IEC 60068-3-13

Edition 1.0 2016-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Environmental testing –
Part 3-13: Supporting documentation and guidance on Test T – Soldering

Essais d'environnement –
Partie 3-13: Documentation d'accompagnement et guide sur les essais T – Brasage

IEC 60068-3-13:2016-05(en-fr)

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FOREWORD

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International Standard IEC 60068-3-13 has been prepared by IEC technical committee 91: Electronics assembly technology.

This first edition cancels and replaces IEC 60068-2-44:1995 and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- information for lead-free solders are added;
- technical update and restructuring.

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

FDIS	Report on voting
91/1345/FDIS	91/1356/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 in the IEC 60068 series, published under the general title *Environmental testing*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

ENVIRONMENTAL TESTING –

Part 3-13: Supporting documentation and guidance on Test T – Soldering

1 Scope

This part of IEC 60068 provides background information and guidance for writers and users of specifications for electric and electronic components, containing references to the test standards IEC 60068-2-20, IEC 60068-2-58, IEC 60068-2-69, IEC 60068-2-83, and to IEC 61760-1, which defines requirements to the specification of surface mounting components.

2 Normative references

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.

IEC 60068-2-20:2008, *Environmental testing – Part 2: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices with leads*

IEC 60068-2-58, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60068-2-69, *Environmental testing – Part 2-69: Tests – Test Te: Solderability testing of electronic components for surface mounting devices (SMD) by the wetting balance method*[1]

IEC 60068-2-83, *Environmental testing – Part 2-83: Tests – Test Tf: Solderability testing of electronic components for surface mounting devices (SMD) by the wetting balance method using solder paste*

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

IEC 62137-3, *Electronics assembly technology – Part 3: Selection guidance of environmental and endurance test methods for solder joints*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document the following terms and definitions apply.

3.1.1
solderability
ability of the lead, termination or electrode of a component to be wetted by solder at the temperature of the termination or electrode, which is assumed to be the lowest temperature in the soldering process within the applicable temperature range of the solder alloy

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[1] A new edition (third edition) is currently under consideration.

Note 1 to entry: The term “solderability” is often used in combination with the term “test”, indicating a specific method to evaluate the wettability or ability to be soldered of a surface under worst case conditions (soldering temperature and contact time with solder). It is not to be confused with the concepts “ability to be soldered” (see 4.1, 5.1.1) or “soldering ability” (see 3.1.4).

3.1.2

resistance to soldering heat

ability of the component to withstand the highest temperature stress in terms of temperature gradient, peak temperature and duration of the soldering process, where the temperature of the component body is within the applicable temperature range of solder alloy

3.1.3

wettability

intrinsic property of the termination material to form an alloy with the solder

Note 1 to entry: Wettability depends on the base metal used to produce the termination or, in the case of a plated termination, the condition and material used to plate the base metal.

3.1.4

soldering ability

ability of a specific combination of components to facilitate the formation of a proper solder joint

Note 1 to entry: See 3.1.3, wettability.

3.2 Abbreviations

SMD	Surface mounted device
SMT	Surface mounting technology
THD	Through-hole mounting device
THT	Through-hole mounting technology
THR	Through-hole reflow soldering

4 Overview

4.1 Factors influencing the formation and reliability of solder joints (ability to be soldered)

The conditions of ease of production and the reliability of a soldered joint can be classified in three groups, as follows.

a) The joint design, determined by the choice of the two metallic elements to be joined (their shape, size, composition, etc.) and of the assembly method (relative position, initial fastening, etc.).

b) The wettability of the surfaces to be joined.

c) The conditions adopted for the soldering operation (temperature, time, flux, solder alloy, equipment, etc.).

The choice of conditions of groups a) and c) concerns the manufacturer of equipment or subassemblies, who shall know the importance of each of the conditions and the limits of their variation. Condition b) depends to a large extent on the component manufacturer, except in cases of unusual handling or storage conditions by the equipment manufacturer. The wettability of surfaces needs to be defined with whatever degree of precision is necessary to allow the equipment manufacturer to choose conditions of classes a) and c) appropriate to that wettability. On the other hand, components of satisfactory surface quality will not necessarily prevent rejectable joints arising from faults in joint design or joining conditions.

This often complex overlapping of responsibilities between component manufacturers and equipment manufacturers creates a need to be able to define with considerable precision the wettability of component terminations or, more generally, the solderability of components.

4.2 Physics of surface wetting

In order to obtain wetting between a substrate and molten solder, the tin in the solder shall react with the substrate to form an alloy. In order to form an alloy the tin and the substrate has to come into molecular contact. In order to do this the surface of both the molten solder and the substrate shall be free from contamination.

In order to better understand how molten solder spreads over a substrate, and what determines solderability, the surface tension property of the solder needs to be examined.

A free droplet of molten solder held in free space will form into a globule shape, just as a free drop of water will form into a spherical shape. The droplet is held in this shape by the surface tension force of the molten solder. Inside the droplet the atoms are uniformly surrounded by other atoms, and the net force on them is zero, ignoring thermal motion. At the surface there is an imbalance in the inter-atomic attraction forces, as the surface atoms experience a net force into the body of the droplet.

The complete system tries to adopt a shape that has the minimum free energy, which means the minimum surface-to-volume ratio. This situation is achieved when the molten solder forms into a sphere. The strength of the surface tension force is determined by the bond energies between the atoms within the molten solder.

If the molten sphere of solder is placed onto a heated, oxidised copper plate, the shape of the sphere is depressed by gravity, to form a sessile drop, as shown in Figure 1 below.

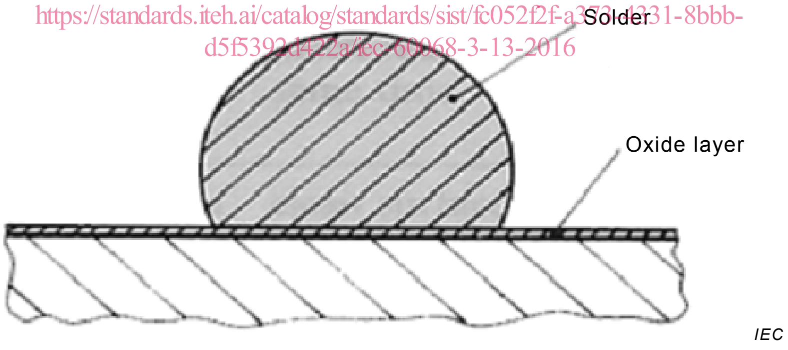

Figure 1 – Sessile drop of solder on oxidised copper

If a suitable flux is added to the sessile drop on the oxidised copper, the oxide layer will be removed from the copper and the solder, and the tin in the solder will react with the copper to form an intermetallic layer, allowing the solder to spread, as shown in Figure 2 below.

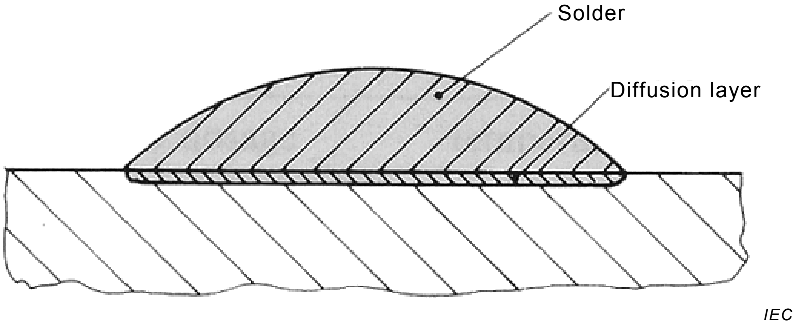

Figure 2 – Sessile drop of solder plus flux on clean copper

The final shape of the spreading solder will depend on the surface tension forces acting at the interfaces. Solid and solid-liquid interfaces also exert a surface tension force, and all try to reduce their surface areas to a minimum to attain a minimum free energy. As a result equilibrium is reached whereby the net force at the advancing solder front is zero.

Figure 3 below shows the forces acting at the advancing solder front. The surface tension of the solid copper in air is balanced by the surface tension between the liquid solder and the air, and the liquid solder and the solid copper.

Figure 3 – Sessile drop equilibrium forces

The resulting forces at the advancing solder front can be written as follows:

$$\gamma_{SA} = \gamma_{LS} + \gamma_{LA} \cos \theta$$

where

γ_{SA} is surface tension between solid copper and air;

γ_{LS} is surface tension between liquid solder and solid copper;

γ_{LA} is surface tension between liquid solder and air.

This equation is known as Young's equation. The contact angle θ can be used as a measure of the degree of spreading obtained. The smaller the contact angle, the greater the spreading, and the better the wetting obtained.

If the cohesive forces within the solder are greater than the adhesive forces between the solder and the copper, then the solder will remain as a non-spreading sessile drop, and the contact angle will be greater than 90°. If the adhesive forces exceed the cohesive forces, then it is energetically favourable for the solder to react with the copper and spread outward, reducing the contact angle below 90°.

The surface tension between solid and air, γ_{SA}, will be high when the solid is free from oxides, sulphides, chlorides, hydrocarbons and other surface contaminants, which will all reduce the surface tension.

For the surface tension between liquid and solid, γ_{LS}, to be low, a metallurgical bond has to be formed between the tin and the substrate.

The surface tension between liquid solder and air, or flux film, will depend on the solder alloy, the soldering temperature and the flux used to solder the parts. The surface tension of the alloy can be markedly affected by the impurities in the solder. Very small levels of impurity can have a large effect on the surface tension. This is because the surface tension of a liquid is determined by the surface composition of the solder and not the composition of the bulk of the solder. Impurities with low surface energies will rapidly segregate to the surface of the liquid, reducing the surface tension, γ_{LA}.

Impurities in the solder alloy, and changes to the alloy composition may also affect the surface tension between the liquid and the solid, altering the intermetallic formation, and can also affect the surface tension between the solid and the air, affecting the diffusion process across the solid, ahead of the liquid front.

Alloy additions or impurities may also affect the spreading and wetting properties of an alloy, by altering the viscosity of the liquid solder.

4.3 Quality and reliability of solder joints

The quality of solder joints is characterised by wetted area, wetting angle, microstructure and specific visual criteria.

One factor affecting the reliability of electronic assemblies is solder joint microstructure, which in turn depends on the thermal conditions under which the solder joint solidifies. Both the bulk microstructure of the solder and the intermetallic layer structure at the interfaces between solder and component termination should be taken into consideration.

IEC 62137-3 gives guidance to test methods for the evaluation of solder joint reliability under consideration of the above described four elements.

5 Component soldering – Processes

5.1 General considerations

5.1.1 Components' ability to be soldered

Because of the large variety of processing conditions a component can no longer simply be classified as suitable e.g. for “flow soldering” or “reflow soldering”, or “lead-free soldering”. Specific attention should be given to the fact, that the suitability of a component for “lead-free soldering” cannot be stated because of the variety of lead-free solder alloys and processing conditions. Typical soldering processes and related process conditions are described in IEC 61760-1.

To be suitable for a certain soldering process a component shall fulfil the following requirements:

a) material and surface of the component termination shall be suitable to be soldered with the solder alloy and soldering method;

b) it shall possess thermal characteristics (thermal demand) small enough for a temperature sufficiently higher than the liquidus of the solder alloy used, to be reached and maintained for the length of time for wetting to occur;

c) it shall withstand without short-term or long-term change the thermal stresses associated with the soldering cycle (including rework and possible repair by soldering iron);

d) it shall withstand without short-term or long-term damage the mechanical and chemical stresses accompanying cleaning operations for the removal of flux residues. Cleaning considerations are not emphasized in this Guide.

Thus, certain components containing lubricated mechanical parts (e.g. switches), or being unsealed are sensitive to contamination (e.g. relays, potentiometers), or containing plastic material with poor heat resistance (e.g. certain capacitors with thermoplastic dielectric), shall be carefully selected for mass-soldering operations because of their inability to withstand one or more of the stresses associated with the process.

For these reasons careful distinction shall be made between the processability (ability to be soldered) of the component, which refers to the total suitability for industrial soldering, and the wettability of the termination, which refers only to the ease of coating the termination with solder. Unfortunately, these concepts are often confused in ordinary language, and such confusion can prevent smooth running of production.

Furthermore, unsuitability of a component for soldering under the general conditions specified (see below) does not mean that its terminations cannot be soldered to a printed circuit board or other support. It entails only that it is necessary to take special precautions depending on the condition it does not satisfy, such as having thermally sensitive insulation, or incompatibility with some or all solvents. Only defective wettability of the terminations prevents the use of soldering for mounting the component. This quality is of prime importance, but does not exclude consideration of the others.

The standardised tests referred to here are all directed to simulating some part of the effects of this set of conditions.

The appropriate choice of a group of these tests, in conjunction with electrical and mechanical measurements, allows to answer the question: "Is this component solderable by the methods normally used in electronics?" This is one of the questions which the equipment manufacturer shall consider before putting a component on a soldering line.

The principle of each standardised test and the degree of information it supplies are defined in Clause 7.

In this way the component specifier can, in full knowledge of the reasons, select the number and type of tests needed to establish the behaviour of the component during soldering, as well as the requirements that shall be determined in every case to reflect the general requirements of the method of manufacture.

Similarly, the person conducting the tests will appreciate the degree of information given.

5.1.2 Soldering processes

Figure 4 shows typical soldering processes grouped into types.

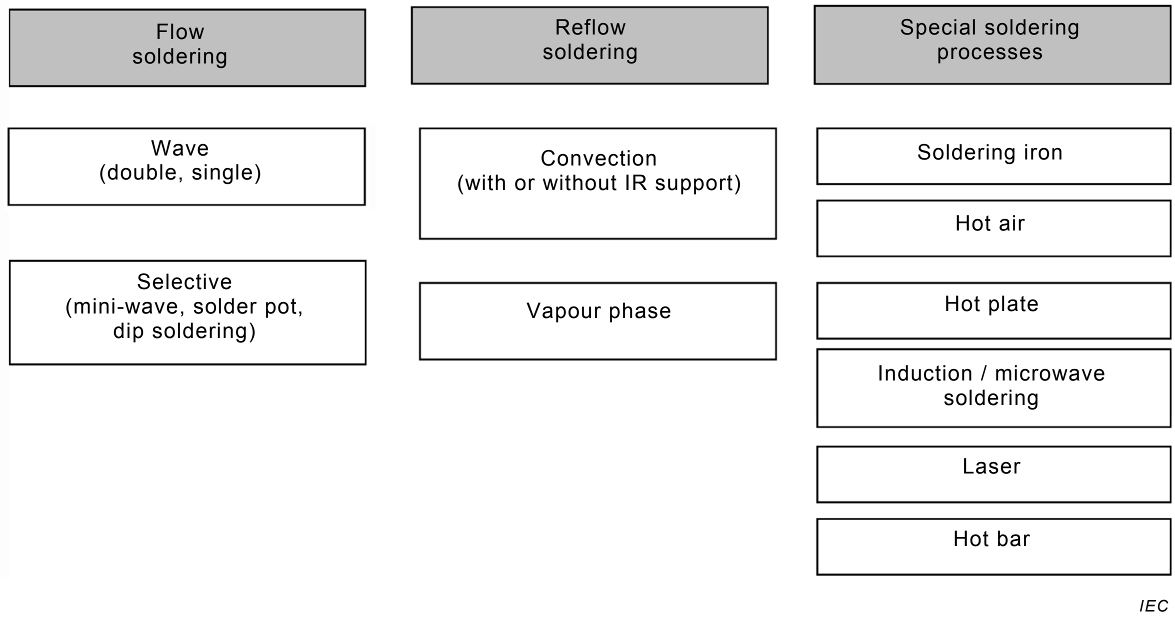

Figure 4 – Typical soldering processes

5.1.3 Soldering defects

The series IEC 61191 and IEC 61192 provide information about requirements for soldered electrical and electronic assemblies and related workmanship standards.

- Non wetting, dewetting
- Tombstoning
- Shifting
- Wicking
- Bridging

5.1.4 Geometrical factors which may influence the soldering result

- Land pattern design
- Component geometry
- Component terminal geometry
- Insertion hole diameter
- Annular ring

5.1.5 Process factors

- Time – Temperature profile
- Temperature spread (different temperatures at solder joints)
- Atmosphere (air, nitrogen)

5.1.6 Material factors

- Solder paste, solder alloy
- Flux activity

5.2 Solder

The composition of the solder alloy affects the surface tension of the liquid solder. Relatively small concentrations of impurities in the solder can have a marked effect on the wetting properties of the solder. Thus, the solder alloy used for soldering and for tests shall be described in the relevant specification.

5.3 Grouping of soldering conditions

The melting temperatures of lead free solder alloys selected for industrial processes are significantly different from those of tin lead solder alloy. Moreover, the melting temperatures of present solder alloys are different from each other but can be clustered in groups. The ability of the SMD to withstand the typical temperature and dwell time conditions shall match the exposure to the process temperature groups using the selected alloys.

The following groups of soldering processes in Table 1 are given as a guideline for selecting the severities for the wetting and resistance to soldering heat tests against the specified soldering heat profile.

Table 1 – Solder process groups

Process temperature group	**1 Low**	**2 Medium**	**3 Medium-high**	**4 High**
Typical solder alloy family	Sn-Bi	Sn-Pb	Sn-Ag-Cu	Sn-Cu
Flow	–	(235 to 250)°C	(250 to 260)°C	(250 to 260)°C
Reflow	(170 to 210)°C	(210 to 240)°C	(235 to 250)°C	–

5.4 Ability to be soldered

The ability to be soldered is determined mainly by the following three properties of a component.

- Solderability of components

The determination of solderability can be made at the time of manufacture, at receipt of the components by the user, or just before assembly and soldering.

- Thermal demand

It is necessary to bring the joint area to the soldering temperature. It is possible that the component design will allow the heat being applied to the joint area to be drained away into the component body, causing the temperature at the joint site to fall too low to produce an adequate solder joint. Preheat may be used to overcome thermal demand issues.

- Resistance to soldering heat

The component shall be able to withstand the thermal stress of the soldering process without any loss of functionality. This is particularly important with current assembly methods where components may experience rapidly changing thermal gradients.

The result of this definition is that a matrix of soldering tests standards have evolved, which measure some or all of these three properties individually or in some cases a combination of the first two properties (see 7.2).

5.5 Moisture sensitivity of components

The relevant specification may prescribe a moisture soak procedure to determine the sensitivity of a component against the influence of humidity during storage to the component body.