



BSI Standards Publication

Electronics assembly technology

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

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

raising standards worldwide™

Full document details: BS EN 62137-3:2012

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 It supersedes DD IEC/PAS 62137-3:2008 which is withdrawn.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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2012

Published by BSI Standards Limited 2012

ISBN 978 0 580 68370 1

ICS 31.190

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 March 2012.

Amendments issued since publication

Amd. No.	Date	Text affected
----------	------	---------------

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 62137-3

January 2012

ICS 31.190

English version

**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)

This European Standard was approved by CENELEC on 2011-12-13. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

© 2012 CENELEC - All rights of exploitation in any form and by any means reserved worldwide for CENELEC members.

Ref. No. EN 62137-3:2012 E

 **Documents**
Document Sharing Hub

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

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.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
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

1	Scope	7
2	Normative references	7
3	Terms and definitions	7
4	General remarks	9
5	Procedure of selecting the applicable test method	10
5.1	Stress to solder joints in the field and test methods	10
5.2	Selection of test methods based on the shapes and terminations/leads of electronic devices	12
5.2.1	Surface mount devices	12
5.2.2	Lead insertion type device	13
6	Common subjects in each test method	14
6.1	Mounting device and materials used	14
6.2	Soldering condition	15
6.2.1	General	15
6.2.2	Reflow soldering	15
6.2.3	Wave soldering	17
6.3	Accelerated stress conditioning	18
6.3.1	Rapid temperature change (applies to all solder alloys in this document)	18
6.3.2	Dry heat (applies to Bi58Sn42 alloy solder only)	19
6.3.3	Damp heat (steady state) (applies to Sn91Zn9 and Sn89Zn8Bi3 alloy solder)	19
6.4	Selection of test conditions and judgement of test results	19
7	Evaluation test method	19
7.1	Solder joint strength test of SMD	19
7.1.1	General	19
7.1.2	Pull strength test	19
7.1.3	Shear strength test	20
7.1.4	Torque shear strength test	21
7.1.5	Monotonic bending strength test	21
7.2	Cyclic bending strength test	22
7.3	Mechanical shear fatigue test	23
7.4	Cyclic drop test and cyclic steel ball drop strength test	24
7.4.1	Overview	24
7.4.2	Cyclic steel ball drop strength test	25
7.5	Solder joint strength test for lead insertion type device	26
7.5.1	Pull strength test for insertion type device	26
7.5.2	Creep strength test for lead insertion type device	26
Annex A (informative)	Condition of rapid temperature change	28
Annex B (informative)	Electrical continuity test for solder joint	30
Annex C (informative)	Torque shear strength test	31
Annex D (informative)	Monotonic bending strength test	34
Annex E (informative)	Cyclic steel ball drop strength test	36
Annex F (informative)	Pull strength test	38
Annex G (informative)	Creep strength test	39

Annex H (informative) Evaluation method for the fillet lifting phenomenon of a lead insertion type device solder joint.....	41
Bibliography.....	43
Figure 1 – Joint regions for the reliability tests.....	9
Figure 2 – Factors affecting the joint reliability made by lead-free solder	10
Figure 3 – An example of the mounting position of SMD for monotonic bending and cyclic bending tests	15
Figure 4 – An example of reflow soldering temperature profile (Sn96,5Ag3Cu,5)	16
Figure 5 – Examples of reflow soldering temperature profile other than Sn96,5Ag3Cu,5	16
Figure 6 – An example of wave soldering temperature profile (Sn96,5Ag3Cu,5).....	17
Figure 7 – An example of wave soldering temperature profile	18
Figure 8 – Pull strength test.....	20
Figure 9 – Shear strength test.....	20
Figure 10 – Torque shear strength test	21
Figure 11 – Monotonic bending strength test.....	21
Figure 12 – Cyclic bending strength test	22
Figure 13 – Structure of cyclic bending strength test.....	23
Figure 14 – Schematic diagram of mechanical shear fatigue for solder joint.....	24
Figure 15 – Cyclic drop test	25
Figure 16 – Cyclic steel ball drop test	25
Figure 17 – Pull strength test.....	26
Figure 18 – Creep strength test	27
Figure A.1 – Stress relation curve for a given strain to a solder joint (Sn96,5Ag3Cu,5)	28
Figure A.2 – Time to reach steady state in the temperature cycle chamber	29
Figure B.1 – Example of the test circuit for an electrical continuity test of a solder joint	30
Figure C.1 – Fixing of substrate for torque shear strength test	32
Figure C.2 – Torque shear strength test jig and position adjustment	33
Figure C.3 – Torque shear strength test for a connector	33
Figure D.1 – Example of a board bending jig.....	34
Figure E.1 – Cyclic steel ball drop test.....	37
Figure E.2 – Comparison of cyclic drop test and cyclic steel ball drop test.....	37
Figure F.1 – Pull strength test.....	38
Figure G.1 – Creep strength test.....	39
Figure H.1 – Fillet lifting phenomenon of solder joint.....	41
Figure H.2 – Example of an electrical continuity test circuit for a lead insertion type device solder joint.....	42
Table 1 – Correlations between test methods and actual stresses in the field	11
Table 2 – Recommended test methods suitable for specific shapes and terminations/leads of SMDs	12
Table 3 – Recommended test methods suitable for application and mass of the lead insertion type device	13
Table 4 – Solder alloy composition	

Table 5 – Diameters of through holes and lands in respect to the nominal cross section and nominal diameter of lead wire	15
Table 6 – Temperature condition for rapid temperature change.....	18

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

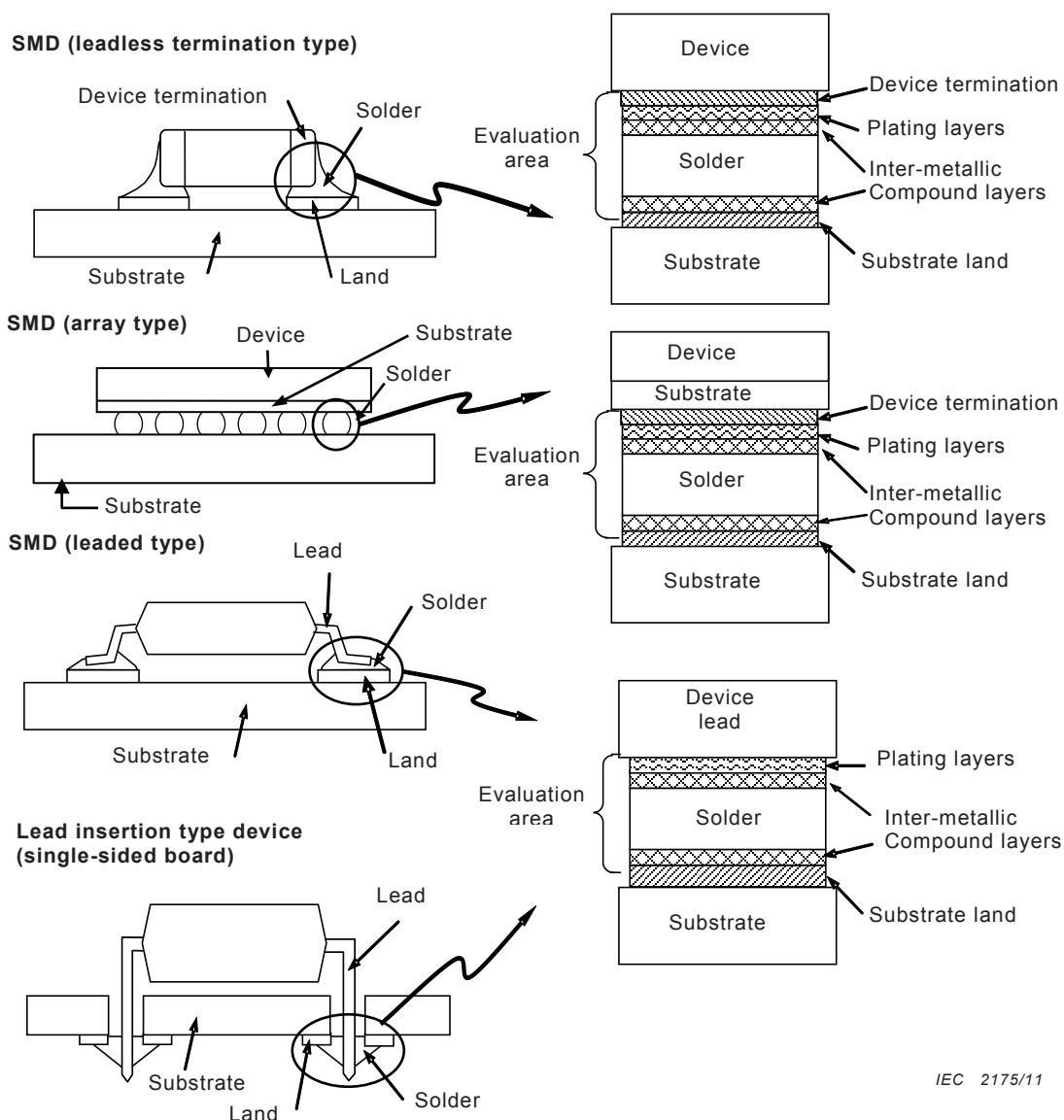
all chains of solder joint connections that are connected in series, see Clause B.2

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

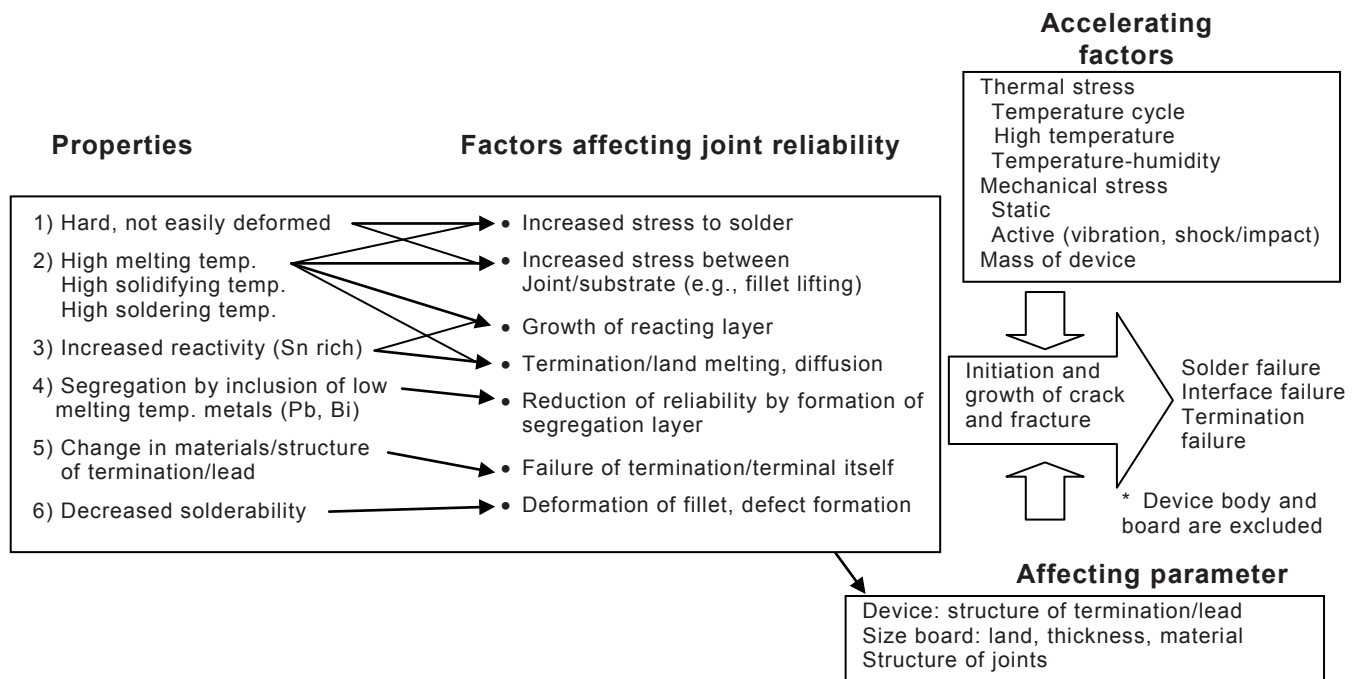
Figure 1 – Joint regions for the reliability tests

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