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**Electronics assembly technology –
Part 3: Selection guidance of environmental and endurance test methods for
solder joints**

**Techniques d'assemblage des composants électroniques –
Partie 3: Guide de choix des méthodes d'essai d'environnement et d'endurance
des joints brasés**



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ELECTRONICS ASSEMBLY TECHNOLOGY –**Part 3: Selection guidance of environmental and endurance
test methods for solder joints**

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International Standard IEC 62137-3 has been prepared by IEC technical committee 91: Electronics assembly technology.

This first edition cancels and replaces IEC/PAS 62137-3, published in 2008, and includes some editorial revisions. The main changes with respect to the PAS include the following:

- no technical changes;
- some editorial changes and corrections;
- for the sake of convenience some constitutive changes.

The text of this standard is based on the following documents:

FDIS	Report on voting
91/986/FDIS	91/1011/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 62137 under the general title *Electronics assembly technology* can be found in the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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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

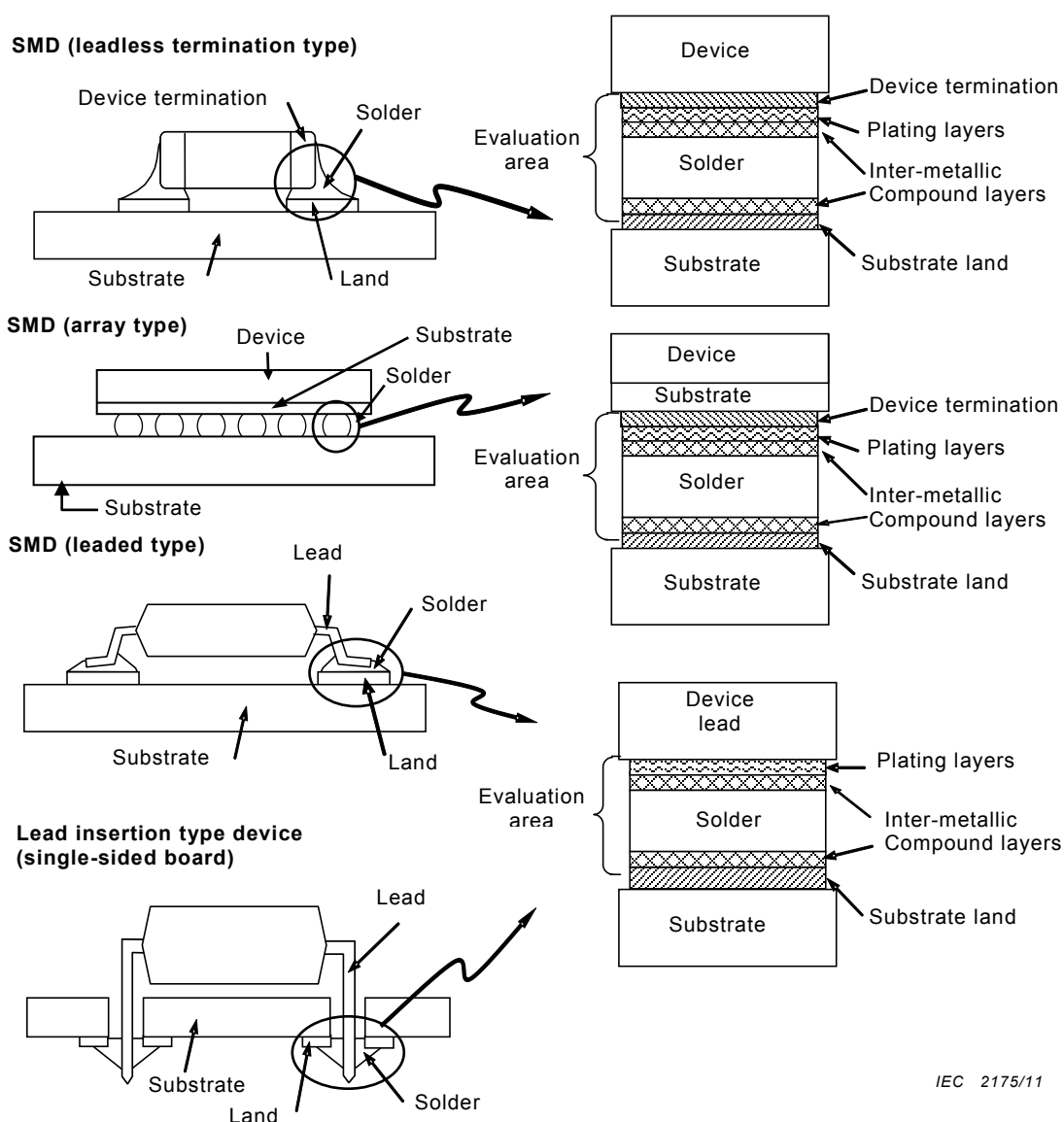
all chains of solder joint connections that are connected in series, see Clause B.2

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.



IEC 2175/11

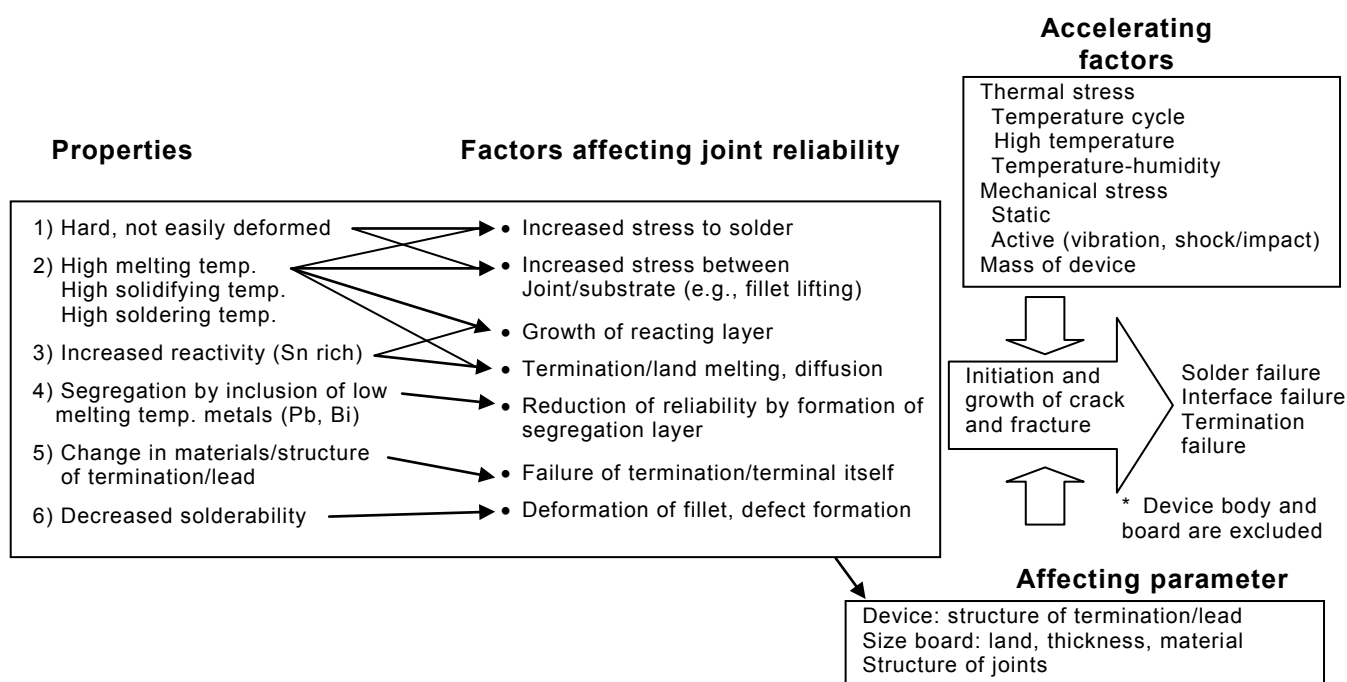
Figure 1 – Joint regions for the reliability tests

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.



IEC 2176/11

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	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	Dry heat ^c Damp heat ^c	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 accelerated 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.

- Pull strength test: SMD with gull wing leads.
- Shear strength test: Small rectangular SMD to which a pushing jig can be pressed to a side of the device.
- 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.

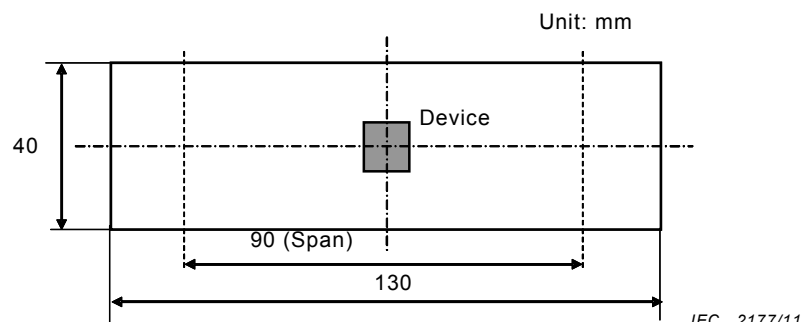
Tests for lead insertion type devices are for mounting the devices on one side of substrate. Tests for lead insertion type devices mounted on a double-sided substrate are not appropriate as the strength of solder joints in this case is much higher than that of leads themselves to the device.

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
$S \leq 0,10$	$d \leq 0,35$	0,8	1,4
$0,10 < S \leq 0,28$	$0,35 < d \leq 0,60$	1,0	1,6
$0,28 < S \leq 0,50$	$0,60 < d \leq 0,80$	1,2	1,8
$0,50 < S \leq 0,79$	$0,80 < d \leq 1,00$	1,4	2,0
$0,79 < S \leq 1,20$	$1,00 < d \leq 1,25$	1,6	2,2

6.2 Soldering condition

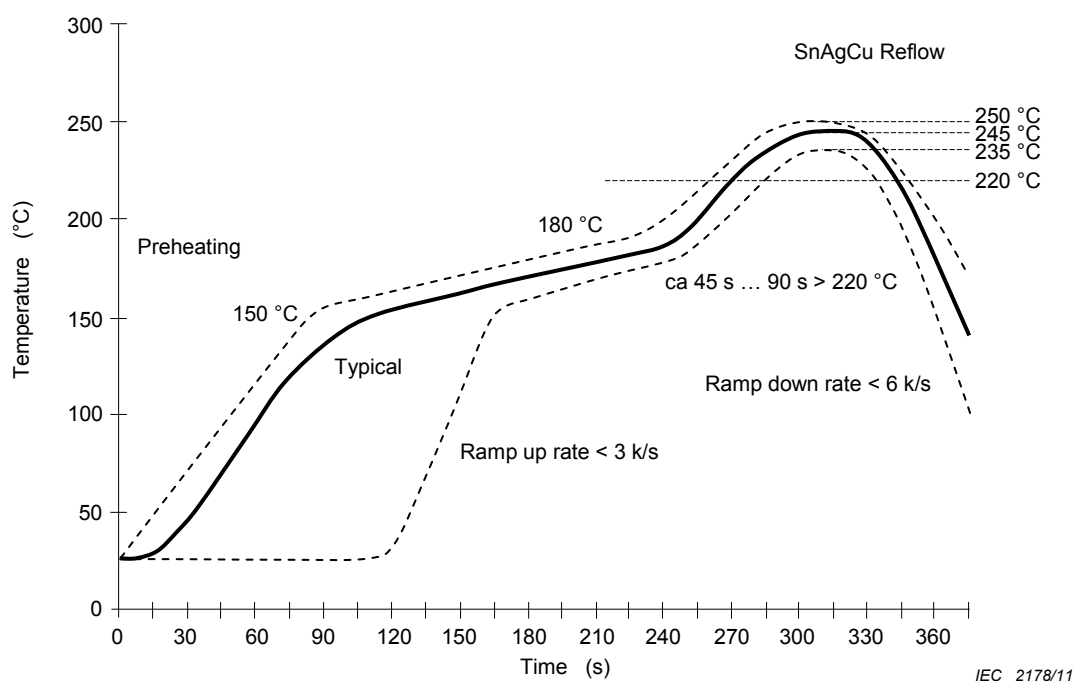
6.2.1 General

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.

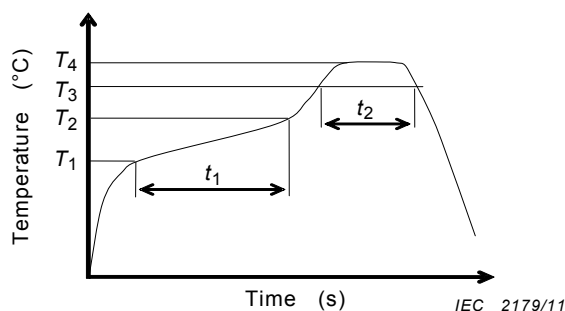


Key

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 N2 atmosphere soldering is recommended.

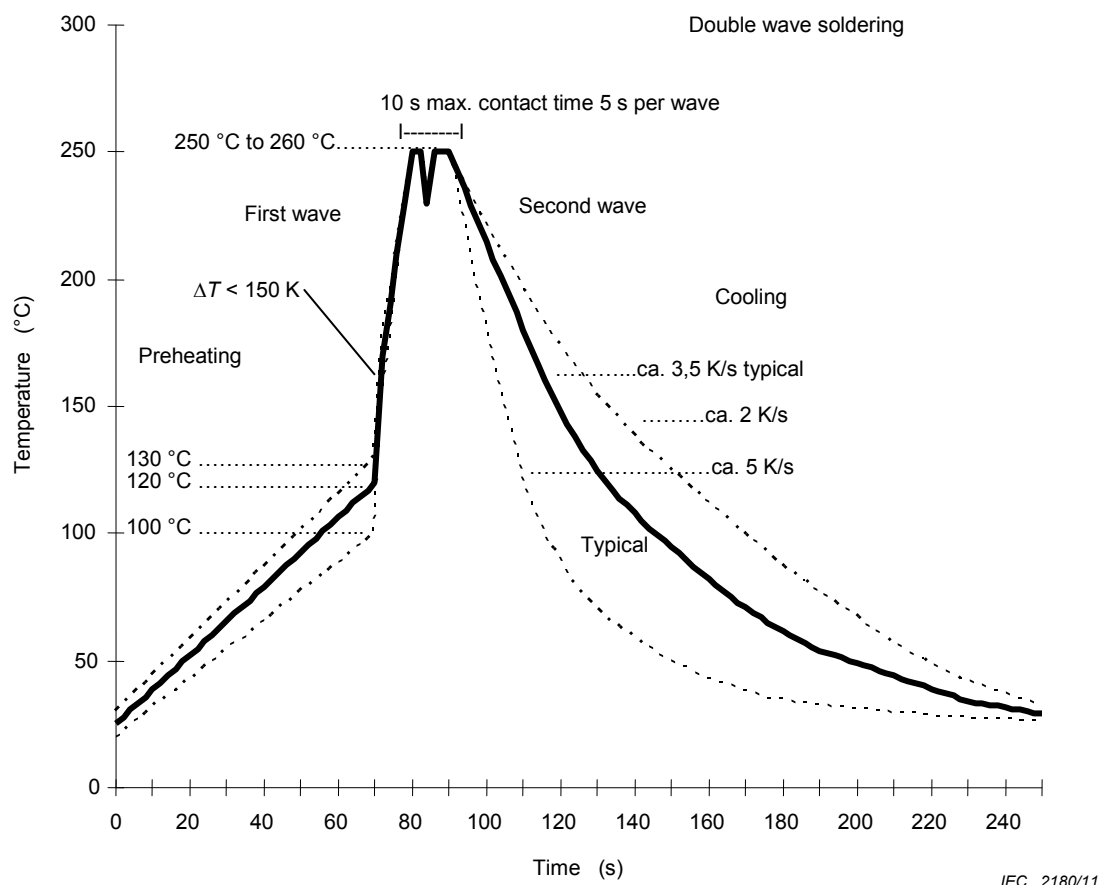
^a Inert gas such as N₂ atmosphere soldering is recommended.

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.

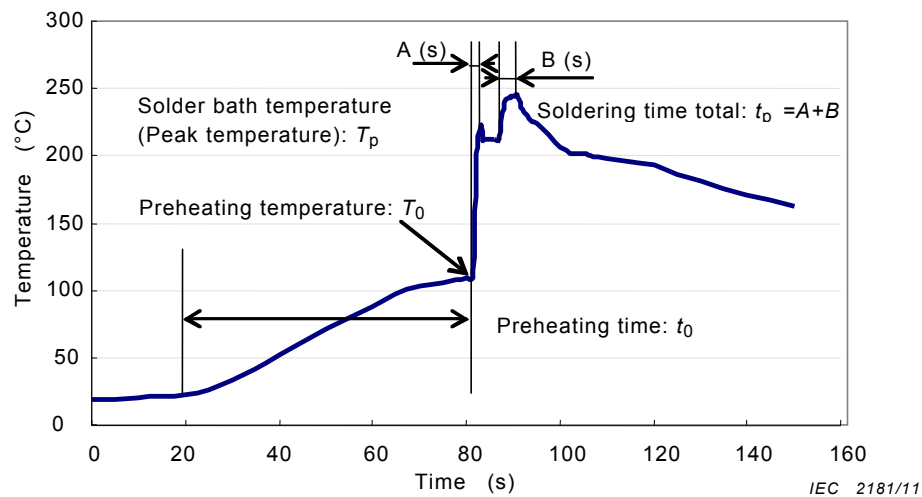


Key

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 $\pm$ 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.

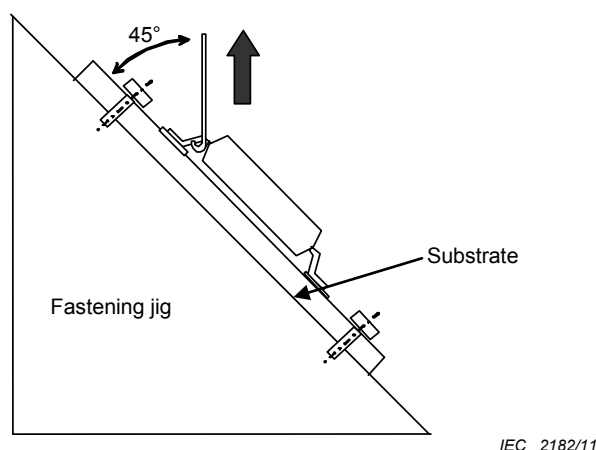


Figure 8 – Pull strength test

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.

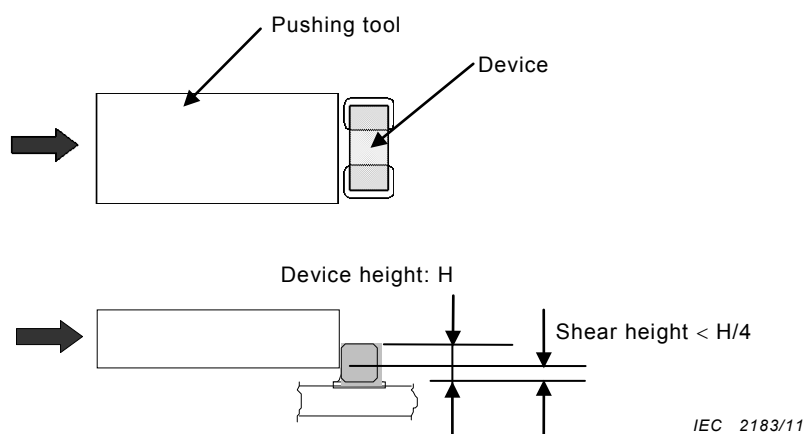


Figure 9 – Shear strength test

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.

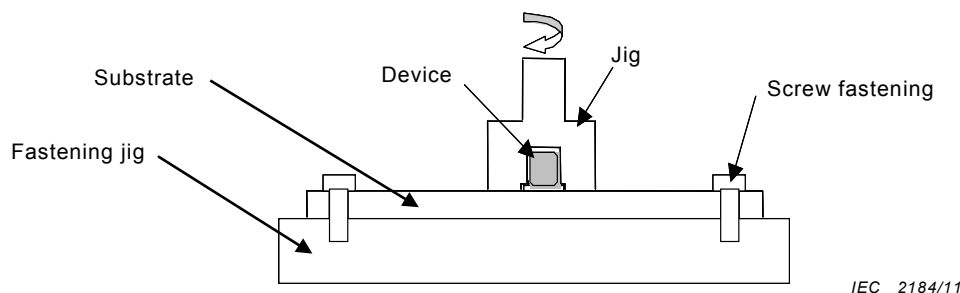


Figure 10 – Torque shear strength test

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 bent 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.

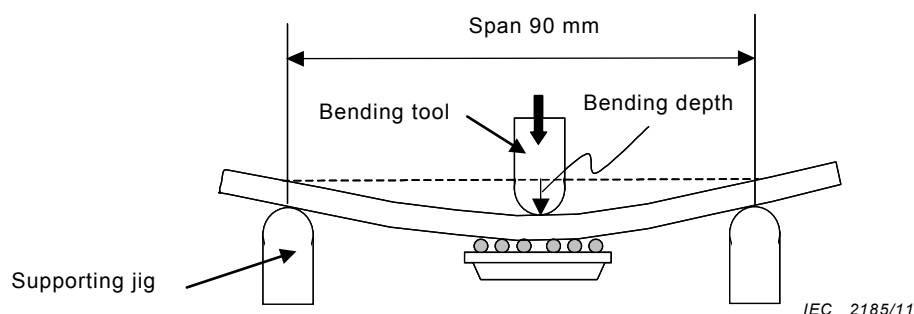


Figure 11 – Monotonic bending strength test

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 bent 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.

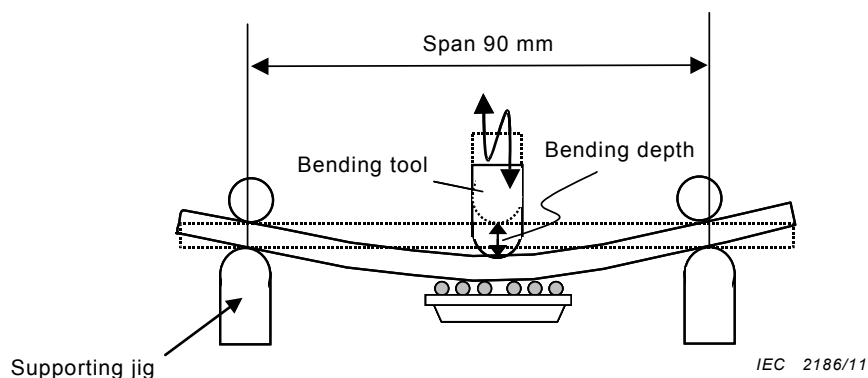


Figure 12 – Cyclic bending strength test

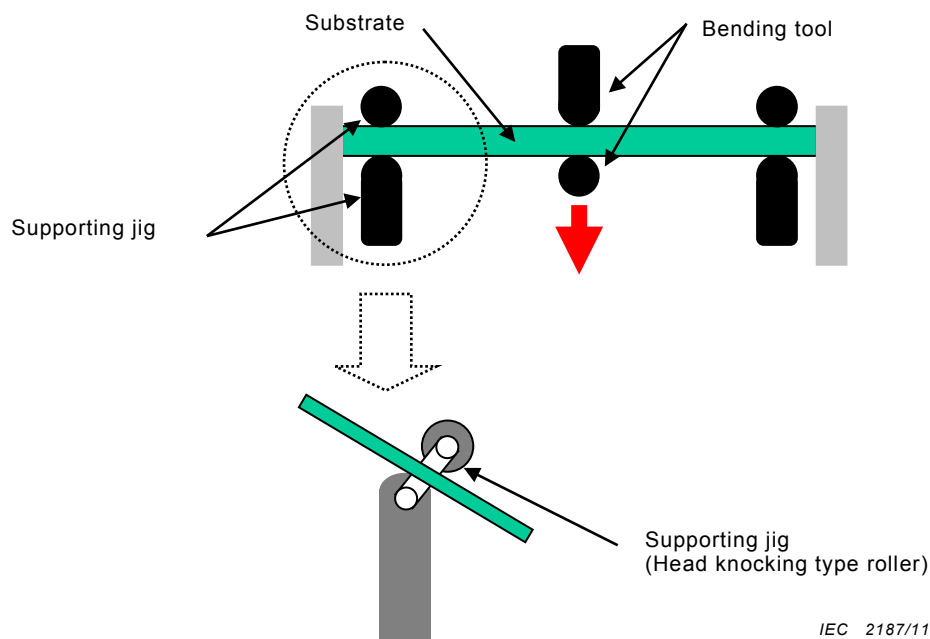


Figure 13 – Structure of cyclic bending strength test

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.

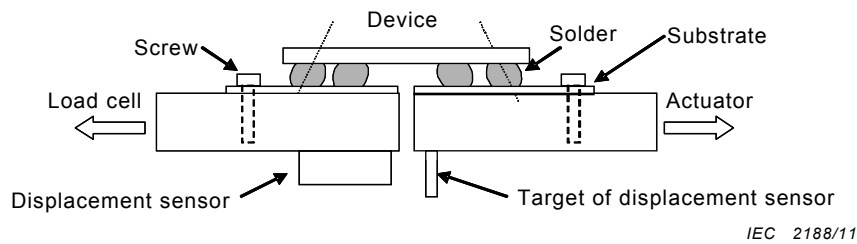


Figure 14a – Straddle method

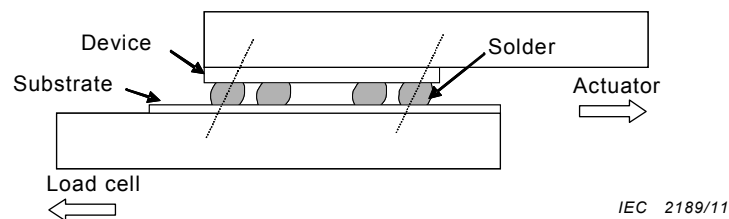


Figure 14b – Lap shear method

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.

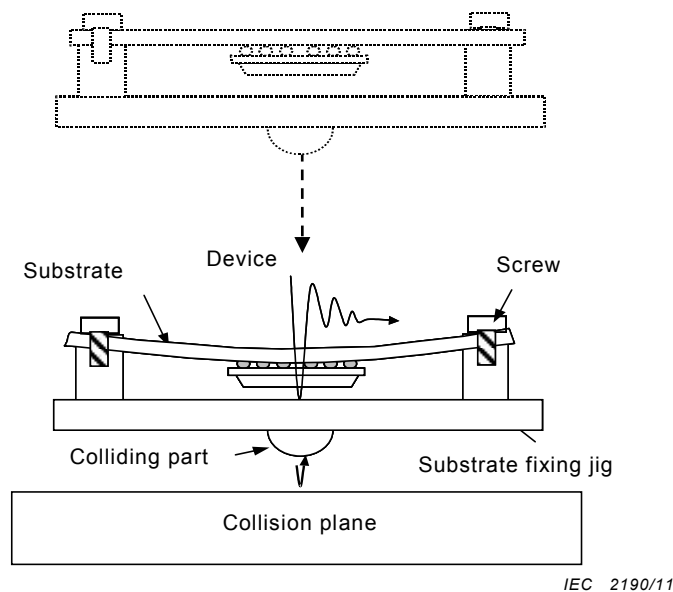


Figure 15 – Cyclic drop test

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.

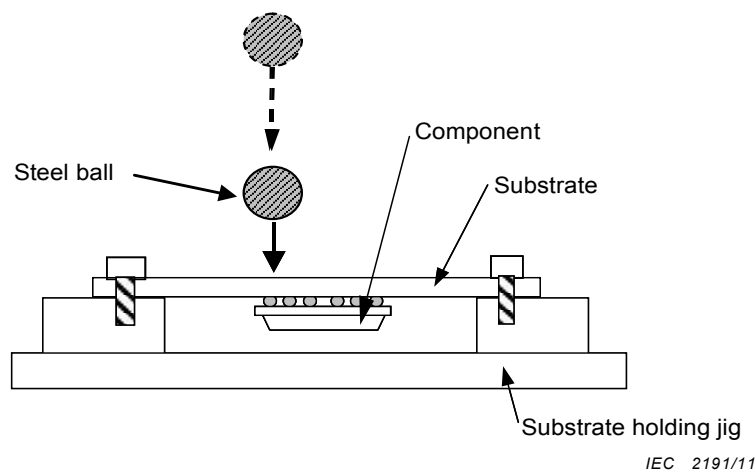


Figure 16 – Cyclic steel ball drop test

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.

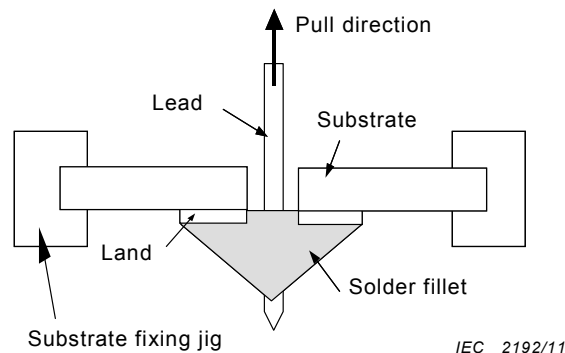


Figure 17 – Pull strength test

7.5.2 Creep strength test for lead insertion type device

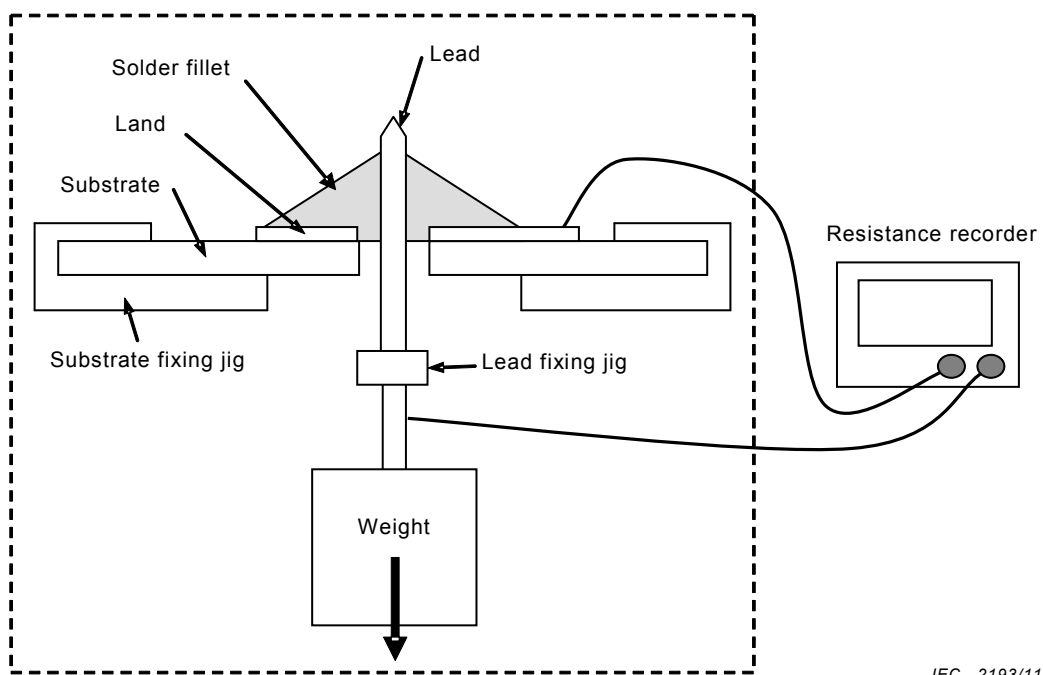
This test is to measure the time required for which a lead solder mounted into a through hole on a test substrate breaks and falls off from the through hole by pulling the lead with a weight and left in a high temperature chamber as shown in Figure 18. A lead cut-off from the device alone may be tested 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 $-50\text{ }^{\circ}\text{C}$ 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 $+125\text{ }^{\circ}\text{C}$. 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.



IEC 2193/11

Figure 18 – Creep strength test