# IEC 62137-3

Edition 1.0 2011-11

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

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inside

## 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

IEC 62137-3:2011

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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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- replaced by a revised edition, or
- amended.

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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.

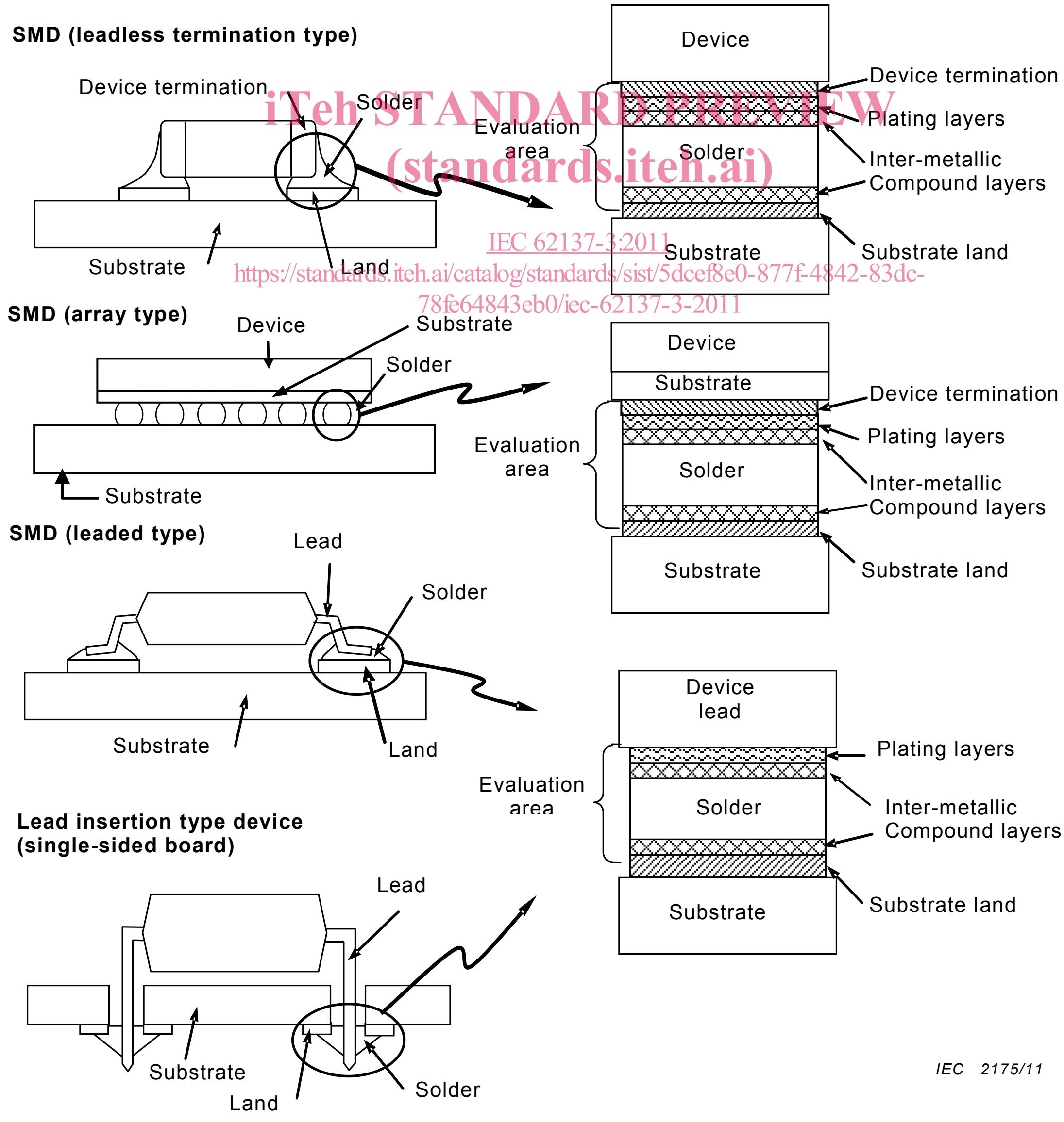


Figure 1 – Joint regions for the reliability tests

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.

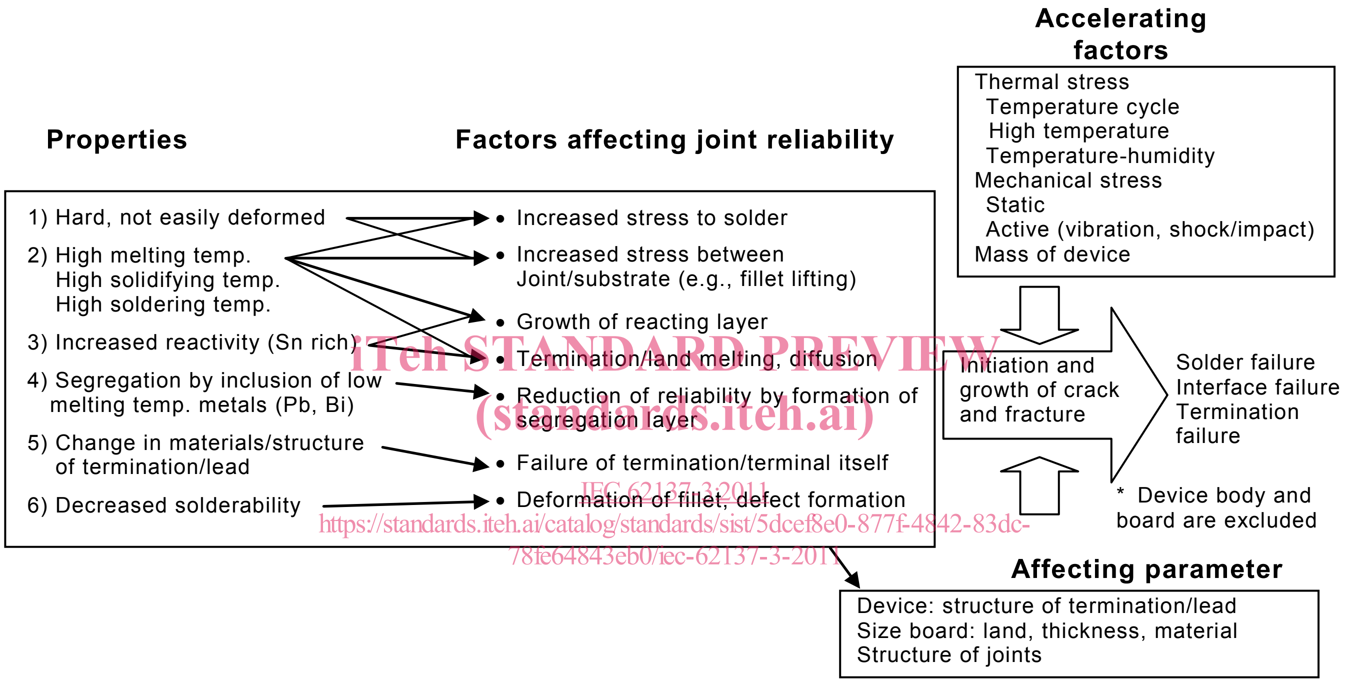


Figure 2 – Factors affecting the joint reliability made by lead-free solder

## 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<br>(Applicable standard) | Accelerated stress conditioning | Applicable board/Components | Stress in the field and applicable products |
|---|---|---|---|
| Continuity test [a, b]<br>Annex B | Rapid temperature change [c]<br>Dry heat [c]<br>Damp heat [c] | SMD | The stresses to be assumed are as follows.<br>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<br>b)High temperature environment<br>c)High temperature and high humidity environment |
| Pull strength [a]<br>IEC 62137-1-1 | | SMD<br>(Gull-wing) | |
| Shear strength [a]<br>IEC 62137-1-2 | | SMD | |
| Torque shear strength [a]<br>Annex C | | SMD | |
| Monotonic bending test [a]<br>Annex D | | SMD | |
| Cyclic bending strength test<br>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<br>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]<br>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]<br>Annex E | Repeated ball drop | SMD | |
| Pull strength test<br>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<br>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<br>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.

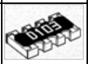
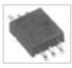
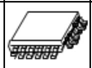
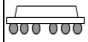
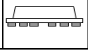
[e] The rapid temperature change is recommended if observed fillet lifting between land and board exists.

## 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 | Monoto-nic 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