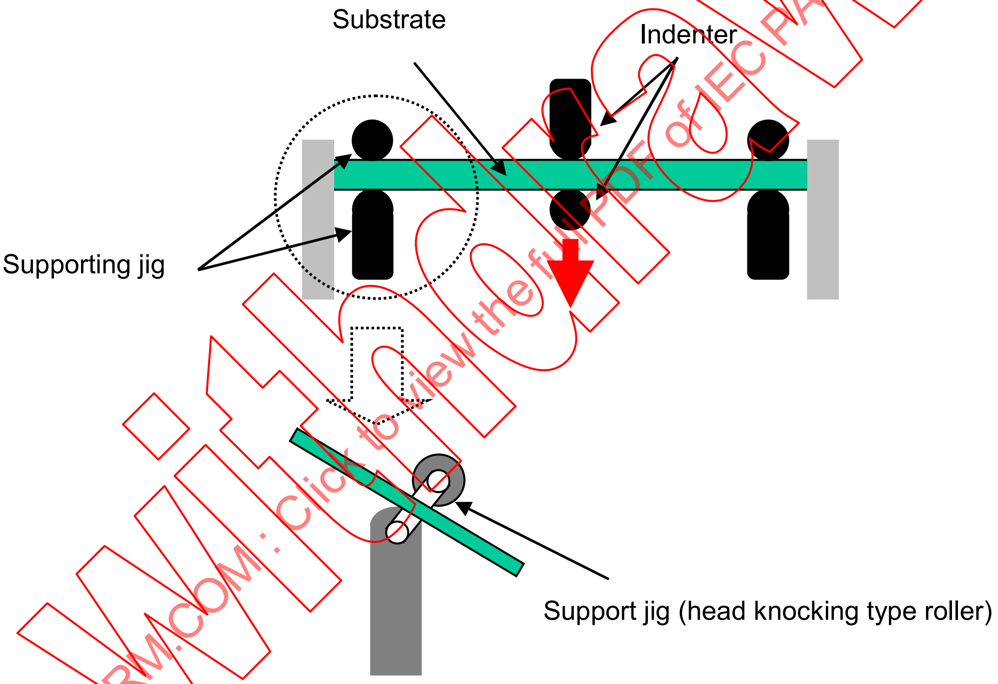


Figure 11 – Structure of cyclic bending strength test

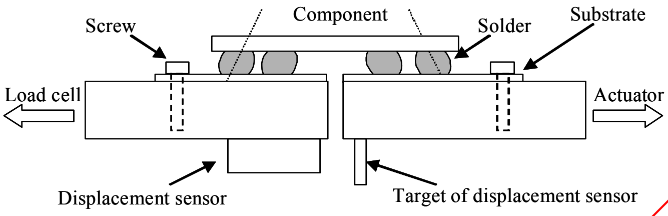
6.3 Mechanical shear fatigue test

The mechanical shear fatigue test is the imposition of cyclic shear deformation on the solder joints by mechanical displacement instead of relative displacement generated by CTE (coefficient of thermal expansion) mismatch in thermal cycling testing. There are two types of load-applying methods for the shear fatigue test as shown in **Figure 12**.

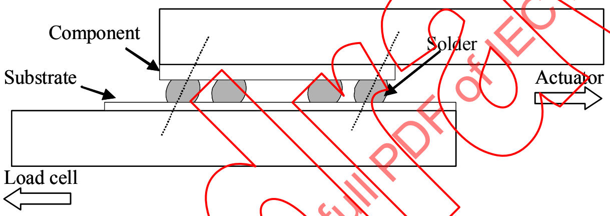
The straddle fatigue method is the imposition of shear deformation on the solder joints by applying mechanical displacement to the substrate divided into two pieces. The lap shear fatigue method is the method that the bottom of the substrate and the top of the component are fixed between the lap shear jigs, and the mechanical displacement is applied to the jig by the actuator, resulting in the solder joint deformation in shear mode. The fatigue tests were displacement-controlled low cycle shear fatigue tests with the loading profile of a symmetrical triangular wave or a sine wave. The tests were performed at 298 K or at elevated temperature.

The mechanical shear fatigue tests continues until the maximum force decreases to a certain value, which corresponds to the appearance of an initial crack, or the electrical resistance-measuring instrument can detect electric continuity interruption, and the number of cycles is recorded as fatigue life.

The details of testing method and testing condition are given in **IEC 62137-1-5.**



(a) Straddle method



(b) Lap shear method

Figure 12 – Schematic illustrations of mechanical shear fatigue for solder joint

6.4 Cyclic drop test

6.4.1 Cyclic drop test

The cyclic drop test is the test for mounting SMDs used in portable equipment. As illustrated in **Figure 13**, a SMD mounted board is held to the board fixing jig with the component mounted face down, and dropped from a certain height onto the impact block. The number of drops until the soldered joint breaks is measured by means of a continuous conduction measurement using a circuit such as the Daisy chain. It is desirable to measure the instantaneous break of the circuit (open).

The break of a joint is caused by the strain in the board induced by the impact of the load at the collision to the board. A thinner board of 0,8 to 1,2 mm thick is suitable for this test comparing to other tests using 1,6 mm thick board.

It is necessary to stabilize the strain induced to the joints to increase the reproducibility of the test. It is recommended to form a hemispherical protrusion to the board fixing jig to avoid asymmetric sock by the fall onto the impact block. The fastening force of the board fixing screws should be equal to all the screws as much as possible. The test equipment should have a structure to minimize the friction of the board holding jig to avoid deviation of falling speed of the jig to the impact block. The block should not have any dent. To check the reproducibility of the test, it is desirable to make a preliminary test to check the form and magnitude of strain using a strain gauge attached near the soldered joint of the device under test.

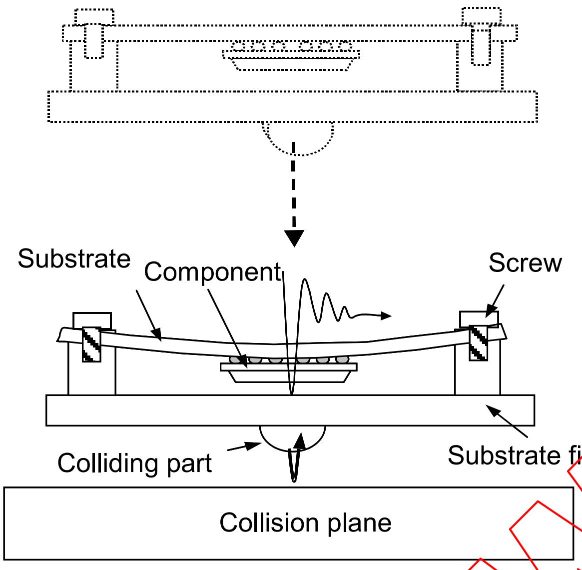


Figure 13 – Cyclic drop test

The details of the test are given in **IEC 62137-1-3**.

6.4.2 Cyclic steel ball drop strength test

As illustrated in **Figure 14** a SMD mounted board is held to the board fixing jig with the component mounted face down, and a steel ball is dropped from a certain height onto the backside of the board. The number of drops until the soldered joint breaks is measured. The position of the ball drop for a large SMD should be near the peripheral of the component which is most vulnerable to such mechanical damages. The number of drops until the soldered joint breaks is judged by means of a continuous conduction measurement using a circuit such as the Daisy chain as in the cyclic drop test. It is desirable to measure the instantaneous break of the circuit (open).

The test equipment should have a good definition of the position of the ball drop to attain good reproducibility of the test. To check the stability of strain waveform in the objective solder joint, it is desirable to make a preliminary test to check the form and magnitude of strain using a strain gauge attached near the soldered joint of the device under test.

The details of the test are given in **Annex E.**

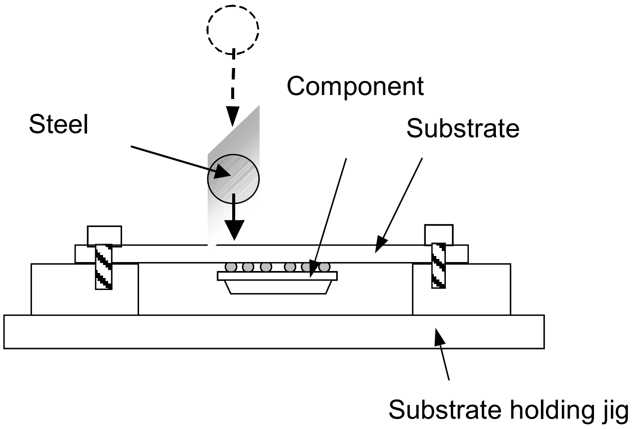


Figure 14 – Cyclic steel ball drop test

6.5 Strength test of leaded component

6.5.1 Pull strength test of leaded component

This is the test to measure the maximum force to break a soldered joint by holding lead terminal of a lead insertion mounted SMD on a single-sided board to the board holding jig and by pulling one of the leads perpendicular to the board as illustrated in **Figure 15**. This test is performed before and after the rapid temperature change test and the degree of degradation of soldered joints is evaluated. A lead cut-off from the component alone may be tested for the pull strength test if the presence of the component makes it difficult to perform this test. The pulling speed shall be selected from 1 mm/min, 2 mm/min, 5 mm/min, 10 mm/min, and 20 mm/min.

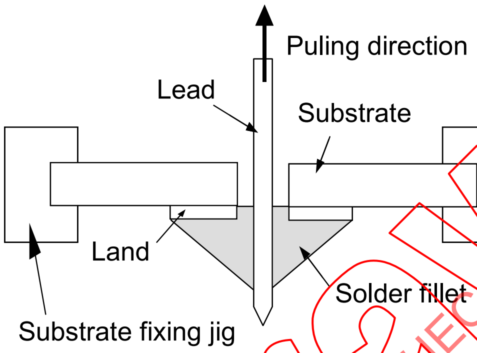


Figure 15 – Pull strength test

The details of the test are given in **Annex F**.

6.5.2 Creep strength test of leaded component

This test is to measure the time required a lead solder mounted into a through hole on a board breaks and falls off from the through hole by pulling the lead with a weight and left in a high temperature chamber as illustrated in **Figure 16**. A lead cut-off from the component alone may be tested for the creep strength test if the presence of the component makes it difficult to perform this test. The time to the break of the soldered lead joint is measured by means of a continuous conduction measurement.

The test condition is determined by the melting temperature of the material used and usually is $T>0,4\ T_m$ (T_m is the melting temperature in absolute temperature of the material). In the case of solder alloys, as the room temperature is roughly 0,6 T_m, it is theoretically possible to perform a creep test from –50 °C to just below the melting temperature. However, it is necessary to consider the strength of leaded component and the deterioration of the mounted board. The practical temperature range of the test for SMDs is from room temperature for low temperature to +125 °C for high temperature test considering heat resistivity of the board used. A higher temperature may be selected for the board with a higher glass transition temperature (T_g). It is desirable to perform a preliminary test as to select a proper load of pulling the lead.

The creep is judged by the weight of the load and the time to break of the soldered lead.

The details of the test are given in **Annex G**.

The entire fixture within the dotted line are placed in a high temperature oven of 125 °C

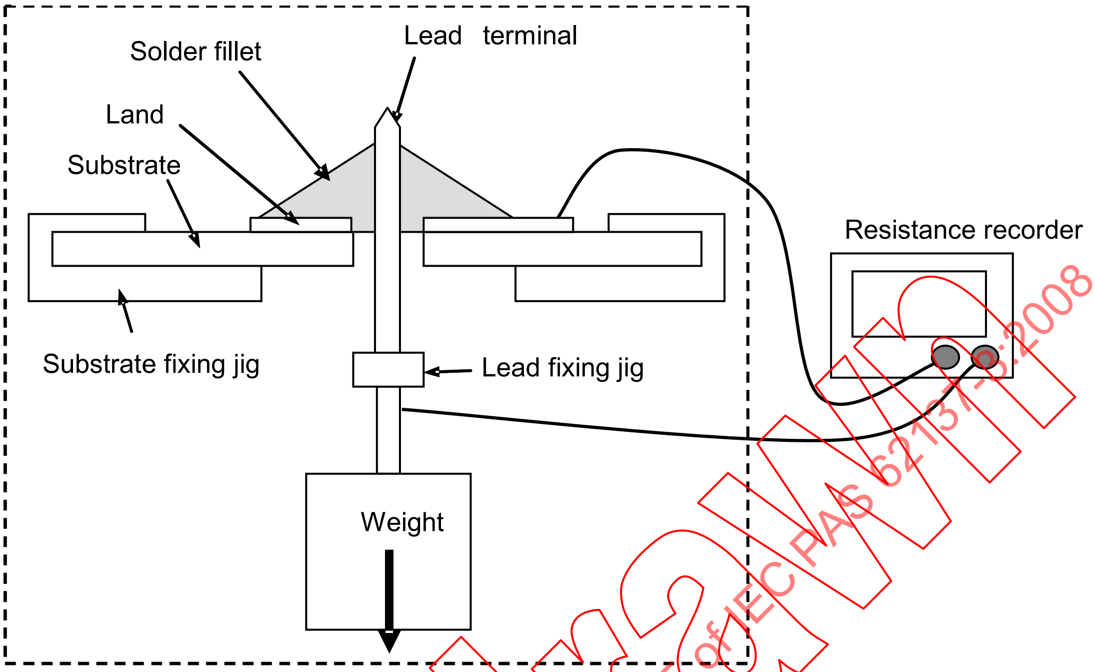


Figure 16 – Creep strength test

6.6 Fillet lifting phenomenon observation of leaded component

It is desirable to record the status of fillet lifting phenomenon immediately after solder mounting of components on board. Observation of fillet lifting phenomenon should be made using a magnifying glass at an angle of 10 to 30° from the board.

The details of the test are given in **Annex H**.

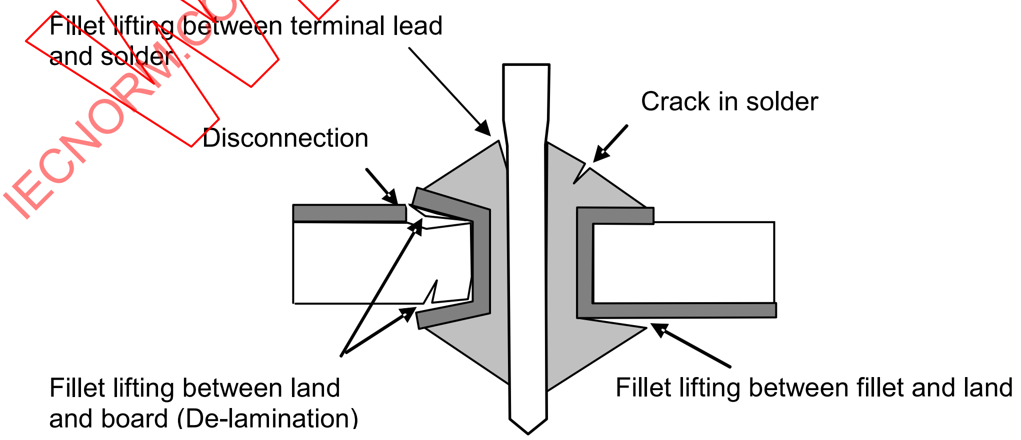


Figure 17 – Fillet lifting phenomenon of soldered joint

Annex A
(informative)

Condition of rapid temperature change test

A.1 Scope

The determination of the test condition of the rapid temperature change test is stated here as reference.

A.2 The time necessary to leave a specimen to an environment for an effective test

The stress relaxation curve with the application of a constant strain to the solder is shown in **Figure A.1**. The stress applied to solder is relaxed as time goes by the introduction of non-ballistic strain in the solder. The initial change of the stress is very large but the stress is reduced as time goes on.

The fatigue of solder by repeated temperature change strongly depends on the non-ballistic strain. The stress induced to the soldered joint by the difference in the thermal expansion coefficients of the board and the component generated by the rapid temperature change test relaxes as time goes on and a non-ballistic strain is induced to cause the fatigue of the soldered joint. It is necessary to keep the joint at a high or low temperature for some time for the durability test of the joint. It is not efficient for the evaluation to leave the joint at the temperature where the stress relaxation is not significant.

It is desirable to keep the specimen at a high or low temperature, therefore, for fifteen minutes.

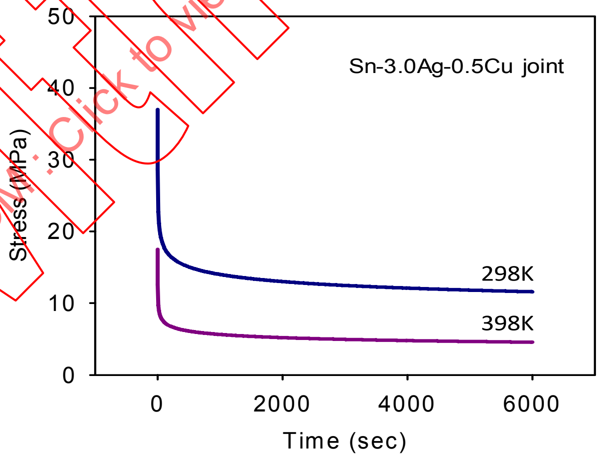
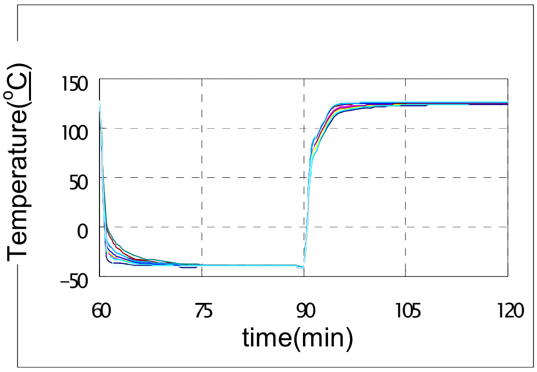


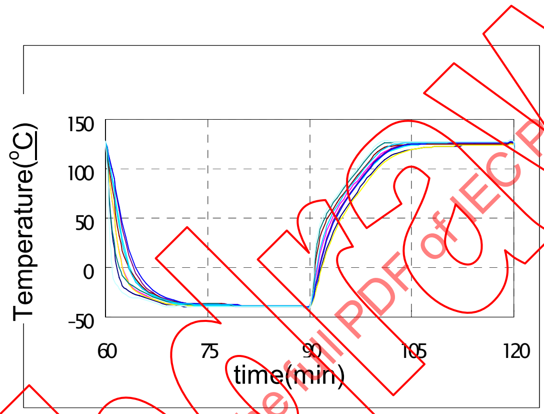
Figure A.1 – Stress relation curve for a given strain to a soldered joint (Sn96,5Ag3Cu,5)

A.3 Time required to the temperature change

The measured temperature of a air type temperature cycle change chamber is shown in **Figure A.2**. The temperature reaches to steady state in about five minutes when the number of boards loaded in the chamber is not large but it takes nearly fifteen minutes when a lot of chamber is loaded in the chamber. Fifteen minutes is necessary to leave specimens in the chamber for the test.



0 Substrate, Temperature distribution (0 substrate), Temperature (°C), Time (min)



240 substrate, Temperature distribution (240 substrates), Temperature (°C), Time (min)

Figure A.2 – Time to reach steady state in the temperature cycle chamber

A.4 Time to leave a specimen at high/low temperature (specification)

The time to leave a specimen at a specified high/low temperature is determined to be 30 min, a sum of the stress relaxation time of fifteen minutes plus the time required to stabilize the temperature of fifteen minuets.

Annex B
(informative)

Soldered joint test by electrical conduction

B.1 Scope

This test is for evaluation of durability of soldered joints by testing electrical conduction through the joint without applying mechanical stress.

This test method is especially suitable to check the joint durability for multi-terminal components such as BGA and LGA to which a static durability test such as shear strength test is not practical.

B.2 Testing component and Daisy chain

The testing component for a semiconductor device is a component within which terminals are connected as illustrated in **Figure B.1**. All of the terminals of the component and of the board are connected alternatively to form a Daisy chain.

It is highly recommended that the structure of the testing component has the same structure as that of the actual semiconductor device to be evaluated.

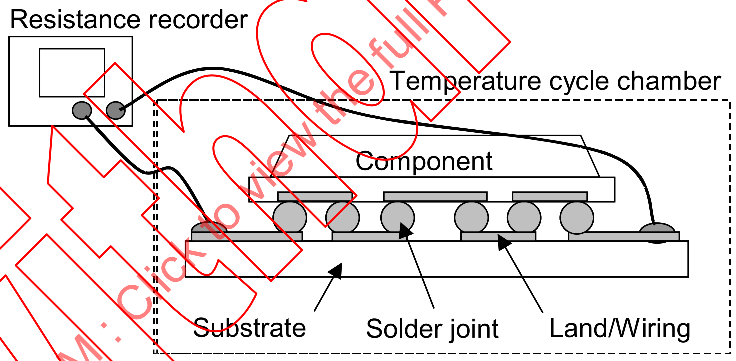


Figure B.1 – Soldered joint test by electrical conduction

B.3 Mounting condition and materials

The mounting device and materials described in **5.1** of the main text are used.

B.4 Test method

Measure the electrical resistance of the Daisy chain before and after the rapid temperature change to evaluate the presence of breaks of soldered joints. The resistance of the chain should be continuously measured to find the degree of degradation of joints. It is desirable to continue resistance measurement until soldered joint breaks. See **IEC62137** for the test method.

Annex C
(informative)

Torque shear strength test

C.1 Object

Annex specifies details of the shear strength test given in **6.2**.

C.2 Test method

The test should be made using the torque shear strength test equipment specified in **4.1** of the main text of this document and the torque shear jig specified in **4.2.1** in accordance to the following test method.

C.2.1 Preconditioning

Pre-conditioning is specified in **7.2**

C.2.2 Fixing of the test board

The test board with SMDs mounted should be fastened to the specimen holding jig using bolts. The test board should be fastened to the holding jig at the four corners of the board, or by inserting it into the jig at the shorter edges of the board as shown in **Figure C.1**. The test board should not bend when the shear force is applied to the component. At the application of a torque shear force, a rotation moment is induced to the test board.

C.2.3 Applying of Torque shear force

The test equipment should be able to adjust the rotation speed in applying torque and should have a scheme that the rotation axis is held vertical to the test board.

C.2.3.1 Displacement rate

Derive the approximate maximum torque before a torque shear strength test by means of a preliminary test using an initial specimen. Choose the displacement rate of the torque shearing jig in a torque shear strength test from the obtained approximate torque in the preliminary tests as to the maximum torque is attained in several tens of seconds to several minutes.

NOTE The displacement rate is not specified in this standard but it is desirable to select a displacement rate in the range of 0,00698 rad/s to 0,0175rad/s (0,4 deg/s to 1,0 deg/s) when the test equipment is capable of adjusting the displacement rate.

In the case the displacement rate is not adjustable rotate the rotation jig as to the torque reaches to the maximum torque in several tens of seconds to several minutes.

C.2.3.2 Position adjustment of torque shear strength test jig

The torque shear strength test jig covers vertically over the test board and then the jig is rotated slowly for torque shear force(see **Figure C.2**). The rotation axis in applying the torque should be adjusted to the center of the component mounted on the board. It is advisable to use a holding jig to suppress the deviation/vibration of rotation axis is plausible.

C.2.3.3 Torque shear strength test failure

The torque shear strength test jig is placed vertically over the component and slowly rotated. Care should be made that the torque meter is kept perpendicular to the board. The rotating speed should be 0,00698 to 0,0175 rad/s (0,4 to 1,0 deg/s) when it is adjustable. When the speed is not adjustable, rotate the jig very slowly until the soldered joint breaks.

C.2.4 Torque shear strength test to a connector

It is recommended that the test equipment can adjust the rotation speed and has a scheme to keep the rotation axis perpendicular to the test board.

C.2.4.1 Torque shear strength test jig for a connector

Prepare a torque shear strength test jig as illustrated in **Figure C.3** for the torque shear strength test of a connector adjustable to the soldered joints of the connector and its shape to assist mechanical strength of the connector. It is desirable that this covering jig should in close fitting to the connector with minimum clearance to improve measurement accuracy in the test. The depth, H, of this covering jig should approximately equal to the height of the connector. Place the covering jig on the connector mounted on a test board.

C.2.4.2 Torque shear displacement rate to a connector

A preliminary test should be made to find an approximate maximum torque shear using an initial specimen. Select the proper displacement rate from the preliminary shearing test of a specimen to find the rotation speed for the displacement rate that the maximum torque is attained at a time of several tens of seconds to several minutes for joint failure.

NOTE The displacement rate is not specified in this standard but it is recommended to select a displacement rate in the range of 0,00698 to 0,0175 rad/s (0,4 to 1,0 deg/s) for the test equipment which can adjust the speed and also radial speed (rotation rate).

In the case the displacement rate is not adjustable, rotate the rotation jig as to the torque reaches to the maximum torque in several tens of seconds to several minutes.

C.2.4.3 Position adjustment of torque shear strength test jig for a connector

The torque shear strength test jig covers vertically over the test board and then the jig is rotated slowly for torque shear force(see **Figure C.3**). The rotation axis in applying the torque should be adjusted to the center of the component mounted on the board. It is advisable to use a holding jig to suppress the deviation/vibration of rotation axis.

C.2.4.4 Torque shear strength test failure of a connector

The torque strength test shear jig covers vertically over the test board and then the jig is rotated slowly for torque shear force. Care should be made to keep the torque meter to be in the vertical position against the board. The rotation displacement rate should be in the range of 0,00698 to 0,0175 rad/s (0,4 to 1,0deg/s) for the test equipment which can adjust the rotation displacement rate. When the equipment is not capable of setting the rotation displacement rate, rotate the torque shear strength test jig very slowly around the connector keeping the rotation axis to perpendicular to the board until the soldered connection breaks.

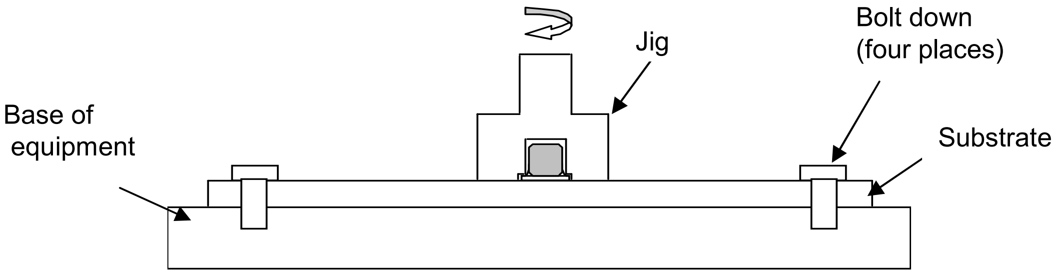


Figure C.1 – Fixing of substrate for torque shear strength test

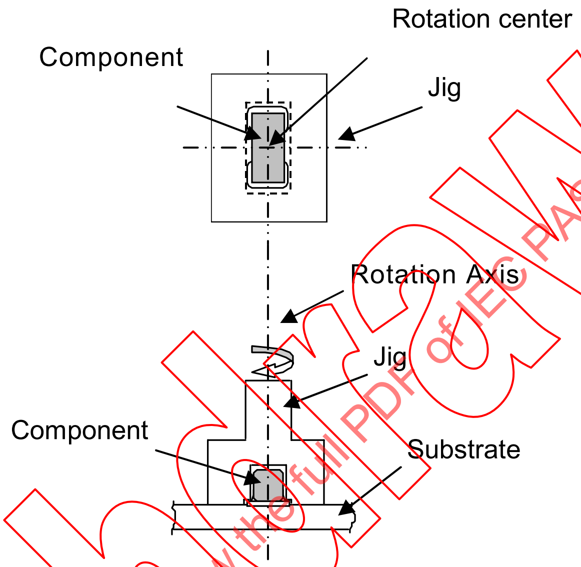


Figure C.2 – Torque shear strength test jig and position adjustment

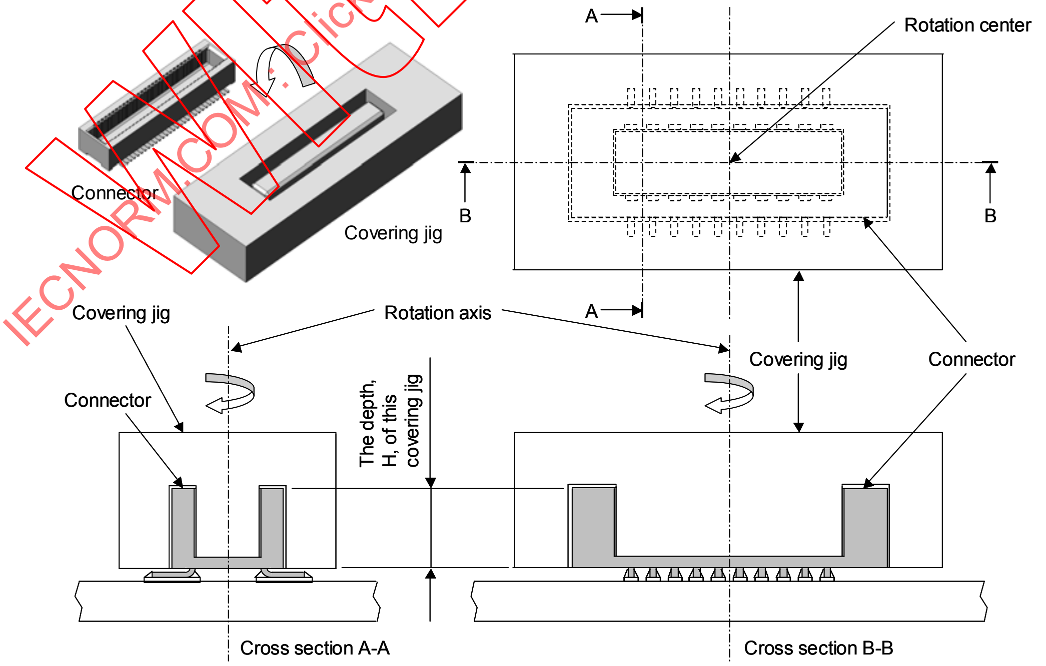


Figure C.3 – Torque shear strength test to a connector

Annex D
(informative)

Monotonic bending strength test

D.1 Scope

This Annex specifies details of the monotonic bending strength test given in **6.2**.

D.2 Monotonic bending strength test equipment

Unless otherwise specified in the product specification, the monotonic bending strength test equipment should be as follows.

D.2.1 Testing machine

The test should be made using the monotonic bending strength test equipment specified in **5.1** of the main text of this document in accordance to the following.

a) The machine should be able to push the indenter at a specified speed to the specified displacement (maximum of 20 mm). The precision of the displacement measurement should be ± 1% of the indication on the test machine (setting value).

b) The machine should be able to measure the force applied to the indenter and the displacement with time passage.

D.2.2 Substrate bending jig

The substrate bending jig should be able to support the specimen with the face down of the component side of the printed circuit board, push the center of the substrate down with the indenter. Unless otherwise specified by the product specifications, the jig should be as follows.

NOTE The structure of the substrate bending jig should be as **Figure D.1**.

a) Material: The material of the jig should be steel.

NOTE It is recommended to use high strength steel to prevent deformation due to cyclically testing.

b) Indenter: The radius of the indenter should be 5 mm ± 0,2 mm.

c) Supporting jig: The radius of the supporting jig should be 2,5 mm ± 0,2 mm.

d) Distance between supporting jigs: The distance should be 90 mm ± 1 mm.

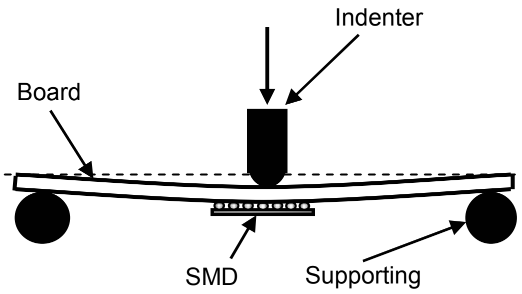


Figure D.1 – An example of board bending jig

D.2.3 Electrical resistance measuring instrument

The electrical resistance measuring instrument should have the mechanism to verify electrical continuity and discontinuity on the test substrate and to be able to judge as interruption when resistance value exceed 1×10^3 Ω. In order to detect electrical discontinuity of least quantity, a desirable instrument is the one that can detect momentary continuity interruption of 10 to 100µs.

D.2.4 Recorder

The recorder should record displacement and force with time passage during the test.

D.3 Test procedure

Unless otherwise specified by the product specifications, the test procedure should be as follows.

a) The test substrate should be fixed to the substrate bending jig as follows.

   1) First, solder lead-wire to terminals (daisy chain) used for monitoring electrical resistance on the substrate, and then connect the wire to a momentary interruption detector.
   2) Confirm that the centers of supporting jigs are at the same distance from the center of the indenter (45 mm ± 0,5 mm).
   3) The test substrate is set on the testing machine with the face down of the surface mount component side. Adjust the position such that the indenter will push at the center of the substrate.
   4) Make sure that the indenter is at the center position by having it in contact with the substrate.

   NOTE Keep pushing the substrate until a force of 1N ± 0,1 N is apply to confirm that the indenter is actually in connect with the substrate.

b) Depress the indenter to the substrate until the electrical discontinuity will be detected. Record the applied force, displacement and the electrical resistance of the Daisy chain.

c) A solder joint is considered failure when the circuit is confirmed as “open”. Record the monotonic bending strength at this moment.

   NOTE Unless otherwise specified by the product specification, the maximum displacement should be 20 mm. The test should be terminated when the conduction failure is not observed with this displacement.

d) Observe the joint failure when necessary. Check and record the failure mode.

D.4 Displacement rate

Unless otherwise specified by the product specification, the displacement rate should be selected in the range of 0,0083 to 0,1 mm/s (0,5 ～6 mm/min).

NOTE The proper displacement rate is to induce solder joint failure in several tens of seconds to several minutes.

Annex E
(informative)

Cyclic steel ball drop strength test

E.1 Scope

This cyclic steel ball drop test is a simplified test for SMDs such as BGA, LGA and QFN mounted in portable equipment to be used as an alternative of cyclic drop test. This test is not to evaluate durability of mounted components on board itself but a test for relative comparison of the joint durability correlation between mounted components to the stress induced by the drop of a steel ball.

E.2 SMDs Mounting condition and materials

The mounting device and materials should be in accordance with cyclic drop test as described in **5.1** of the main text. The thickness and material of the board should be such that may bend with a reasonable radius of curvature at the shock of drop of the ball but should not be deformed. The recommended thickness of the board is 1,6 mm, thicker than the cyclic drop test of **6.3** stated in the main test.

E.3 Test method

As illustrated in **Figure E.1**, a SMD mounted board is held to the board fixing jig with the component mounted face down, and a steel ball is dropped from a certain height onto the backside of the board. The number of drops until the soldered joint breaks is measured. The position of the ball drop for a large SMD should be near the peripheral of the component which is most vulnerable to such mechanical damages. The number of drops until the soldered joint breaks is judged by means of a continuous conduction measurement using a circuit such as the Daisy chain as in the cyclic drop test. It is desirable to measure the instantaneous break of the circuit (open).

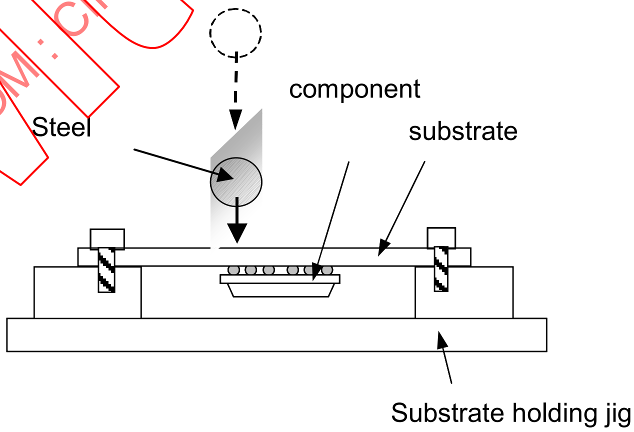
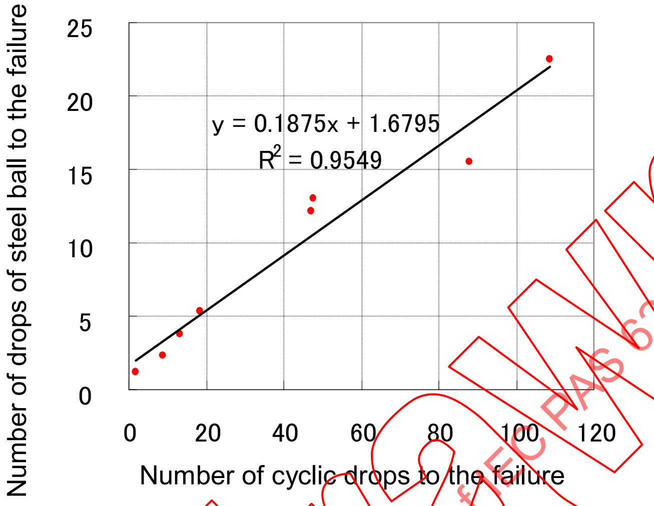


Figure E.1 – Cyclic steel ball drop test

The test equipment should have a good definition of the position of the ball drop to attain good reproducibility of the test. To check the stability of strain waveform in the objective solder joint, it is desirable to make a preliminary test to check the form and magnitude of strain using a strain gauge attached near the soldered joint of the device under test.

E.4 Correlation of this test to the cyclic drop test (an example)

Comparison of tests for the cyclic drop and cyclic steel ball drop were made for several combinations of various electrode materials and solder alloys for 0,5 mm pitch – 64 pin QFN mounted on 1,6 mm FR-4 board. The numbers of drops to break soldered joint were compared as shown in **Figure E.2**. A good correlation between two tests was observed.



Cyclic drop test : Drop height – 0,75 m
Steel ball drop test : Ball – 10 g, drop height – 1,5 m

Figure E.2 – Comparison of cyclic drop test and cyclic steel ball drop test

Annex F
(informative)

Pull strength test

F.1 Scope

This Annex specifies details of the pull strength test specified in **6.5.1** of this standard.

F.2 Test procedure

The test should be made using the pull strength test equipment specified in **5.1** of the main text of this document in accordance to the following procedure.

a) The specimen should be kept in the standard atmospheric environment as specified in **IEC 60068-1, 5.3** for more than 4 h before the test. The test should be performed after the appearance inspection of the specimen.

b) The test board should be fastened to the pull strength test equipment as illustrated schematically in **Figure F.1**.

NOTE When fastening the test board, the lead terminal to be tested should be fixed at the center of the board fastening jig as to the lead is perpendicular to the lead fastening jig.

c) Fasten the lead terminal to the jig of the pull strength test equipment

NOTE 1 Care should be made when the lead terminal is required to be cut-off from the component not to impose mechanical, thermal or chemical stress to the soldered joint of the lead and land.

NOTE 2 Record the way of fixing the test board and the relative position of the fastening jig and the lead terminal.

NOTE 3 Any possible care should be made not to impose bend or twist force to the joint when the lead is fixing to the pulling jig of the equipment.

d) The pulling speed of the jig should be selected from the following, 0,167 mm/s (1 mm/min), 0,333 mm/s (2 mm/min), 0,833 mm/s (5 mm/min) 1,67 mm/s (10 mm/min) or 3.33 mm/s (20 mm/min). The pulling speed is stated in the product specification of the component.

NOTE The pulling speed should be selected as to it takes several tens of seconds to several minutes to break the joint from the start of pulling.

e) Pull a lead of the component mounted at a speed selected as in **d)** until the joint is broken. Record the maximum force when the joint is broken.

NOTE When recording the change of the force, it is desirable to record also the change of displacement at several points near the joint.

f) Record the broken position of the joint and the failure mode.

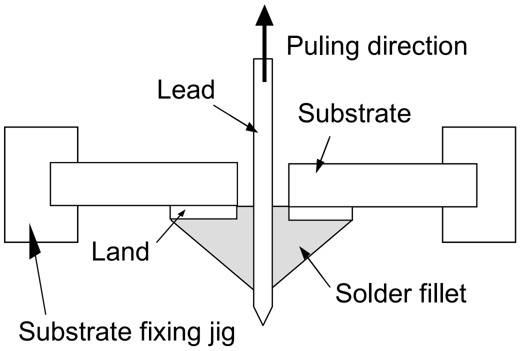


Figure F.1 – Pull strength test