BS EN 62137-3:2012

BSI Standards Publication

Electronics assembly technology

Part 3: Selection guidance of environmental and endurance test methods for solder joints

National foreword

This British Standard is the UK implementation of EN 62137-3:2012. It is identical to IEC 62137-3:2011. It supersedes DD IEC/PAS 62137-3:2008 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/501, Electronic assembly technology.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Electronics assembly technology - Part 3: Selection guidance of environmental and endurance test methods for solder joints (IEC 62137-3:2011)

Techniques d'assemblage des composants électroniques - Partie 3: Guide de choix des méthodes d'essai d'environnement et d'endurance des joints brasés (CEI 62137-3:2011)

Montageverfahren für elektronische Baugruppen - Teil 3: Leitfaden für die Auswahl von Umwelt- und (Lebens)dauerprüfungen für Lötverbindungen (IEC 62137-3:2011)

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Foreword

The text of document 91/986/FDIS, future edition 1 of IEC 62137-3, prepared by IEC/TC 91 "Electronics assembly technology" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62137-3:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2012-09-13
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2014-12-13

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Endorsement notice

The text of the International Standard IEC 62137-3:2011 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60068-1:1988 + A1:1992	NOTE	Harmonized as EN 60068-1:1994 (not modified).
IEC 60068-2-2	NOTE	Harmonized as EN 60068-2-2.
IEC 60068-2-14	NOTE	Harmonized as EN 60068-2-14.
IEC 60068-2-78	NOTE	Harmonized as EN 60068-2-78.
IEC 61760-1	NOTE	Harmonized as EN 61760-1.
IEC 62137:2004	NOTE	Harmonized as EN 62137:2004 (not modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60194	-	Printed board design, manufacture and assembly - Terms and definitions	EN 60194	-
IEC 61188-5	Series	Printed boards and printed board assemblies - Design and use - Part 5: Attachment (land/joint) considerations	EN 61188-5	Series
IEC 61249-2-7	-	Materials for printed boards and other interconnecting structures - Part 2-7: Reinforced base materials, clad and unclad - Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad	EN 61249-2-7	-
IEC 62137-1-1	2007	Surface mounting technology - Environmental and endurance test methods for surface mount solder joint - Part 1-1: Pull strength test	EN 62137-1-1	2007
IEC 62137-1-2	2007	Surface-mounting technology - Environmental and endurance test methods for surface mount solder joint - Part 1-2: Shear strength test	EN 62137-1-2	2007
IEC 62137-1-3	2008	Surface mounting technology - Environmental and endurance test methods for surface mount solder joint - Part 1-3: Cyclic drop test	EN 62137-1-3	2009
IEC 62137-1-4	2009	Surface mounting technology - Environmental and endurance test methods for surface mount solder joint - Part 1-4: Cyclic bending test	EN 62137-1-4	2009
IEC 62137-1-5	2009	Surface mounting technology - Environmental and endurance test methods for surface mount solder joint - Part 1-5: Mechanical shear fatigue test	EN 62137-1-5	2009

CONTENTS

ELECTRONICS ASSEMBLY TECHNOLOGY –

Part 3: Selection guidance of environmental and endurance test methods for solder joints

1 Scope

This part of IEC 62137 describes the selection methodology of an appropriate test method for a reliability test for solder joints of various shapes and types of surface mount devices (SMD), array type devices and leaded devices, and lead insertion type devices using various types of solder material alloys.

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

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

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

IEC 62137-1-1:2007, *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 – Part 1-2: Shear strength test*

IEC 62137-1-3:2008, *Surface mounting technology – Environmental and endurance test methods for surface mount solder joint – Part 1-3: Cyclic drop test*

IEC 62137-1-4:2009, *Surface mounting technology – Environmental and endurance test methods for surface mount solder joint – Part 1-4: Cyclic bending test*

IEC 62137-1-5:2009, *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
pull strength for SMD
maximum force to break the joint of a lead to substrate when a gull-wing lead of a surface mount device is pulled using a pulling tool at an angle of 45° to the substrate surface

[IEC 62137-1-1:2007, modified]

3.2
shear strength for SMD
maximum force applied parallel to the substrate and perpendicular to the specimen lateral surface to break the joint of SMD mounted on a substrate

[IEC 62137-1-2:2007, modified]

3.3
torque shear strength for SMD
maximum rotation moment to SMD which is applied in parallel to the substrate surface, to break the solder joint between an SMD termination/lead and the land on the substrate

3.4
monotonic bending strength for SMD
strength of solder joints of SMD mounted on substrate when the substrate is bent convex toward to the mounted SMDs expressed by the maximum bending depth to the break of joints

3.5
cyclic bending strength for SMD
intensity of the strength, which is expressed in the number of cycles to attain the joint fracture between SMD termination/lead mounted on the substrate and the copper land of the substrate after bending the substrate cyclically to a specified degree to allow the surface of the device side of the substrate to become a convex shape

[IEC 62137-1-4:2009, modified]

3.6
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 specified 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.

3.7
cyclic drop test for SMD
number of drops to break solder joints of an SMD to the lands on a substrate which is fixed to a jig when the substrate is dropped from a specified height

3.8
cyclic steel ball drop strength for SMD
number of drops to break solder joints of a SMD to the lands on a substrate when the steel ball is dropped from a specified height on a substrate

3.9
pull strength for lead insertion type device
maximum applied force to break the solder joint of a lead insertion type device to a land on substrate when the lead is pulled using a jig

3.10
creep strength for lead insertion type device
strength of a solder joint expressed by the time to break the joint when a continuous force is applied to a lead of a lead insertion type device soldered to a land

3.11
fillet lifting phenomenon for lead insertion type device
phenomenon whereby a solder fillet of a lead is lifting from a land on a substrate, or of the land from the substrate (de-lamination)

3.12
daisy chain
all chains of solder joint connections that are connected in series, see Clause B.2

NOTE Lands on both sides of a substrate and lead are solder-connected in a chain in the case of a fillet lifting test.

4 General remarks

The regions of the joints to be evaluated are shown in Figure 1. The test methods given here are applicable to evaluate the durability of joints of a device mounted on substrate but not to test the mechanical strength of the device itself.

The conditions for accelerated stress conditioning (rapid temperature change and dry heat) may exceed the maximum allowable temperature range for a device.

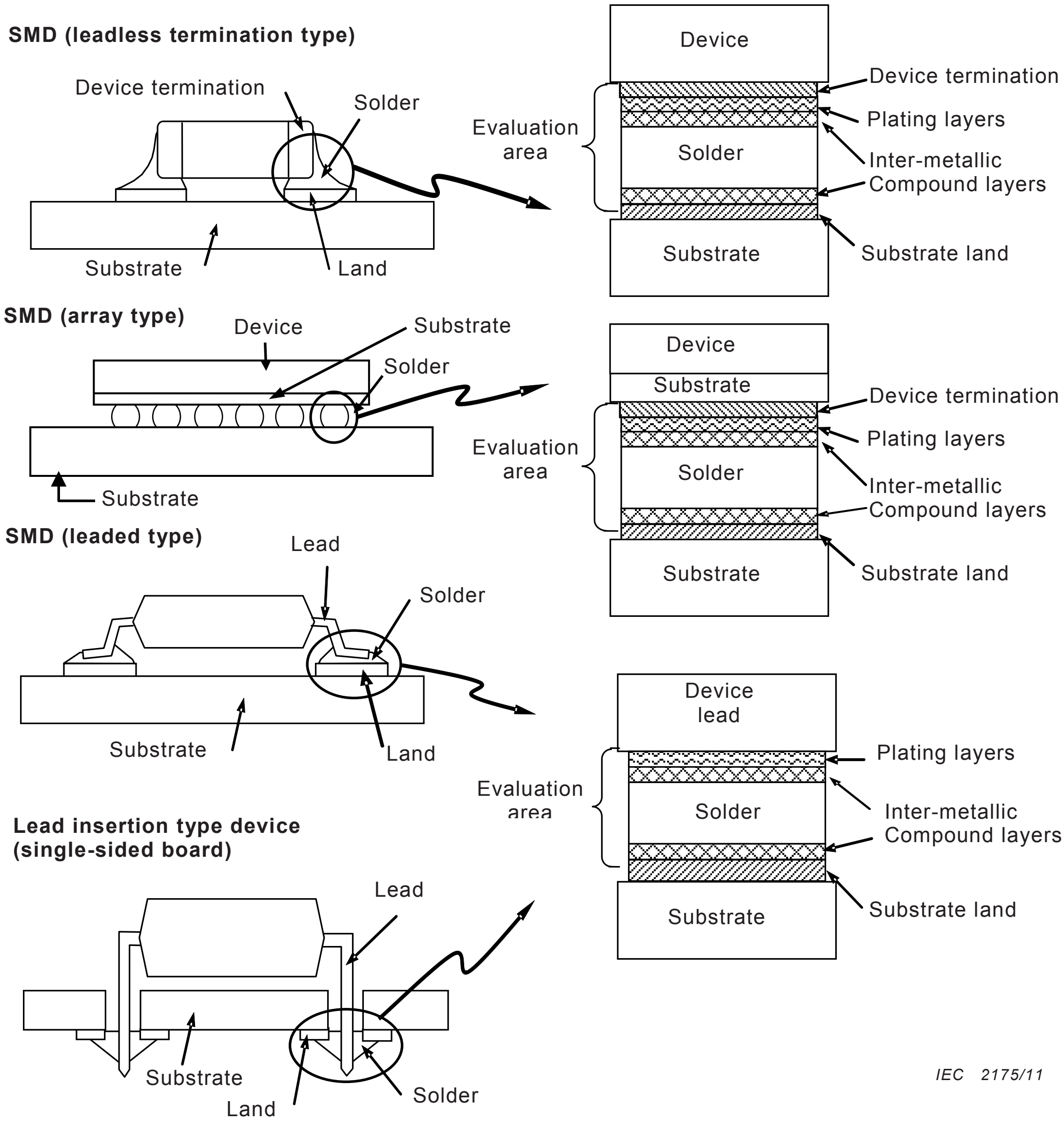


Figure 1 – Joint regions for the reliability tests

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

The example of factors affect to the joint reliability when using Sn96,5Ag3Cu,5 solder are shown in Figure 2. This solder has the properties of a higher melting temperature and is harder than the tin-lead eutectic solder and is hard to deform in the solid-state. Consequently, the stress induced to the joint becomes higher than the tin-lead eutectic solder.

These properties may induce break of a solder joint by accelerated stress conditioning.

The termination/lead finishes of SMD could affect the test result not only for the drop test, but also for other tests. Therefore all tests should consider them.

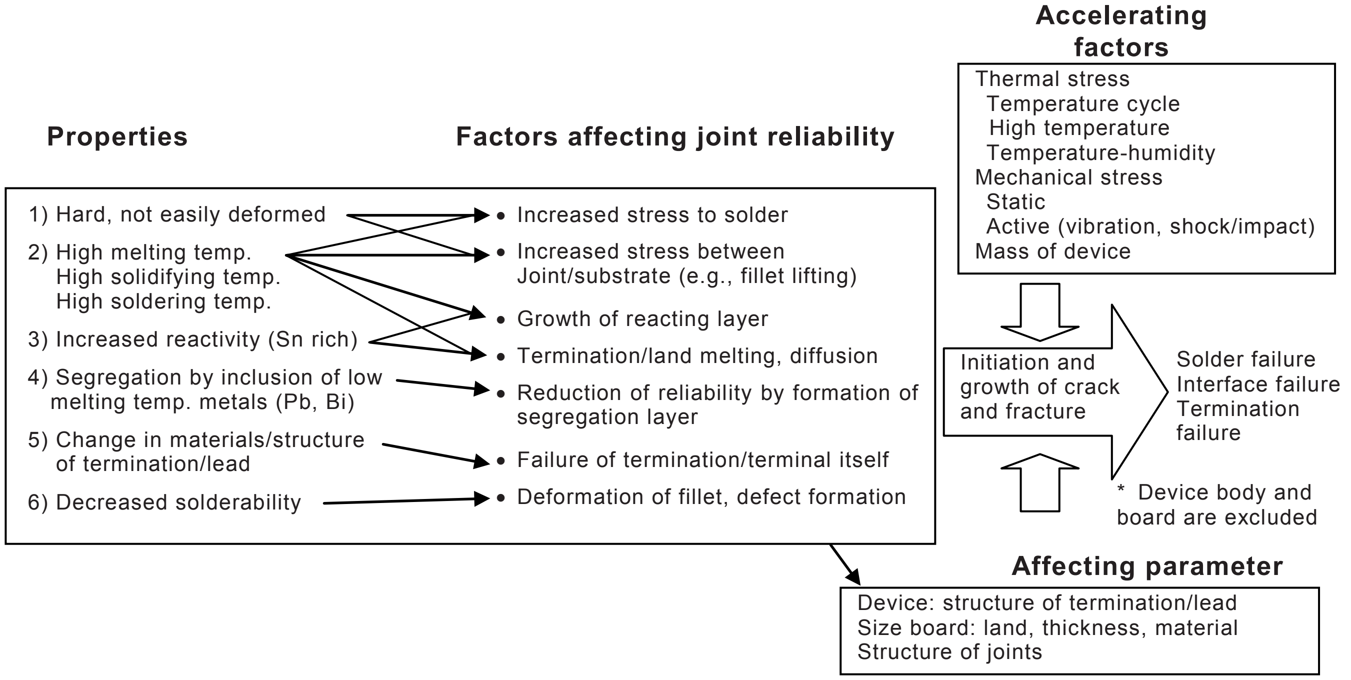


Figure 2 – Factors affecting the joint reliability made by lead-free solder

5 Procedure of selecting the applicable test method

5.1 Stress to solder joints in the field and test methods

The correlations between the test methods and the actual stress induced to devices are shown in Table 1. The type of substrate and the shapes of termination/lead which affect the test results to actual stress conditions of the mounted SMDs in the field are also shown as reference. The selection of a test method suitable for a specific shape and termination/lead are given in 5.2.

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

Test method (Applicable standard)	Accelerated stress conditioning	Applicable board/Components	Stress in the field and applicable products
Continuity test [a, b] Annex B	Rapid temperature change [c] Dry heat [c] Damp heat [c]	SMD	The stresses to be assumed are as follows. a)Repeated thermal stress caused by the difference in thermal expansion coefficients of device and substrate at the ON/OFF of equipment and/or temperature changes in the surrounding environment b)High temperature environment c)High temperature and high humidity 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 solder joints and substrate 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 device and substrate 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 solder 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	Rapid temperature change [c]	Single-sided TH/Lead insertion type	Repeated thermal stress caused by the difference in thermal expansion coefficients of device and board at the ON/OFF of equipment and/or temperature changes in the surrounding environment
Creep strength test Annex G	Mass load at elevated temperature	Single-sided TH/Lead insertion type	Degradation of solder joint when a continuous force is applied
Observe of fillet lifting phenomenon Annex H	Not applicable [e]	Double-sided TH/Lead insertion type	The fillet lifting phenomenon may occur between the solder alloy and the lead plating and/or land after soldering

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

[a] This test is to evaluate degradation of joint strength with repeated thermal stress induced to the joint by means of rapid temperature change, dry heat and damp heat as accelerated stress conditioning. A proper test should be selected according to the features of the device under test such as the shape of its leads.

[b] This test is to check if there is a failure at a solder joint by measuring changes of resistance of the joint without applying mechanical stress. This test method is referred to here as an alternative method as it is a useful test especially for BGA and LGA.

[c] The applicable accelerate stress conditioning by the solder alloy is as shown below.
1) Rapid change of temperature: Sn-Zn, Sn-Bi and Sn-In
2) Damp heat: Sn-Zn
3) Dry heat: Sn-Bi

[d] The applicable test method for Sn-Zn, Sn-Bi and Sn-In alloy is the cyclic steel ball drop strength test.

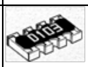
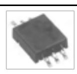
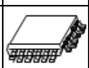
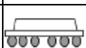
[e] The rapid temperature change is recommended if observed fillet lifting between land and board exists.

5.2 Selection of test methods based on the shapes and terminations/leads of electronic devices

5.2.1 Surface mount devices

The recommended test methods suitable for specific shapes and terminations/lead of devices are shown in Table 2.

Table 2 – Recommended test methods suitable for specific shapes and terminations/leads of SMDs

	Types and terminations/leads of a device				Apply the accelerated stress conditioning					Cyclic bending test	Cyclic drop test	Mechanical shear fatigue test
	Terminations/Leads		Number of terminations/ leads	Examples	Pull test	Shear strength test	Torque shear test	Continuity test	Monotonic bending test			
General electronics components	Terminations on 2 sides (bent leads)		2	Tantalum capacitor, Inductor	-	A,B	-	-	-	-	C	-
	Terminations on 3 sides		2	Rectangular chip Resistor/Film capacitor	-	A,B	-	-	-	-	C	-
	Terminations on 5 sides (including cap)		2	Laminated capacitor, Thermistor, Laminated inductor, Fuse	-	A,B	-	-	-	-	C	-
	Multi terminations (terminations 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	-
	Terminations on bottom		2	Inductor, Tantalum capacitor	-	A,B	B	-	-	-	C	-
	Round termination (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 terminations on bottom		Multiple	BGA, FBGA	-	-	-	A,B	C	B	B	B
	Terminations on bottom without ball		Multiple	LGA, FLGA	-	-	-	A,B	C	B	B	B

NOTE 1 A: Recommended for accelerated stress conditioning, B: Applicable, C: Applicable when conditions are met, -: Not applicable.

NOTE 2 One of the following static mechanical tests is performed before and after the accelerated stress conditioning according to the shape of the device under test.

a) Pull strength test: SMD with gull wing leads.

b) Shear strength test: Small rectangular SMD to which a pushing jig can be pressed to a side of the device.

c) Torque shear strength test: SMD that has the shape to which the regular shear strength test is difficult to apply, and to rather a large device with many-terminations or leads such as a semiconductor device or a connector.

NOTE 3 The continuity test is applicable to devices to which a daisy-chain can be formed on the mounting substrate or within the device under test itself.

Examples are those semiconductor devices not with leads such as BGA, LGA or QFN.

NOTE 4 The monotonic bending limit test is applicable to those devices with height or large size to which the resistance measurement test is available and which are not easily deformed.

NOTE 5 The cyclic bending strength test and cyclic drop test are applicable to those devices mainly used in portable equipment.

The use of these tests should be specified in the specification of the product.

The cyclic bending strength test for substrate is suitable to semiconductor devices mounted on a substrate.

NOTE 6 Each temperature test is applied in the case of the following alloys.

a) Rapid temperature change: Sn-Ag-Cu, Sn-Zn, Sn-Bi and Sn-In

b) Damp heat: Sn-Zn

c) Dry heat: Sn-Bi

NOTE 7 The shape of semiconductor devices is defined in IEC 60191. However, "Terminations on the bottom without ball package" is not defined yet. Here, "Terminations on the bottom without ball package" defines it as package (shape) of BGA without solder ball.

5.2.2 Lead insertion type device

The pull strength test is the basic test for lead insertion type devices. The creep test should also be used for devices of 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 device to be mounted on one side only of a substrate. In many cases, the strength of leads in lead insertion type devices may be inferior compared to those of solder joints. These tests are not appropriate for equipment using this type of substrates.

Recommended test methods suitable for the mass of the lead insertion type device, the kind of board and application of the load are given in Table 3.

Table 3 – Recommended test methods suitable for application and mass of the lead insertion type device

Substrate type	Application, device type		Test		Evaluation	
	Application	Device mass	Pull strength test	Creep strength test	Observation of fillet lifting phenomenon	Continuity evaluation
Single-sided TH	No continuous load	Light	B	–	–	–
		Heavy	C	B	–	–
	Continuous load	Light	B	–	–	–
		Heavy	C	C	–	–
Double-sided TH	General lead insertion type device		–	–	B	C
	Daisy chain applicable lead insertion type device		–	–	B	B

NOTE 1 B: Applicable, C: Applicable when conditions 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) Fillet lifting observation: Room temperature

d) Continuity evaluation: Rapid temperature change environment to prescribe in a product standard

NOTE 3 For these tests, the Sn - Ag - Cu alloy and Sn - Zn solder alloy are suitable

NOTE 4 In case of using double-sided TH substrate, the strength of the lead tends to be less than the strength of solder joint. Therefore, this type substrate is not suitable for a pull strength test.

NOTE 5 The details of the evaluation for double-sided through hole (TH) are given in Annex H.

6 Common subjects in each test method

6.1 Mounting device and materials used

a) Solder

Various compositions of the lead-free solder alloy for interconnections are used in the field. Unless otherwise specified in the product specification, the lead-free solder alloy shall be selected from Table 4 given by the solder alloy type.

Table 4 – Solder alloy composition

Solder alloy type	Alloy (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) Test substrate

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

The materials hard to deform such as ceramic shall not be used as the test substrate for monotonic bending strength test, cyclic bending strength test and cyclic drop test.

Other items are specified in the relevant test method.

c) Mounting devices to test substrate

The following are mounting devices to the test substrate.

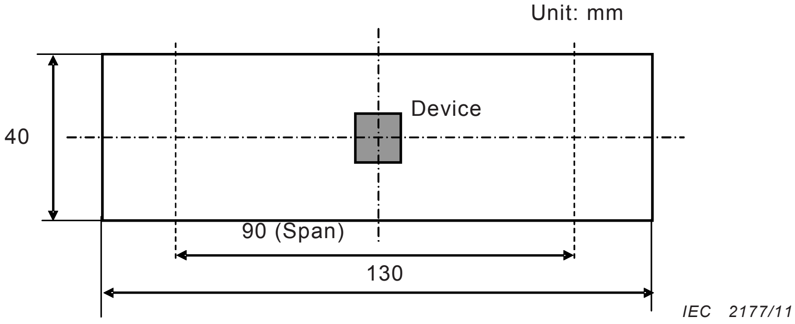
Tests for SMDs are performed by mounting the devices on single-sided or one side of double-sided substrate.

Tests for lead insertion type devices are for mounting the devices on one side of substrate. Tests for lead insertion type devices mounted on a double-sided substrate are not appropriate as the strength of solder joints in this case is much higher than that of leads themselves to the device.

Soldering method for SMDs should be reflow soldering and for lead insertion type device should be wave soldering.

d) Position of devices 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 in the centre of a test substrate, as shown in Figure 3. The position of the device under test for other tests may be determined in an appropriate place on the test substrate as agreed between user and supplier. Unless otherwise specified in the product standard, the land pattern in the IEC 61188-5 series shall be used.



Key

PWB thickness 1,6.

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

The lead insertion type device to be tested in the pull strength test and creep strength test to evaluate the strength of solder joint between device and land when connected using lead-free solder. The test evaluates the durability of a solder joint until break when connecting the lead of a lead insertion type device to single-sided substrate by wave soldering while measuring the electric resistance of the joint by applying a specified weight to the lead in a temperature chamber. Time to break is evaluated because resistance increases if solder joint breaks.

The diameter of a through hole and the diameter of a land are given in Table 5.

Table 5 – Diameters of through holes and lands in respect to the nominal cross section and nominal diameter of lead wire

Nominal cross sectional area (S) mm^2	Nominal diameter(d) of a round cross section type lead mm	Through hole diameter mm	Land diameter mm
S≦0,10	d≦0,35	0,8	1,4
0,10<S≦0,28	0,35<d≦0,60	1,0	1,6
0,28<S≦0,50	0,60<d≦0,80	1,2	1,8
0,50<S≦0,79	0,80<d≦1,00	1,4	2,0
0,79<S≦1,20	1,00<d≦1,25	1,6	2,2

6.2 Soldering condition

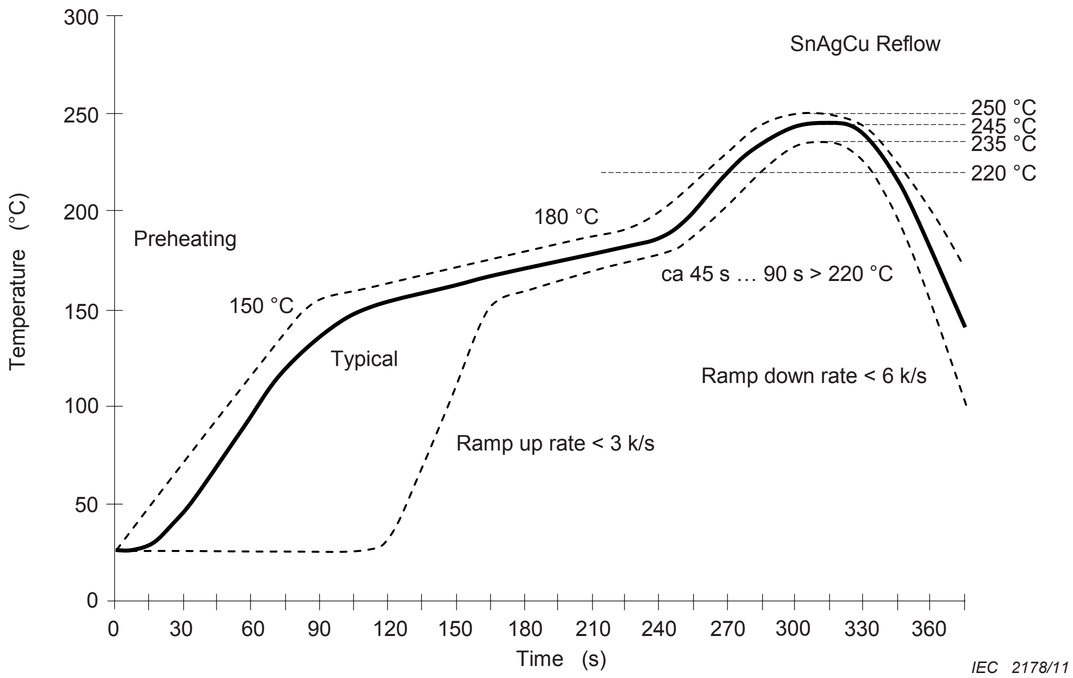
6.2.1 General

A proper soldering condition shall be selected to form an appropriate solder fillet. Examples of the temperature profile for the lead free solder for reflow and wave soldering are shown in 6.2.2 and 6.2.3 respectively.

6.2.2 Reflow soldering

Reflow soldering temperature profiles used for actual substrate assembly should always be optimised by substrate assembler depending on devices substrate layout, and so on. For Sn96,5Ag3Cu,5 solder, the soldering temperature profile should follow the defaults of IEC 61760-1 as indicated in Figure 4. Examples of soldering temperature profile other than Sn96,5Ag3Cu,5 solder are shown in Figure 5.

Details of other conditions are given in relevant test methods.

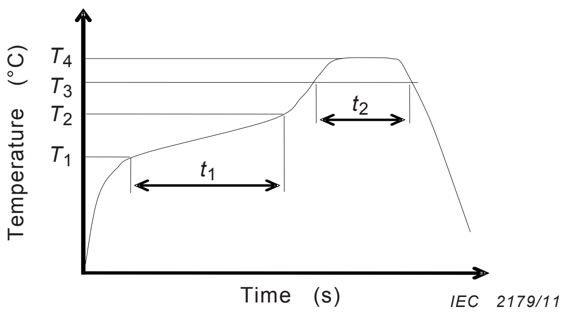


Key

Continuous line: Typical process (termination/lead temperature).

Dotted line: Process limits; Bottom process limit (termination/lead temperature); upper process limit (top of device temperature).

Figure 4 – An example of reflow soldering temperature profile (Sn96,5Ag3Cu,5)



Symbol and description		Solder composition		
		Sn91Zn9 [a], Sn89Zn8Bi3	Bi58Sn42	Sn88In8Ag3,5Bi,5
T_1	Minimum preheat temperature	130 °C	100 °C	140 °C
T_2	Maximum preheat temperature	150 °C	120 °C	160 °C
T_3	Soldering temperature	200 °C	150 °C	206 °C
T_4	Peak temperature	220 °C ± 5 °C	190 °C ± 5 °C	220 °C ± 5 °C
t_1	Preheat time	90 s ± 30 s	90 s ± 30 s	90 s ± 30 s
t_2	Soldering time	20 s to 60 s	20 s to 60 s	20 s to 60 s

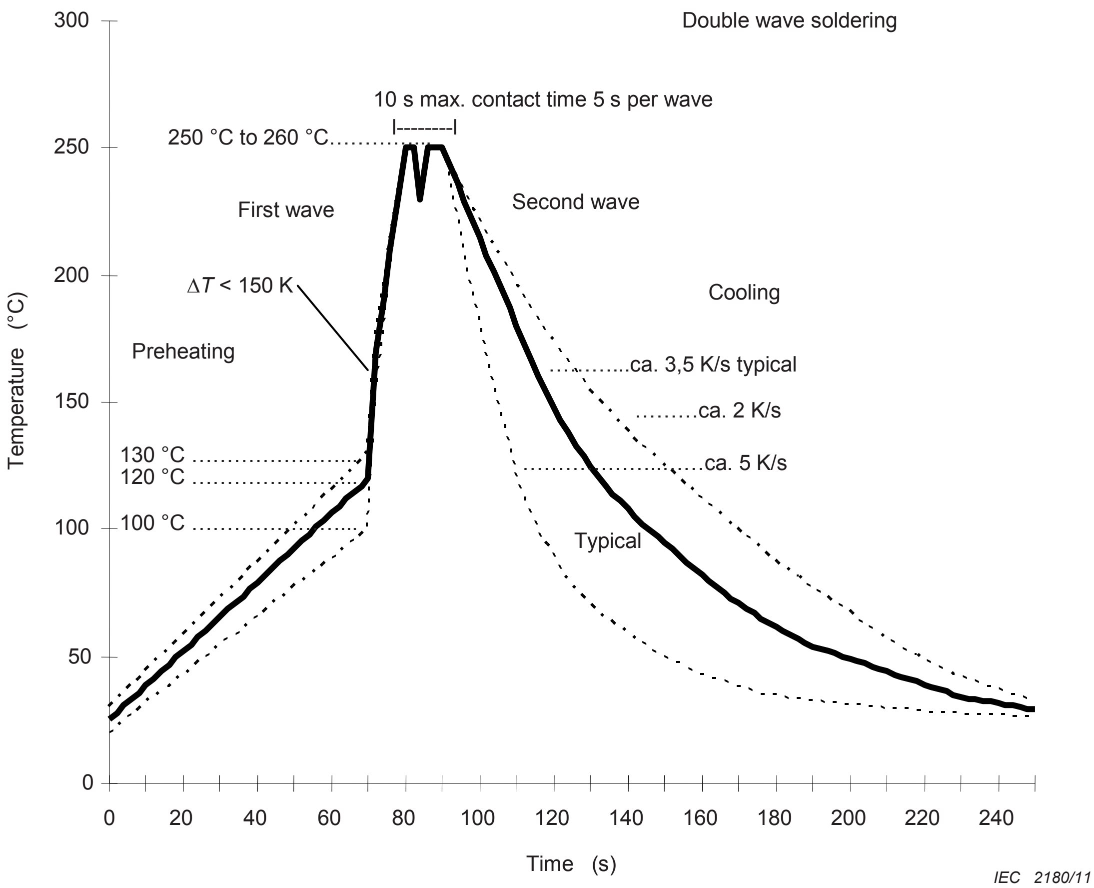
[a] Inert gas such as N_2 atmosphere soldering is recommended.

Figure 5 – Examples of reflow soldering temperature profile other than Sn96,5Ag3Cu,5

6.2.3 Wave soldering

Wave soldering temperature profiles used for actual substrate assembly should always be optimised by substrate assembler depending on devices, substrate layout, and so on. For Sn96,5Ag3Cu,5 solder, the soldering temperature profile should follow as shown in Figure 6 or Figure 7.

Details of other conditions are given in relevant test methods.

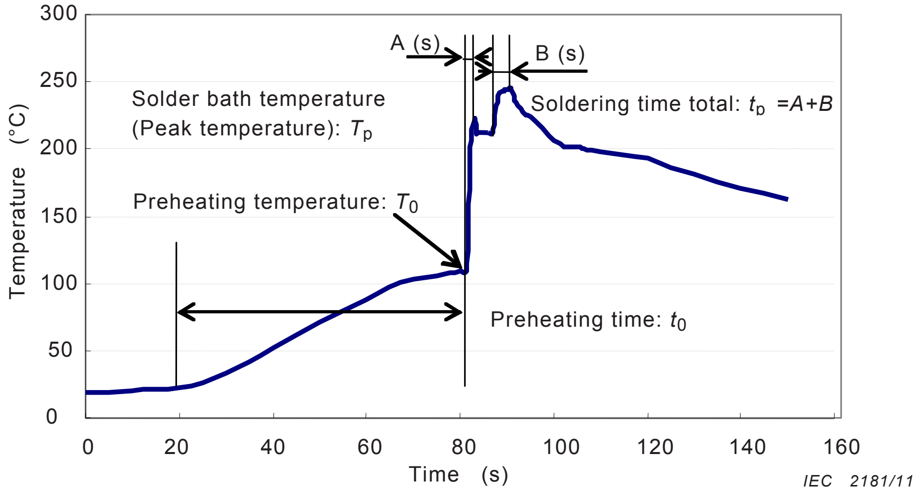


Key

Continuous line: Typical process (termination/lead temperature).

Dotted line: Process limits; Bottom process limit; upper process limit.

Figure 6 – An example of wave soldering temperature profile (Sn96,5Ag3Cu,5)



Solder composition	Preheat		Soldering	
	Preheat temperature T_0	Preheat time t_0	Peak temperature T_p	Soldering time t_p
Sn99,3Cu,7(C7)	100 °C to 120 °C	30 s to 90 s	250 °C ± 5 °C	3 s to 5 s

Figure 7 – An example of wave soldering temperature profile

6.3 Accelerated stress conditioning

6.3.1 Rapid temperature change (applies to all solder alloys in this document)

Test N (Rapid change of temperature with prescribed time of transfer) specified in IEC 60068-2-14 should be performed for pull, shear, torque shear, and monotonic bending tests for SMDs and pull test for lead insertion type devices. The temperature condition should be chosen considering the effect of temperature variation characteristics of a solder 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 test substrate, or the number of test substrates tested at the same time (see Annex A).

Recommended temperature conditions are given in Table 6.

Unless otherwise specified, the number of cycles are 500 and 1 000 except for the resistance measurement.

Table 6 – Temperature condition for rapid temperature change

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

6.3.2 Dry heat (applies to Bi58Sn42 alloy solder only)

Dry heat as specified in IEC 60068-2-2 should be performed for peel strength test, shear strength test, torque shear strength test, and monotonic bending test of SMD and pull strength test of lead insertion type devices, under the following conditions.

6.3.2 Dry heat (applies to Bi58Sn42 alloy solder only)

Dry heat as specified in IEC 60068-2-2 should be performed for peel strength test, shear strength test, torque shear strength test, and monotonic bending test of SMD and pull strength test of lead insertion type devices, under the following conditions.

a) Temperature: 85 °C

b) Duration: 500 h and 1 000 h

6.3.3 Damp heat (steady state) (applies to Sn91Zn9 and Sn89Zn8Bi3 alloy solder)

Test Cab (damp heat, steady state) specified in IEC 60068-2-78 should be performed for peel strength test, shear strength test, torque shear strength test, and monotonic bending test of SMD and pull strength test of lead insertion type device, under the following conditions.

a) Temperature and humidity: 65 °C, 85 %

b) Duration: 500 h and 1 000 h.

6.4 Selection of test conditions and judgement of test results

a) Load application speed

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

b) Test substrate fixing

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

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

c) Test result

The test result should be analysed by confirming and recording not only the strength and time to break of a solder joint but also the mode of break.

7 Evaluation test method

7.1 Solder joint strength test of SMD

7.1.1 General

The pull, shear, torque shear, and monotonic bending tests before and after the accelerated stress conditioning are used to evaluate the degree of degradation of solder joint strength and other characteristics of a solder joint.

7.1.2 Pull strength test

The pull strength test is applicable to SMDs with gull-wing type leads. As shown in Figure 8, 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 analysed from the changes of the maximum pulling force and mode of break before and after the accelerated stress conditioning. This test is applicable to both reflow and wave soldering.

The proper pulling speed for a 0,5 mm pitch QFP (Quad Flat Pack) is 0,008 3 mm/s (0,5 mm/min).

A detailed description of the test is given in IEC 62137-1-1.

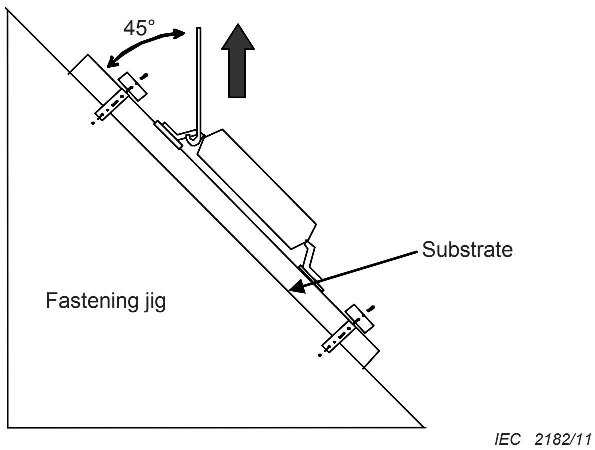


Figure 8 – Pull strength test

7.1.3 Shear strength test

The shear strength test is applicable for SMDs of rather small size. As shown in Figure 9, the maximum testing force is measured when a force is applied parallel to the surface of substrate and perpendicular to the specimen. The device is soldered to a test substrate by reflow soldering.

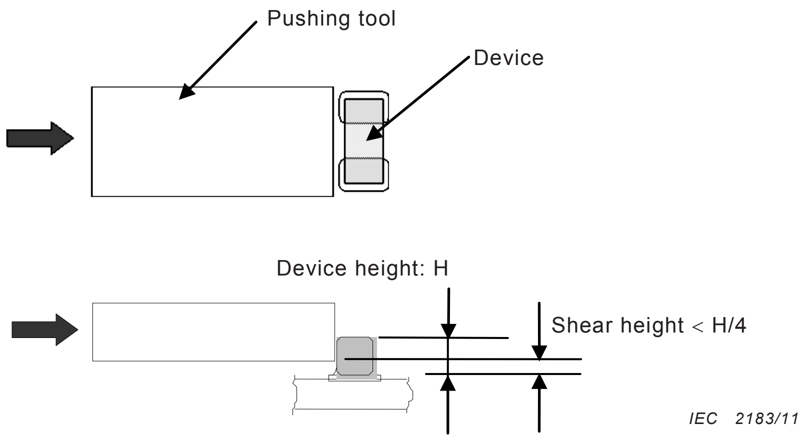


Figure 9 – Shear strength test

It is necessary to keep the shear height constant at less than 1/4 of the specimen's height, but not in touch with the land pattern, to obtain an accurate measurement. The proper speed of applying the force is 0,008 3 mm/s to 0,15 mm/s (0,5 mm/min. to 9 mm/min.).

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

7.1.4 Torque shear strength test

The torque shear strength test is an alternative test method to the shear strength test for devices to which the shear strength test is not easily applicable due to their shapes. This test is also applicable to a rather large device. A concave shaped jig, as shown in Figure 10, holds a device and a torque force is applied through the jig to rotate the device. The maximum torque to shear the device is measured when a rotating moment is applied parallel to the test substrate.

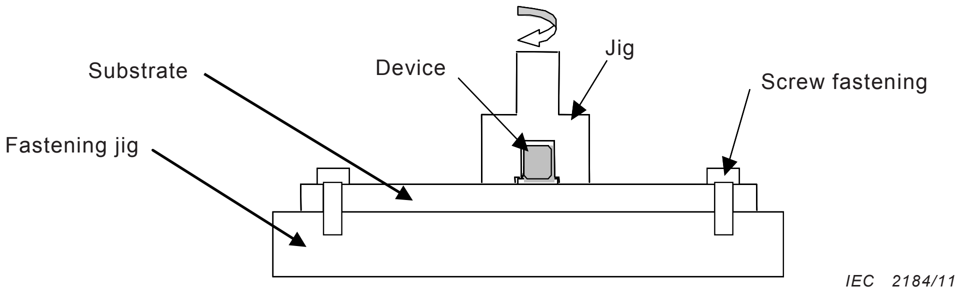


Figure 10 – Torque shear strength test

The depth of the jig should be the same as to the height of the device to obtain accurate measurement. The centre of rotation shall be the centre of the device, and swaying of the rotation axis shall be avoided. The proper rotation speed, if adjustable, is 0,006 98 rad/s to 0,017 5 rad/s.

The details of the test are given in Annex C.

7.1.5 Monotonic bending strength test

The monotonic bending strength test is a test appropriate to a device of rather a large size. As shown in Figure 11, the test substrate with an SMD mounted is placed between two supporting jigs with the mounted face down, and the test substrate is bended using the bending tool on the back side until the solder joint breaks, and the bending depth is measured. This test shall be performed before and after the accelerated stress conditioning to evaluate the degree of degradation of solder joints.

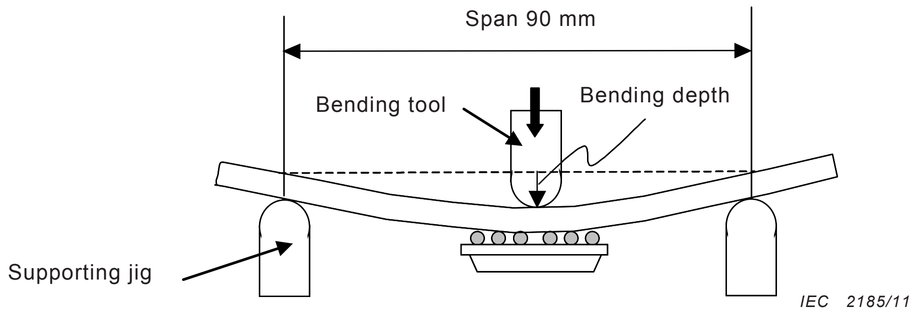


Figure 11 – Monotonic bending strength test

It is desirable that the test substrate is bent with a circular bending. This test is not appropriate for a thin board or a ceramic substrate. The bending depth to break the solder joint is preferably detected by electrical discontinuity of a circuit such as a daisy chain as in Annex B, using an electrical resistance measuring instrument (refer to D.2.3). 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 bending tool shall be 5 mm.

The test condition should be selected in such a way that the relation between the strain induced to the test substrate and the bending depth becomes linear behaviour. It is desirable to make a preliminary test to check the relation of bending depth and strain, and also the limit of the depth at a predetermined bending speed using a strain gauge attached near the solder joint of the device under test.

The proper bending speed is 0,008 3 mm/s (0,5 mm/min.) for a glass-epoxy copper-clad laminate test substrate with 1,6 mm. The maximum limit of bending depth is 10 mm.

The details of the test are given in Annex D.

7.2 Cyclic bending strength test

The cyclic bending strength test is a test for rather a large leadless SMD used in portable equipment. As shown in Figure 12, the test substrate 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 test substrate is repeatedly bended using a bending tool on the back side to a specified depth until the solder joint break. The solder joint break is detected by electrical discontinuity of a circuit such as a daisy chain as in Annex B, using electrical resistance measuring instrument (refer to D.2.4). Record the number of cycles to break the solder joint.

The test equipment and the structure of the supporting jigs are similar to those of the monotonic bending strength test. The test substrate, 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 test substrate is smooth and kept constant. Figure 13 shows such a device supporting jig and the bending tool scheme to bend back the test substrate compulsively to the original flatness by holding both ends of the test substrate to supporting jigs and the bending tool 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 bending for each SMD of different size as to the joint breaks at a bending of several thousands. Since the relation between bending depth and the number of bending to break give a roughly straight line on a log-log scale, 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.

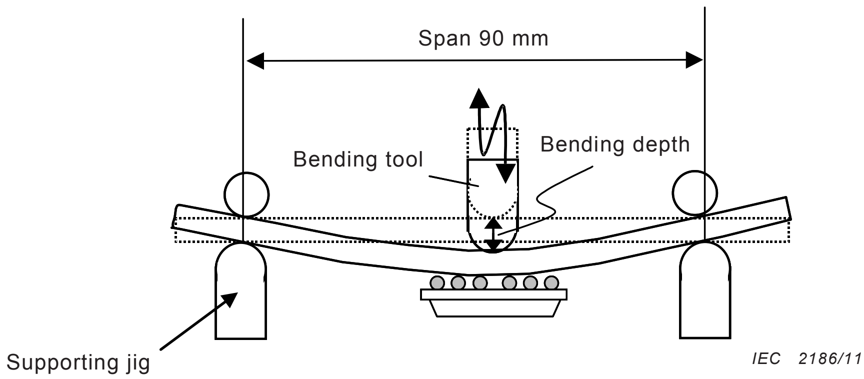


Figure 12 – Cyclic bending strength test

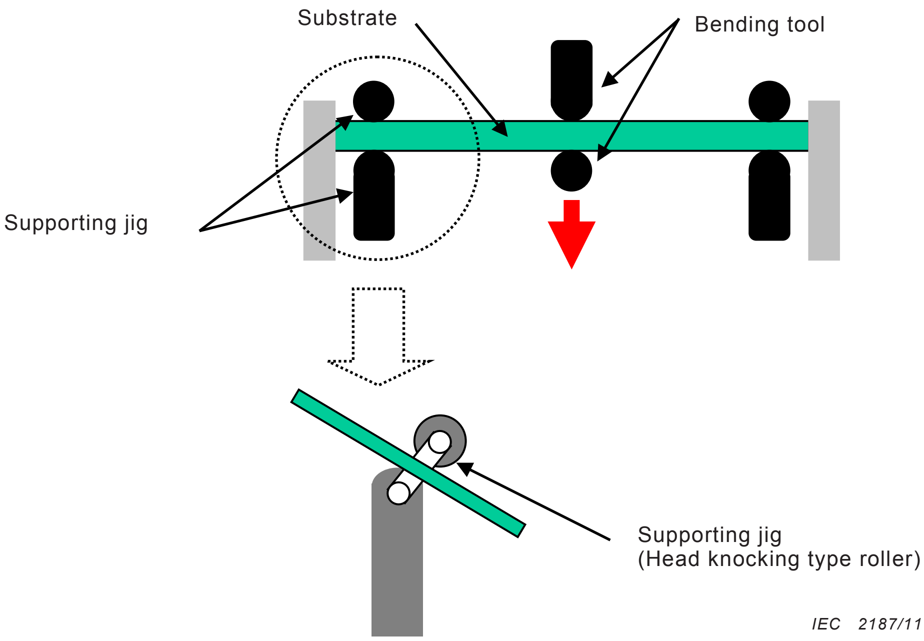


Figure 13 – Structure of cyclic bending strength test

7.3 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 14.

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 device 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 25 °C or at an elevated temperature.

The mechanical shear fatigue test continues until the solder joint break:

– the maximum force decreases to a specified value, which corresponds to the appearance of an initial crack;
– the solder joint break is detected by electrical discontinuity of a circuit such as daisy chain as in Annex B, using electrical resistance measuring instrument (refer to D.2.4).

Record the number of cycles to break the solder joint.

The details of the test method and test condition are given in IEC 62137-1-5.

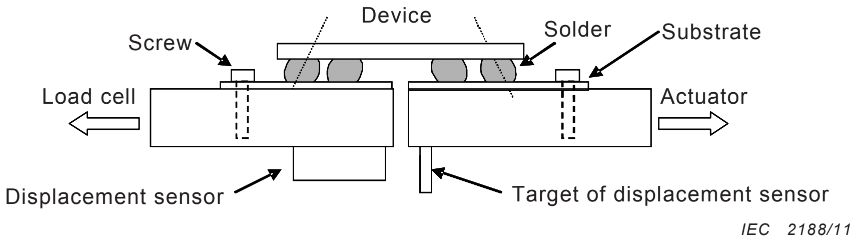


Figure 14a – Straddle method

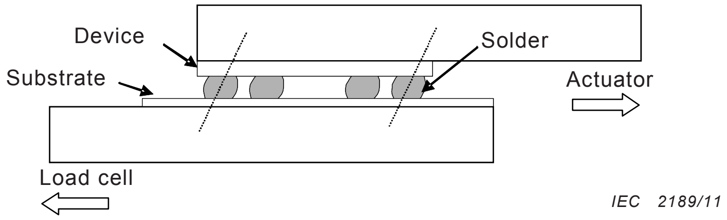


Figure 14b – Lap shear method

Figure 14 – Schematic diagram of mechanical shear fatigue for solder joint

7.4 Cyclic drop test and cyclic steel ball drop strength test

7.4.1 Cyclic drop test

The cyclic drop test is the test for mounting SMDs used in portable equipment. As shown in Figure 15, a SMD mounted on a test substrate is held to the test substrate fixing jig with the device mounted face down, and dropped from a specified height onto the impact block. The solder joint break is detected by electrical discontinuity of a circuit such as a daisy chain, as in Annex B, using an electrical resistance measuring instrument (refer to D.2.4).

Record the number of drops to break the solder joint.

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

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 test substrate fixing jig to avoid asymmetric shock by the fall onto the impact block. The tighten torque of the test substrate 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 test substrate 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 solder joint of the device under test.

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

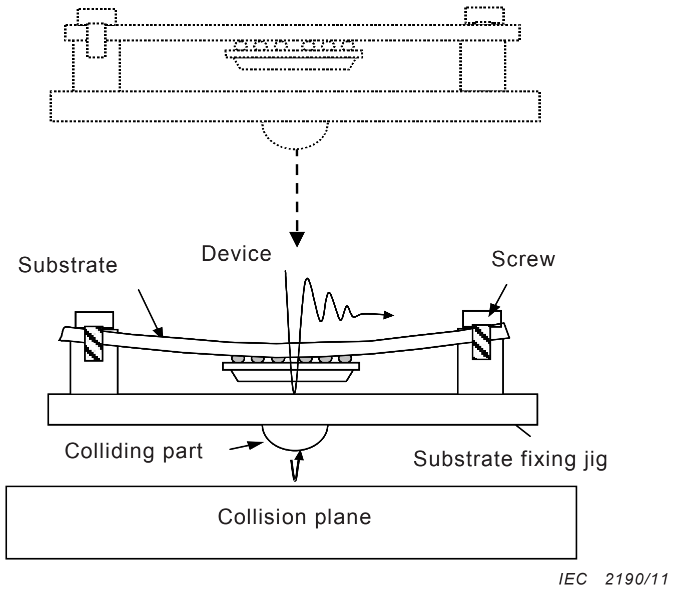


Figure 15 – Cyclic drop test

7.4.2 Cyclic steel ball drop strength test

As shown in Figure 16, a SMD mounted test substrate is held to the test substrate fixing jig with the device mounted face down, and a steel ball is dropped from a specified height onto the backside of the test substrate. The position of the ball drop for a large SMD should be near the peripheral of the devices which is most vulnerable to such mechanical damages. The solder joint break is detected by electrical discontinuity of a circuit such as daisy chain as in Annex B, using an electrical resistance measuring instrument (refer to D.2.4).

Record the number of drops to break the solder joint.

The test equipment should have a good precision 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 solder joint of the device under test.

This is test for slight shock. The details of the test are given in Annex E.

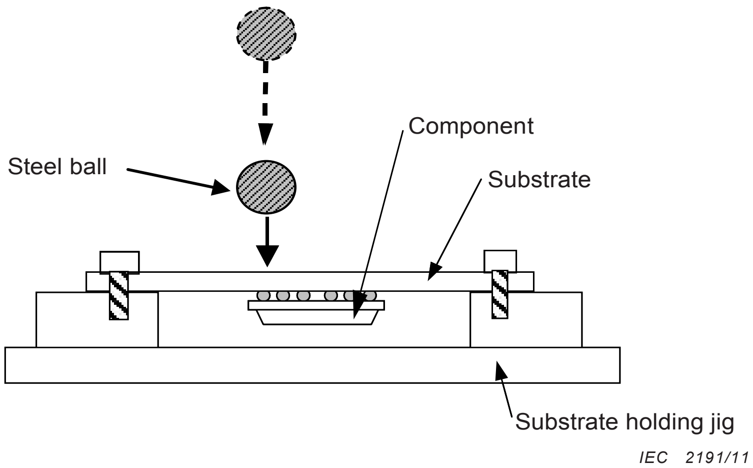


Figure 16 – Cyclic steel ball drop test

7.5 Solder joint strength test for lead insertion type device

7.5.1 Pull strength test for insertion type device

This is the test to measure the maximum force to break a solder joint by holding lead of a lead insertion type device on a single-sided test substrate to the test substrate holding jig and by pulling one of the lead perpendicular to the test substrate as shown in Figure 17. This test is performed before and after the accelerated stress conditioning and the degree of degradation of solder joints is evaluated. A lead cut-off from the device alone may be tested for the pull strength test if the presence of the device makes it difficult to perform this test. The pulling speed should be selected from 1 mm/min, 2 mm/min, 5 mm/min, 10 mm/min and 20 mm/min.

The details of the test are given in Annex F.

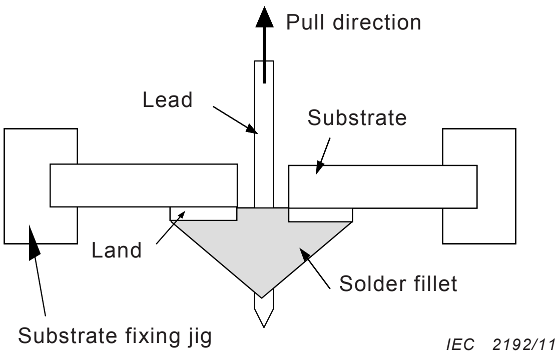


Figure 17 – Pull strength test

7.5.2 Creep strength test for lead insertion type device

This test is to measure the time required for which a lead solder mounted into a through hole on a test substrate breaks and falls off from the through hole by pulling the lead with a weight and left in a high temperature chamber as shown in Figure 18. A lead cut-off from the device alone may be tested for the creep strength test if the presence of the device makes it difficult to perform this test. The solder joint break is detected by electrical discontinuity in the solder joint, using an electrical resistance measuring instrument (refer to D.2.4).

Record the time to break the solder joint.

The test condition is determined by the melting temperature of the material used and usually the test temperature is higher than 0,4 times of T_m (T_m is the melting temperature in Kelvin of the material). In the case of solder alloys, as the room temperature is roughly 0,6 times of 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 thermal resistivity of a lead insertion type device and the deterioration of the mounted test substrate. The practical temperature range of the test for the device is from room temperature to +125 °C. A higher temperature may be selected for the test substrate with a higher glass transition temperature (T_g). It is desirable to perform a preliminary test so 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.

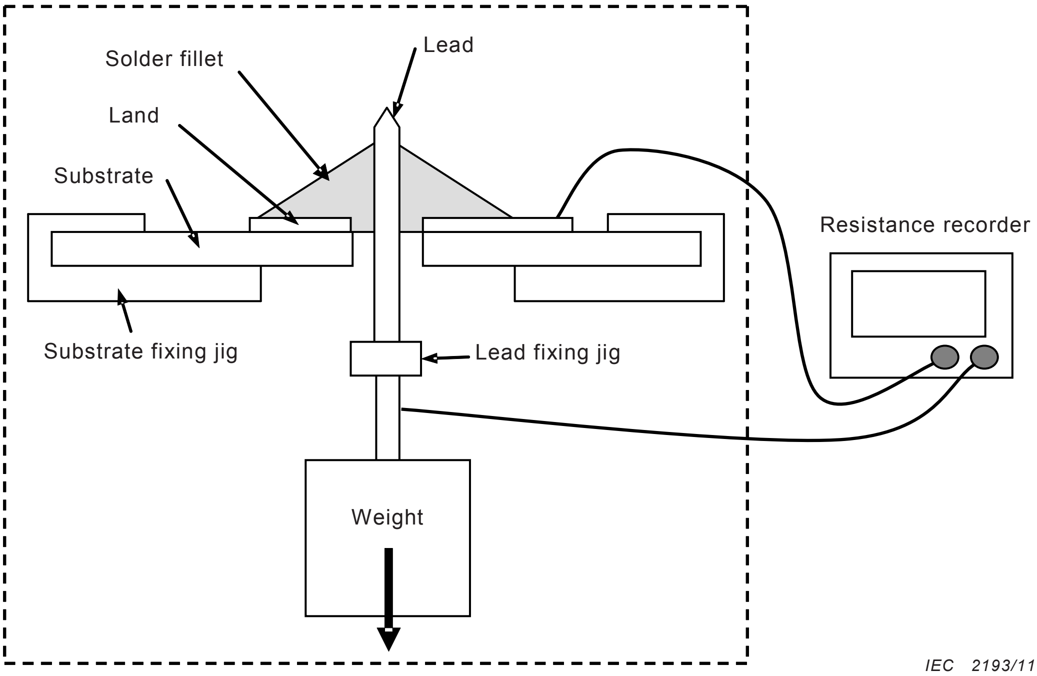


Figure 18 – Creep strength test

Annex A
(informative)

Condition of rapid temperature change

A.1 General

This annex describes the determination of the test condition of the rapid temperature change given in 6.3.1.

A.2 The time necessary to leave a specimen in 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 passes 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 by.

The fatigue of solder by repeated temperature change strongly depends on the non-ballistic strain. The stress induced to the solder joint by the difference in the termination/lead expansion coefficients of the test substrate and the device generated by the rapid temperature change relaxes as time passes and a non-ballistic strain is induced to cause the fatigue of the solder joint. It is necessary to keep the joint at a high or low temperature for some time for the endurance 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.

Therefore, it is desirable to keep the specimen at a high or low temperature, for 15 min to relax given stress.

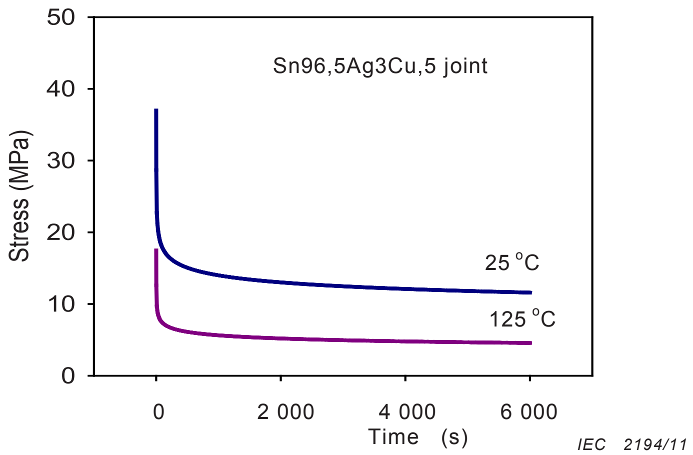
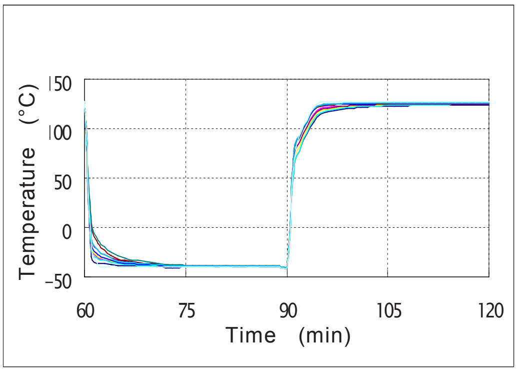


Figure A.1 – Stress relation curve for a given strain to a solder joint (Sn96,5Ag3Cu,5)

A.3 Time required to the temperature equilibrium

The measured temperature of an air type temperature cycle change chamber is shown in Figure A.2. The temperature reaches steady state in about 5 min when the number of test substrates loaded in the chamber is not large but it takes nearly 15 min when a lot of substrates are loaded in the chamber. 15 min are necessary to leave specimens in the chamber for the test.



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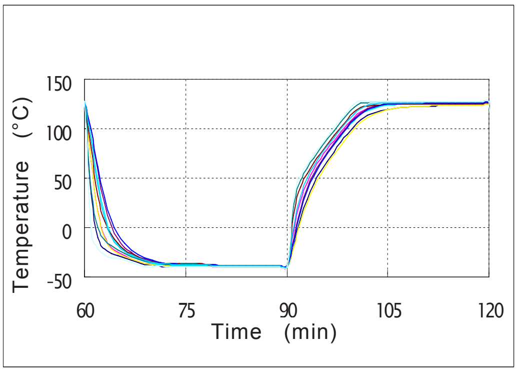
a) Temperature distribution (0 substrate)



IEC 2196/11

b) Temperature distribution (240 substrates)

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 15 min plus the time required to stabilize the temperature of 15 min.

Annex B
(informative)

Electrical continuity test for solder joint

B.1 General

This test evaluates the durability of solder joints by monitoring electrical continuity through the joint without applying mechanical stress.

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

B.2 Specimen and daisy chain

The specimen for a semiconductor device is a device within which terminations are connected as shown in Figure B.1. All of the terminations of the specimen and of the test substrate are connected alternately to form a daisy chain.

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

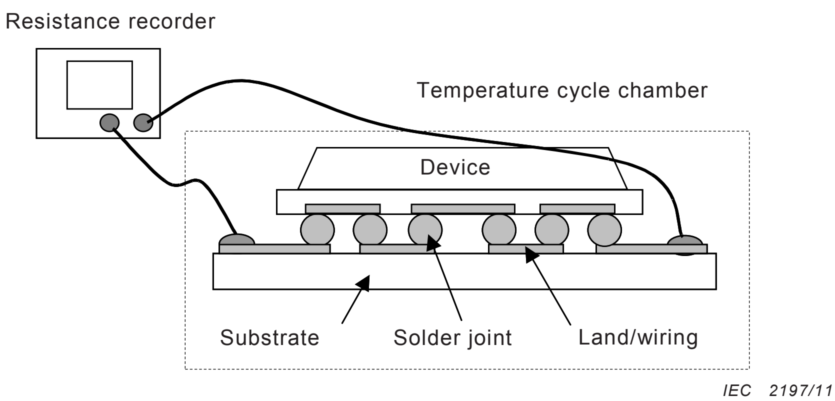


Figure B.1 – Example of the test circuit for an electrical continuity test of a solder joint

B.3 Mounting condition and materials

See 6.1 for details.

B.4 Test method

Measure the electrical resistance of the daisy chain before and after the accelerated stress conditioning to evaluate the presence of a solder joint break. The resistance value of the chain should be continuously measured to find the degree of degradation of solder joints. It is desirable to continue the resistance measurement until a solder joint break is detected. See IEC 62137 for the test method.

Annex C
(informative)

Torque shear strength test

C.1 General

This annex describes in detail the shear strength test given in 7.1.4.

C.2 Test method

C.2.1 Test equipment and test jig

The test should be made using the torque shear strength test equipment specified in C.2.3 and the torque shear jig shown in Figure C.2 and Figure C.3.

C.2.2 Fixing of the test substrate

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

C.2.3 Applying of a torque shear force

C.2.3.1 General

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

C.2.3.2 Displacement rate

Derive the approximate maximum torque before a torque shear strength test by means of a preliminary test using an initial device. Choose the displacement rate of the torque shearing jig in a torque shear strength test from the obtained approximate torque in the preliminary tests so that 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 0,006 98 rad/s to 0,017 5 rad/s when the test equipment is capable of adjusting the displacement rate.

When the displacement rate is not adjustable, rotate the rotation jig so that the torque reaches the maximum torque in several tens of seconds to several minutes.

C.2.3.3 Position adjustment of torque shear strength test jig

The torque shear strength test jig covers vertically the test substrate and then the jig is rotated slowly for torque shear force (see Figure C.2). The rotation axis when applying the torque should be adjusted to the centre of the device mounted on the test substrate. It is advisable to use a holding jig to suppress the possible deviation/vibration of the rotation axis.

C.2.3.4 Torque shear strength test failure

The torque shear strength test jig is placed vertically over the device and slowly rotated. Care should be taken that the torque meter is kept perpendicular to the test substrate. The rotating speed should be 0,006 98 rad/s to 0,017 5 rad/s when it is adjustable. When the speed is not adjustable, rotate the jig very slowly until the solder joint breaks.

C.2.4 Torque shear strength test to a connector

C.2.4.1 Test equipment requirements

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 substrate.

C.2.4.2 Torque shear strength test jig for a connector

Prepare a torque shear strength test jig, as shown in Figure C.3, for the torque shear strength test of a connector adjustable to the solder joints of the connector and its shape to reinforce the mechanical strength of the connector. It is desirable that this covering jig should be fitting closely to the connector with minimum clearance to improve the measurement accuracy of the test. Depth, *H*, of this covering jig should approximately be equal to the height of the connector. Place the covering jig on the connector mounted on a test substrate.

C.2.4.3 Torque shear displacement rate on 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 device to find the rotation speed for the displacement rate so 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 0,006 98 rad/s to 0,017 5 rad/s for the test equipment which can adjust the speed and also radial speed (rotation rate).

When the displacement rate is not adjustable, rotate the rotation jig so that the torque reaches the maximum torque in several tens of seconds to several minutes.

C.2.4.4 Position adjustment of torque shear strength test jig for a connector

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

C.2.4.5 Torque shear strength test failure of a connector

The torque strength test shear jig covers vertically the test substrate and then the jig is rotated slowly for torque shear force. Care should be taken to keep the torque meter in a vertical position against the test substrate. The rotation displacement rate should be in the range of 0,006 98 rad/s to 0,017 5 rad/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 by keeping the rotation axis perpendicular to the test substrate until the soldered connection breaks.

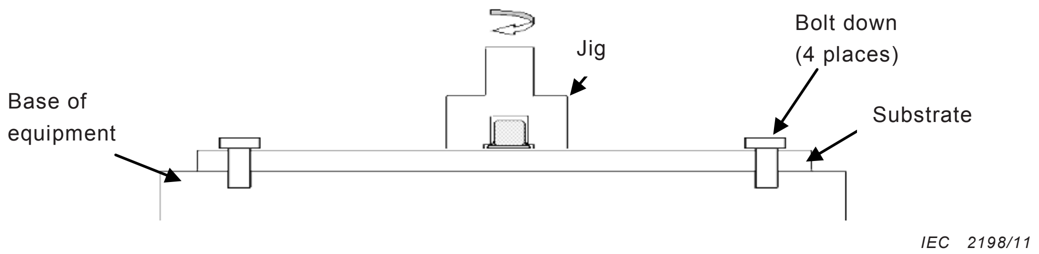


Figure C.1 – Fixing of substrate for torque shear strength test

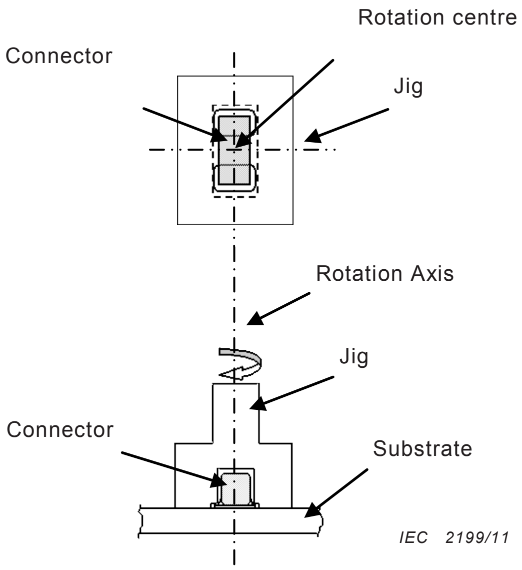


Figure C.2 – Torque shear strength test jig and position adjustment

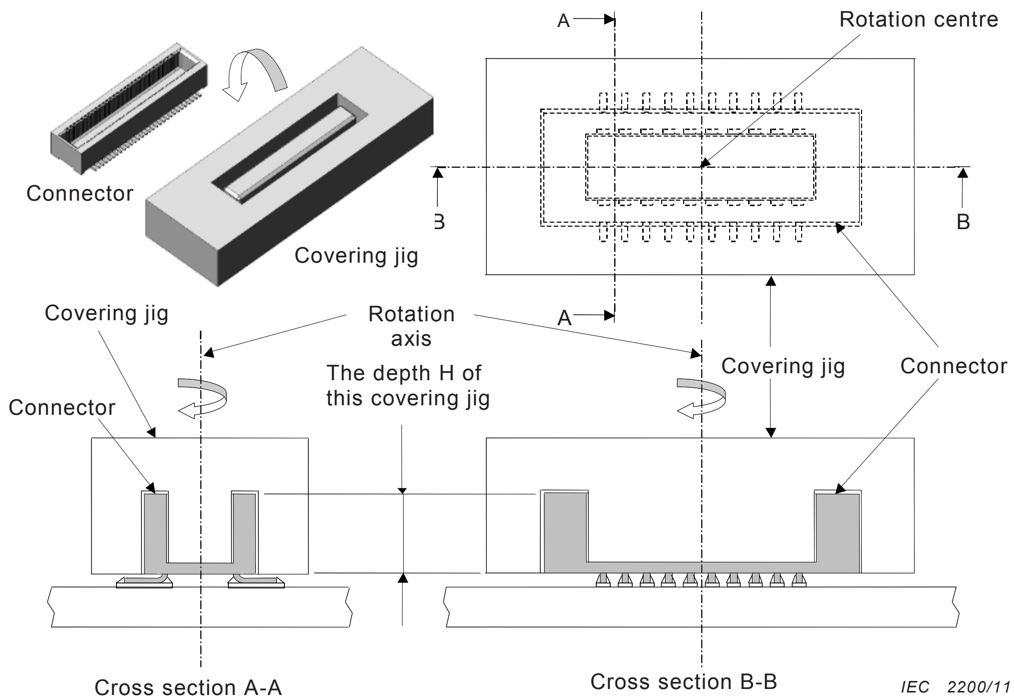


Figure C.3 – Torque shear strength test for a connector

Annex D
(informative)

Monotonic bending strength test

D.1 General

This annex describes in detail the monotonic bending strength test given in 7.1.5.

D.2 Monotonic bending strength test equipment

D.2.1 Test equipment requirements

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

D.2.2 Testing machine

The test should be made using the monotonic bending strength test equipment specified in 7.1.5 with following details.

a) The machine should be able to push the bending tool 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 bending tool and the displacement with passing time.

D.2.3 Substrate bending jig

The substrate bending jig should be able to support the device with the face down of the device side of the printed circuit board, by pushing the centre of the substrate down with the bending tool. Unless otherwise specified by the product specifications, the jig should be as follows.

The structure of the substrate bending jig should be as shown in 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 cyclic testing.

b) Bending tool: The radius of the bending tool 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.

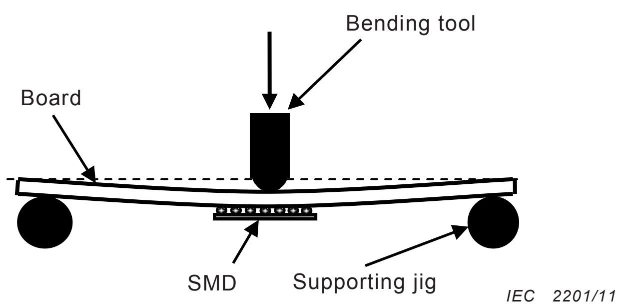


Figure D.1 – Example of a board bending jig

D.2.4 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 qualify as interruption when resistance values exceed 1×10^3 Ω. The measuring instrument should be able to measure an interruption of 10 μs to 100 μs in order to detect electrical discontinuity.

D.2.5 Recorder

The recorder should record displacement and force with passing time 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 placed on the substrate bending jig as follows.
   - First, solder lead-wire to daisy chain leads used for monitoring the electrical resistance on the substrate, and then connect the wire to a momentary interruption detector.
   - Confirm that the centres of supporting jigs are at the same distance from the centre of the bending tool (45 mm ± 0,5 mm).
   - The test substrate is set on the testing machine with its face down on the SMD side. Adjust the position in such a way that the bending tool will push at the centre of the substrate.
   - Make sure that the bending tool is in the centre by having it in contact with the substrate.

NOTE Keep bending the substrate until a force of 1 N ± 0,1 N is applied so as to confirm that the bending tool is actually connected with the substrate.

b) Depress the bending tool to the substrate until the electrical discontinuity is detected. Record the applied force, displacement and electrical resistance of the daisy chain.
c) A solder joint is considered a 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 10 mm. The test should be terminated when discontinuity or open 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 0,008 3 mm/s to 0,1 mm/s (0,5 mm/min to 6 mm/min).

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

Annex E
(informative)

Cyclic steel ball drop strength test

E.1 General

This annex describes in detail the cyclic steel ball drop strength test given in 7.4.2.

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 (for slight shocks). This test does not evaluate the durability of mounted devices on the board itself, but it is a test to enable the relative comparison of the joint durability correlation between mounted devices 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 as described in 6.1. The thickness and material of the test substrate should be such that it bends with a reasonable radius of curvature at the shock of drop of the ball but should not be deformed. The recommended thickness of the test substrate is 1,6 mm, thicker than in the cyclic drop test in 7.4.2.

E.3 Test equipment

The test equipment should have a good precision of the position of the ball drop to attain good reproducibility of the test. To check the stability of the 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 solder joint of the device under test.

E.4 Test procedure

As shown in Figure E.1, a SMD mounted test substrate is held to the test substrate fixing jig with the device mounted face down, and a steel ball is dropped from a specified height onto the backside of the test substrate. The position of the ball drop for a large SMD should be near the peripheral of the devices which is most vulnerable to such mechanical damages. The solder joint break is detected by electrical discontinuity of a circuit such as a daisy chain as in Annex B, by using an electrical resistance measuring instrument (refer to D.2.4).

Record the number of drops to break the solder joint.

This is test for slight shock.

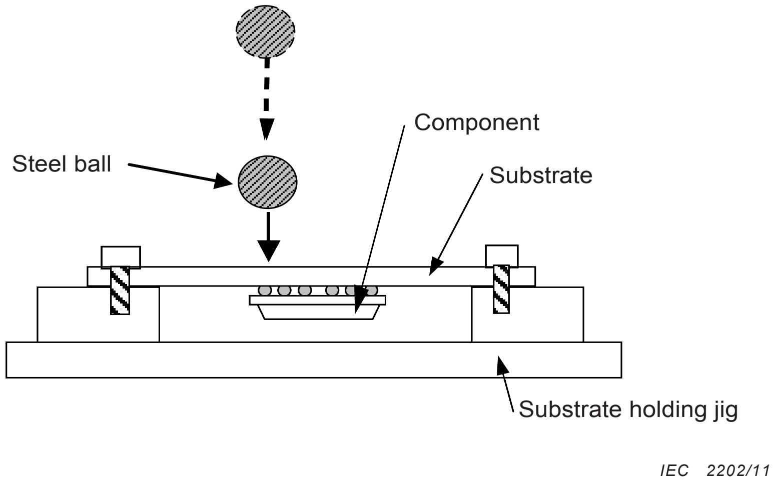
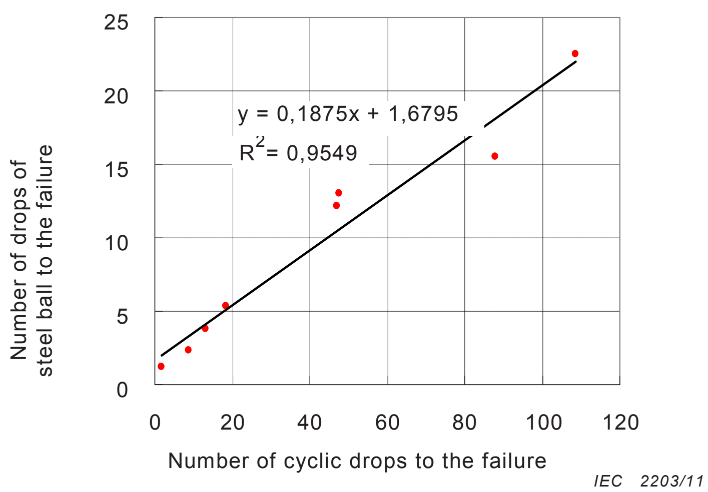


Figure E.1 – Cyclic steel ball drop test

E.5 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 termination 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 solder joints were compared as shown in Figure E.2. A good correlation between two tests was observed.



Key
Cyclic drop test: Drop height – 0,75 m
Steel ball drop test: Ball mass – 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 General

This annex describes in detail the pull strength test specified in 7.5.1.

F.2 Test procedure

The test procedure is shown below.

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

b) The test substrate should be fixed to the pull strength test equipment as shown in Figure F.1.

NOTE When fixing the test substrate, the lead to be tested should be fixed at the centre of the test substrate fixing jig, so that the lead is perpendicular to the lead fixing jig.

c) Fix the lead to the jig of the pull strength test equipment.

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

NOTE 2 The method of fixing the test substrate, the relative position of the fixing jig and the lead should be recorded.

NOTE 3 All possible care should be taken not to impose any bend or twist force to the joint when the lead is fixed to the pulling jig of the equipment.

d) The pulling speed of the jig should be selected from the following, 0,016 7 mm/s (1,0 mm/min), 0,033 3 mm/s (2 mm/min), 0,083 3 mm/s (5 mm/min) 0,167 mm/s (10 mm/min) or 0,333 mm/s (20 mm/min). The pulling speed should be stated in the product specification of the device.

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

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

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

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

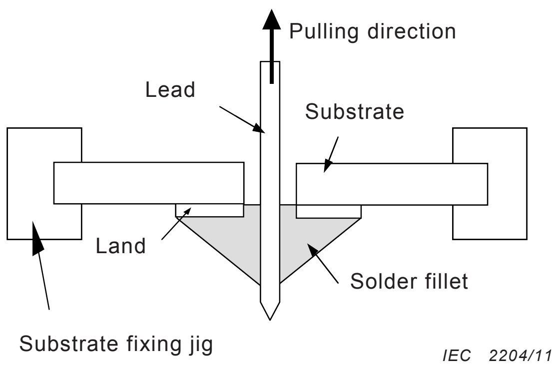


Figure F.1 – Pull strength test

Annex G
(informative)

Creep strength test

G.1 General

This annex describes in detail the creep strength test specified in 7.5.2.

G.2 Test procedure

The test should be carried out according to the following procedure using the equipment.

a) The specimen should be visually inspected after the pre-treatment.

b) Connection is made for the continuity test to a pattern connected to the land, but separated from it by more than 10 mm, as a positive terminal and the weight jig to hold the lead as a negative terminal.

c) The test substrate is fixed to the creep test equipment.

NOTE 1 When the test substrate is fixed to the equipment, the lead to be tested should be positioned in the centre of the lead fixing jig so that the lead is in line with the lead fixing jig.

d) Unless otherwise specified in the product specification, fix the test substrate in the temperature chamber. The temperature chamber should be at the temperature specified in relevant standards.

NOTE 2 The temperature specified in relevant standards should be lower than the heat resistant temperature of the test substrate.

NOTE 3 Care should be paid not to induce excessive chemicals, thermal, or mechanical load to the joint of the lead and the land.

NOTE 4 The method of fixing the test substrate, the relative position of the fixing jig and the testing joint should be recorded.

e) A schematic diagram of the test is shown in Figure G.1.

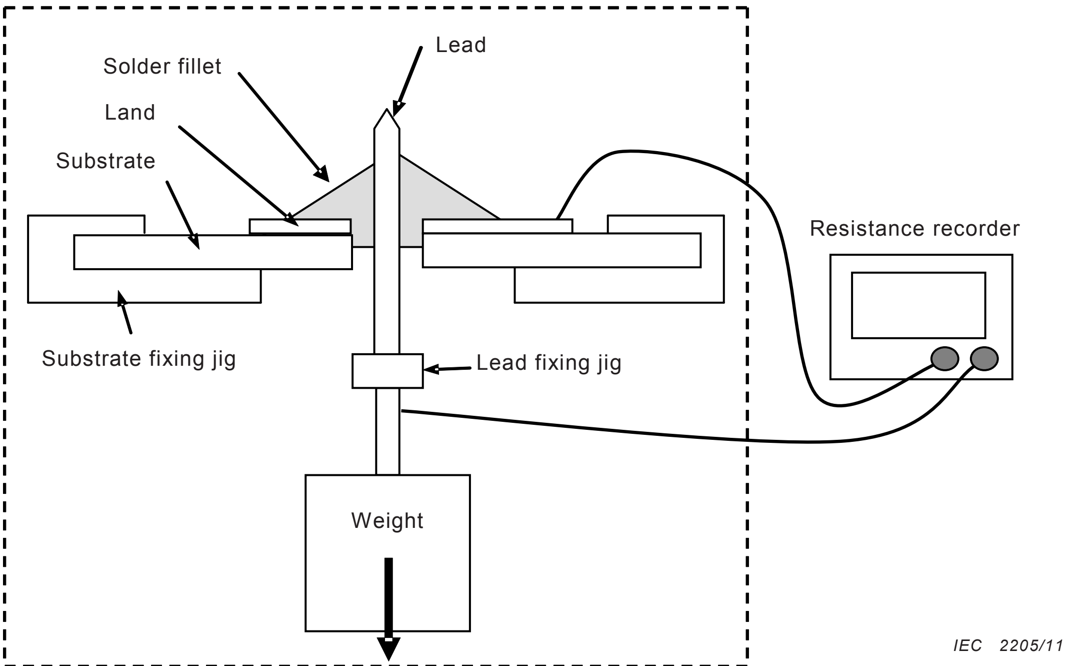


Figure G.1 – Creep strength test

f) Apply the force specified in the product specification to the lead. A predetermined weight to the jig is used to apply the force to the lead. The accuracy of the force to the lead should be less than ±1 %.

NOTE 5 Care should be paid to prevent the lead and the weight to touch the jig and other subjects in the chamber.

NOTE 6 Care should be paid not to apply any dynamic force to the test substrate when a weight is added to the loading jig.

NOTE 7 In selecting an appropriate force (mass of the weight), it is efficient to start a test from a rather large force (e.g., 90 % of pull strength of the joint) considering the results of a pulling test and of the creep strength to break. Use of a log-log plot of force to creep strength to break for extrapolation to select a weak force is desirable by reducing the force along the line in the graph.

g) Switch on the power supply and the monitor and start the measurement.

h) Record the time from start of loading until the joint breaks.

i) Record the position and the failure mode as the joint breaks.

NOTE 8 Confirm the operation of the equipment, presence of circuit noise and open of the measuring circuit prior to the creep strength test by performing a continuity test before the loading of a weight without applying any external force to the joint.

NOTE 9 It is desirable to limit the estimated life within one order of magnitude when the life of a joint is extrapolated from experimental data.

Annex H
(informative)

Evaluation method for the fillet lifting phenomenon of a lead insertion type device solder joint

H.1 General

This annex describes an evaluation method for fillet lifting phenomenon of a lead insertion type device solder joint.

There are three types of fillet lifting phenomena as shown in Figure H.1.

- Fillet lifting between lead and solder
- Fillet lifting between fillet and land
- De-lamination between land and board

NOTE This method is for the evaluation of the generation of a fillet lifting phenomenon and electrical disconnection for a specified combination of a device, solder and substrate. Electrical disconnection is often observed when fillet lifting between land and board exists. It is recommended to perform the electrical continuity evaluation to check the discontinuity.

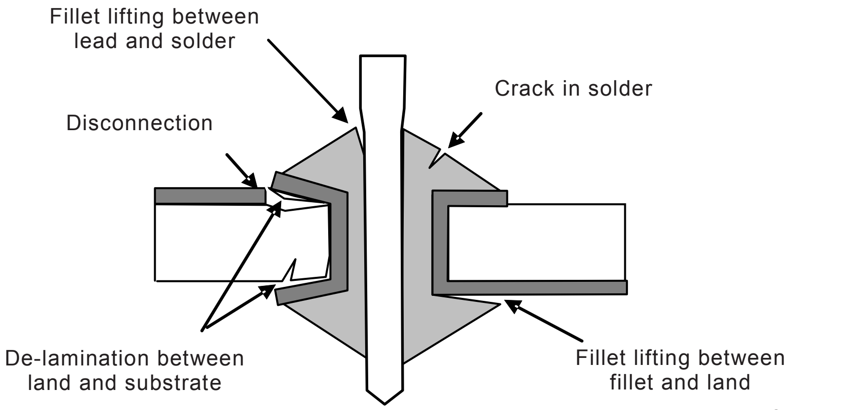


Figure H.1 – Fillet lifting phenomenon of solder joint

H.2 Observation of fillet lifting phenomenon

Fillet lifting should be observed by visual inspection using a magnifying glass at an angle of 10° to 30° from the test substrate. It is desirable to record the status of fillet lifting generation immediately after solder mounting of devices on test substrate.

H.3 Electrical continuity evaluation

Electrical discontinuity at a solder joint is checked by the electrical continuity evaluation conduction before and after the accelerated stress conditioning as described in 6.3. Electrical discontinuity at a solder joint is detected by electrical discontinuity of a circuit such as a daisy chain, as in Figure H.2, using an electrical resistance measuring instrument (refer to D.2.4).

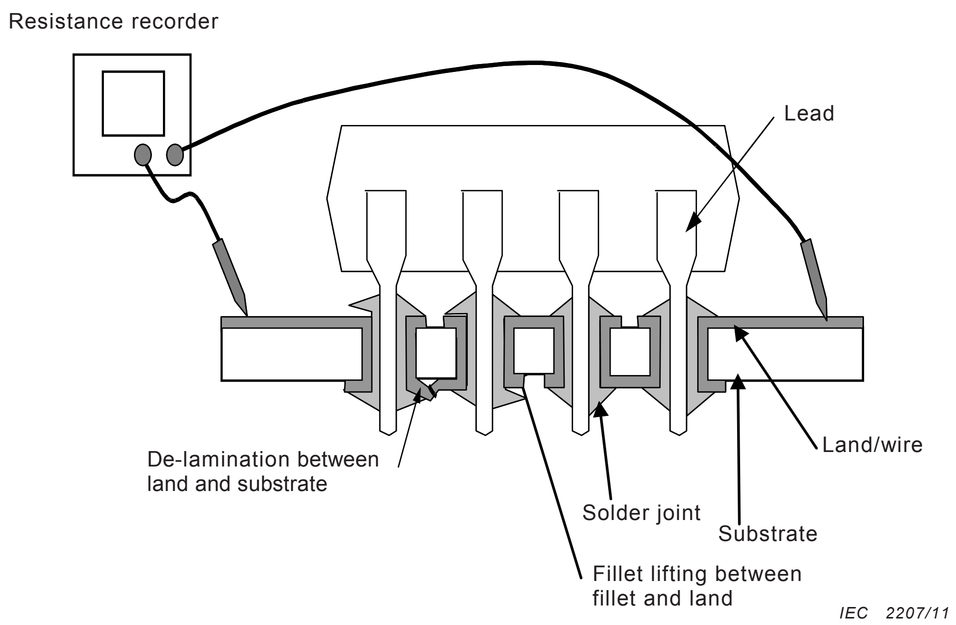


Figure H.2 – Example of an electrical continuity test circuit for a lead insertion type device solder joint

Bibliography

IEC 60068-1:1998, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

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

IEC 61760-1, *Surface mounting technology – Part 1: Standard method for the specification of surface mounting components (SMDs)*

IEC 62137:2004, *Environmental and endurance testing – Test methods for surface-mount boards of area array type packages FBGA, BGA, FLGA, LGA, SON and QFN*

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