IEC TR 60068-3-15

Edition 1.0 2024-02

TECHNICAL REPORT

Environmental testing –
Part 3-15: Supporting documentation and guidance – Vacuum-assisted reflow soldering

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

colour inside

IEC TR 60068-3-15:2024-02(en)

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2024 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

IEC TR 60068-3-15

Edition 1.0 2024-02

TECHNICAL REPORT

colour inside

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

Environmental testing –
Part 3-15: Supporting documentation and guidance – Vacuum-assisted reflow soldering

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 19.040; 31.190

ISBN 978-2-8322-8169-7

Warning! Make sure that you obtained this publication from an authorized distributor.

® Registered trademark of the International Electrotechnical Commission

CONTENTS

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

ENVIRONMENTAL TESTING –

Part 3-15: Supporting documentation and guidance – Vacuum-assisted reflow soldering

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

IEC TR 60068-3-15 has been prepared by technical committee 91: Electronics assembly technology. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
91/1916/DTR	91/1930/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

INTRODUCTION

As defined in ISO 857-2, reflow soldering is a joining process using an additional metal (solder) with a liquidus temperature of 450 °C or less, in which solder paste or preforms are reflowed.

Reflow soldering can be carried out with the technical processes of convection (air or nitrogen), condensation (vapour phase), radiation (e.g. infrared) or contact heat.

Sometimes it is not possible to achieve the required void level for an assembly only with methods listed above despite the use of all technical possibilities.

Regarding void-induced asymmetrical stress constellations, a reduction of voiding can lead to a mitigated stress condition within the solder joints.

Various technical requirements only tolerate very small void dimensions. To achieve these requirements, vacuum-assisted soldering can be applied with the above mentioned reflow soldering processes.

In some product applications, a hermetic seal is required. The reliable fulfilment of this requirement is very demanding to the process technology especially complex assemblies. Vacuum-assisted soldering creates significantly more consistency in the results here.

Further benefits of vacuum-assisted soldering are improved thermal management or high frequency performance (contour adaptation, mitigation of blow holes).

Vacuum-assisted soldering, however, requires a different equipment with more complex structure and process control. Since the vacuum process has an impact on the process time, the suitability of the components and solder paste that are used need to be checked.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

ENVIRONMENTAL TESTING –

Part 3-15: Supporting documentation and guidance – Vacuum-assisted reflow soldering

1 Scope

This part of IEC 60068 describes vacuum-assisted soldering considering the thermal profiling, soldering methods, suitability of the components and vacuum features of soldering systems. It is based on practical experiences from manufacturers, component, material, and soldering systems suppliers. It supports manufacturers by providing information about the functionality of vacuum and effect of vacuum on components performance.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

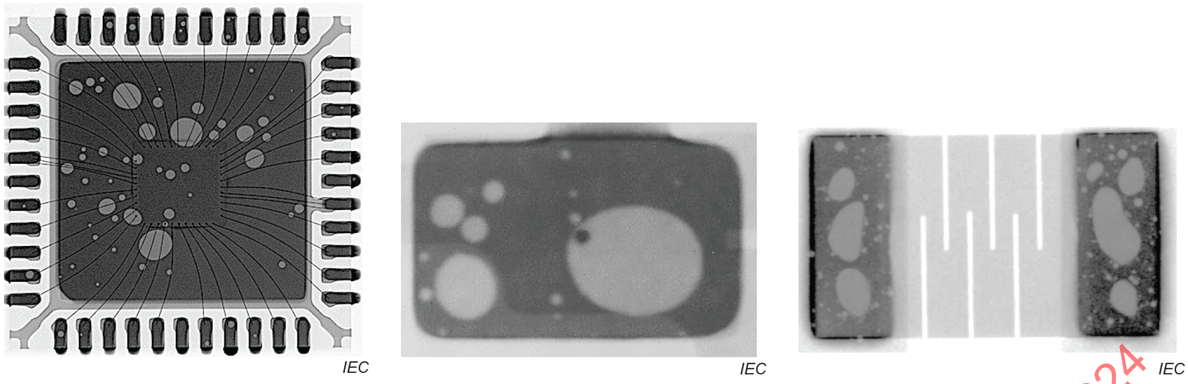
4 Voids in solder joints

4.1 Type of voids

After soldering, many different macro and micro disturbances of the solder structure can be detected in the solder joints with e.g. X-Ray inspection, ultrasonic inspection or cross sectioning. Some of them represent the so-called voids which are divided according to their causes and type.

The definitions and classification of different void types can be found for example in IPC-7095, IPC-7093 or IEC TR 61191-8. This document describes the use of vacuum to prevent so-called macro voids. Figure 1 shows examples of macro voids in solder joints of different component types.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024



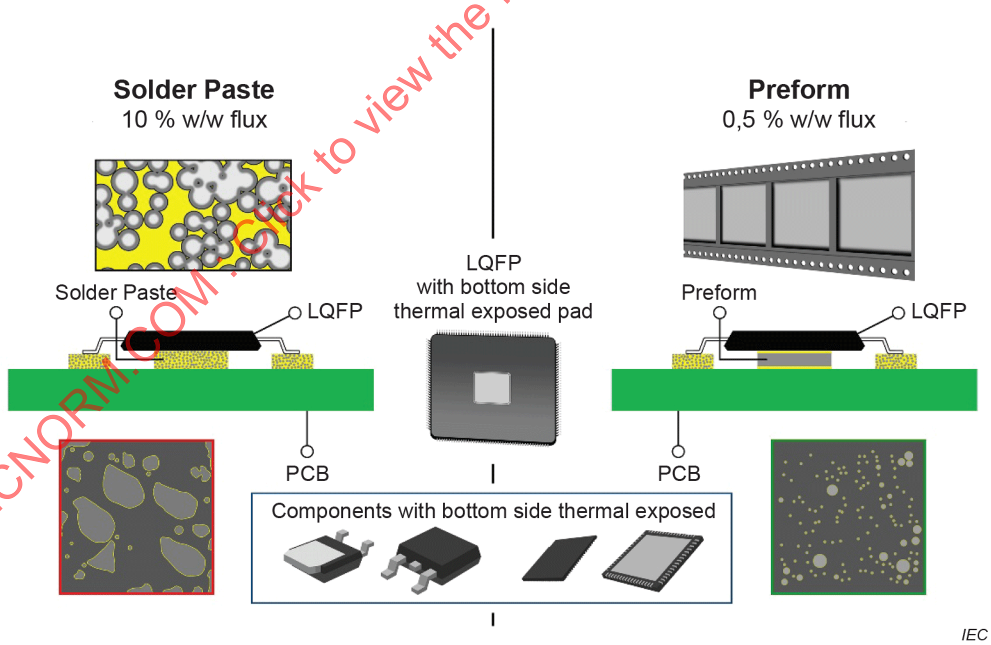
QFN **Power LED** **Power Resistor**

Reproduced with permission by Rehm Thermal Systems GmbH

Figure 1 – X-Ray examples of voids in solder joints in different SMD-Components

4.2 Reasons for voids

The research results to date lead to the essential finding that the mechanisms of void formation depend on many factors. When soldering with conventional solder pastes, the main factor is the use of flux. After remelting of the solder alloy, flux residues are trapped on the surfaces of the circuit board (PCB) and the soldered components. At high temperatures, these evaporate, and the products of these outgassing are trapped in the solder joint volume in the form of gas bubbles, i.e., voids. With a reduction of the flux amount, the proportion of voids can be reduced, as shown in the example in Figure 2.



Reproduced with permission by Indium Corporation of Europe

Figure 2 – Reduction of voids with low flux soldering & preforms

In addition, the void formation is influenced by the interaction of solder paste, quality and type of surface finish (PCB and component) and geometry of the solder joint. As a rule, void ratios in the range of 20 % to 50 % can occur by soldering under normal pressure / condition. Depending on the application and the required minimum void ratio, with vacuum-assisted soldering void ratios below 10 % can be realized.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

4.3 Influence of voiding on solder joint performance

A solder joint has several functions on an assembly: electrical contact, mechanical fixation and thermal connection. These functions are classified here into two areas: mechanical integrity and thermal performance. Macrovoids in solder joints can have a negative impact on both areas. More information can be found in IPC-A-610, IPC-7095, IPC-7093, IEC TR 61191-8.

5 Vacuum-assisted soldering processes

5.1 Purpose

Vacuum has been used for many years in reflow soldering technology as an additional process step. Depending on the combination of soldering method with vacuum, the void content in solder joints of different products can be reduced.

In vacuum-assisted soldering, the pressure-time profile is recorded in addition to the temperature profile.

The parameters of vacuum profiling are:

a) The vacuum steps and the vacuum level (the reached minimum pressure), pressure in Pascal (Pa) referred to zero;
b) the frequency of vacuum use and the holding time of the specified vacuum level in seconds (s)

While in convection soldering with vacuum, the vacuum is applied above the liquidus temperature of the solder, in vapour phase and conduction soldering with vacuum the vacuum can be applied at any time of the process. Figure 4, Figure 5 and Figure 6 demonstrates examples of temperature-pressure time profiles for vacuum-assisted convection, condensation and conduction soldering. The so-called pre-vacuum can be used to change atmospheric gases, dry assemblies or even pastes.

To reduce voids, the vacuum is applied in all reflow soldering processes above the liquidus temperature of the solder. Since the application of vacuum requires additional time, the time above liquidus is extended. For the time above liquidus, however, the specifications given by common norms and standards must be complied with.

In general, the requirements and limitations of the temperature-time envelope curve apply to the profiles of vacuum-assisted soldering processes as well. More information can be found in IEC TR 60068-3-12. This applies in particular to the time above liquidus.

The cycle time of the complete soldering process depends on the vacuum level and the holding time of vacuum. Usually, the cycle time will be increased by addition of a vacuum step due to speed limitations of vacuum chamber for the opening and closing as well as for the evacuation and venting procedures.

5.2 Combination of soldering process with vacuum

All reflow soldering technologies, such as convection, condensation (vapour phase) and conductive (contact heat) processes are currently available on the market with additional vacuum technology.

Depending on the technology used, the vacuum process can be used before and during the preheating process as well as during the soldering process, in the molten phase of the solder joint. Table 1 contains different vacuum-assisted soldering processes and typical parameters. In Figure 3 an example of a product for the different vacuum-assisted soldering processes is shown.

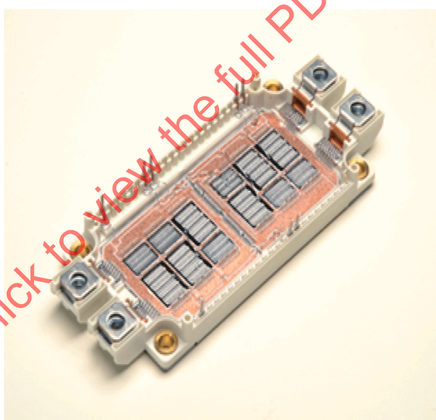
IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

Table 1 – Combination of soldering processes with vacuum

Soldering process	Typical application of vacuum	Frequency of use	Vacuum level [hPa]	Holding time [s]*	Minimum additional time above liquidus for applying of vacuum [s]**	Examples of products
Convection	Above liquidus	Continuously	10 to 100	0 to 60	> 14	Power electronics, lightning
Condensation	At all temperatures	Multiple times	10 to 100	0 to 60	> 9	High thermal masses, maximum temperature limitation
Contact heat	At all temperatures	Continuously, multiple times	0,2 to 150	0 to 360	> 9	Module in power electronics, Die-Attach

* At minimum vacuum level

** To reduce the void formation, a vacuum is applied at a temperature above the liquidus of the solder alloy. In order to generate a reliable solder joint, the time above liquidus needs to be considered. The application of the vacuum needs additional time above the liquidus temperature of solder alloy. This time consist of times for transportation of the assembly into the vacuum chamber, closing the chamber, evacuation down to the vacuum level, vacuum holding time and venting of the chamber.



IEC

Reproduced with permission by Semikron-Danfoss.

Figure 3 – Example of a product for vacuum-assisted soldering processes

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

5.3 Typical temperature-pressure-time curves

5.3.1 Convection soldering with vacuum

In a convection soldering system, the vacuum chamber is usually situated after or is a part of the peak zones.

Figure 4 shows the example of a temperature-pressure-time curve of a vacuum-assisted convection soldering process.

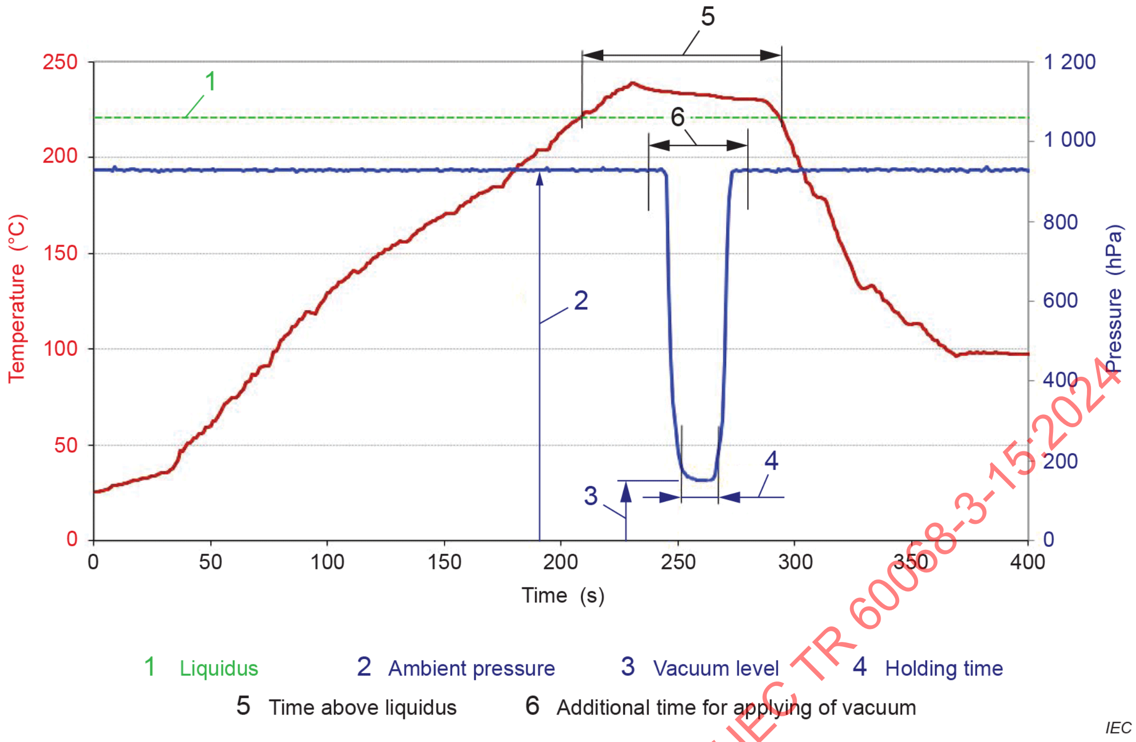


Figure 4 – Typical profile – vacuum-assisted convection soldering

5.3.2 Vapour phase soldering with vacuum

In this process, the vacuum can be applied selectively before (solder is solid), during (solder is liquid) and after the peak zone of the reflow soldering process. For a vapour soldering process, a vapor phase (VP[1]) medium is used as a heat transfer medium.

Purpose of vacuum:

a) before liquidus
   - drying of the solder paste
   - reaching an airless inert environment
   - VP injection into the vacuum
b) during liquidus
   - influencing the peak temperature
   - removing of pores/voids
c) after liquidus
   - removing/evaporation of VP medium

Figure 5 shows the example of a temperature-pressure-time curve of a vacuum-assisted vapour phase soldering process.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

1 Mostly applied are Perfluoropolyethers (PFPE). The following trade names are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of these products: Galden®.

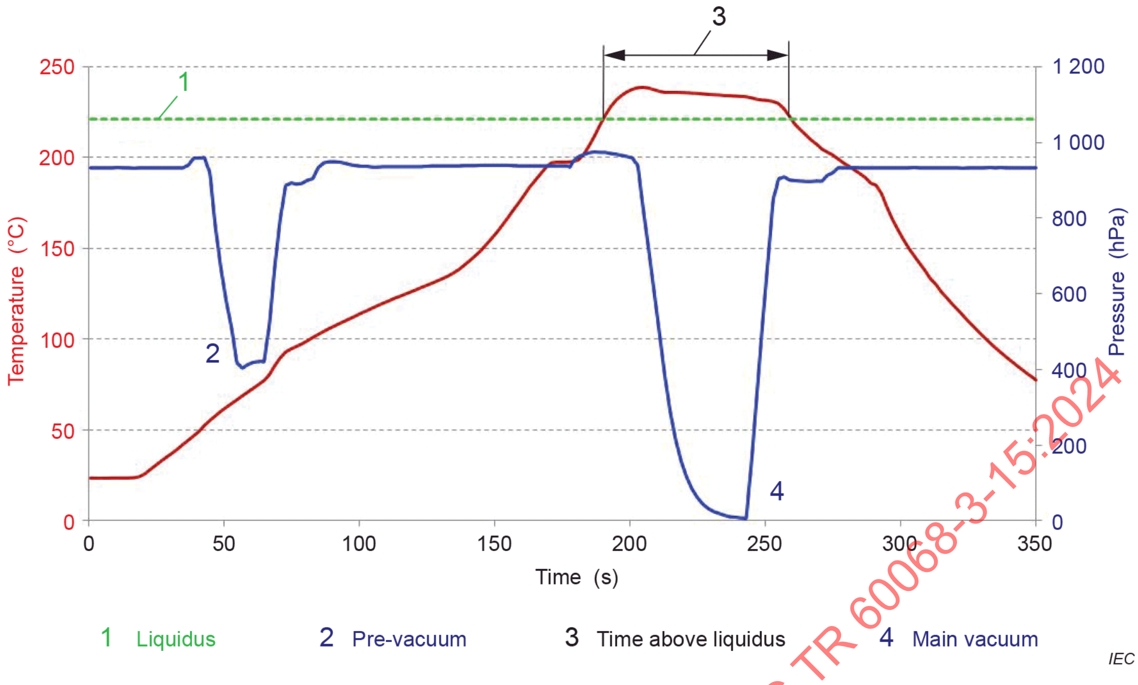


Figure 5 – Typical profile – vacuum-assisted vapour phase soldering

5.3.3 Contact soldering with vacuum

In this process, the vacuum can be applied selectively before, during and after the peak zone of the reflow soldering process.

Purpose of vacuum:

a) before liquidus (Step 7 in Figure 6)
   – gas exchange after evacuation
   – reduction of the amount of oxygen that can interact with the metals of the solder joint

b) during liquidus (Step 8 in Figure 6)
   – influencing the breaking up of films on the surface of the molten solder metal
   – influencing the wetting behaviour
   – removing of pores/voids

Figure 6 shows the example of a temperature-pressure-time curve of a vacuum-assisted conductive soldering process.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

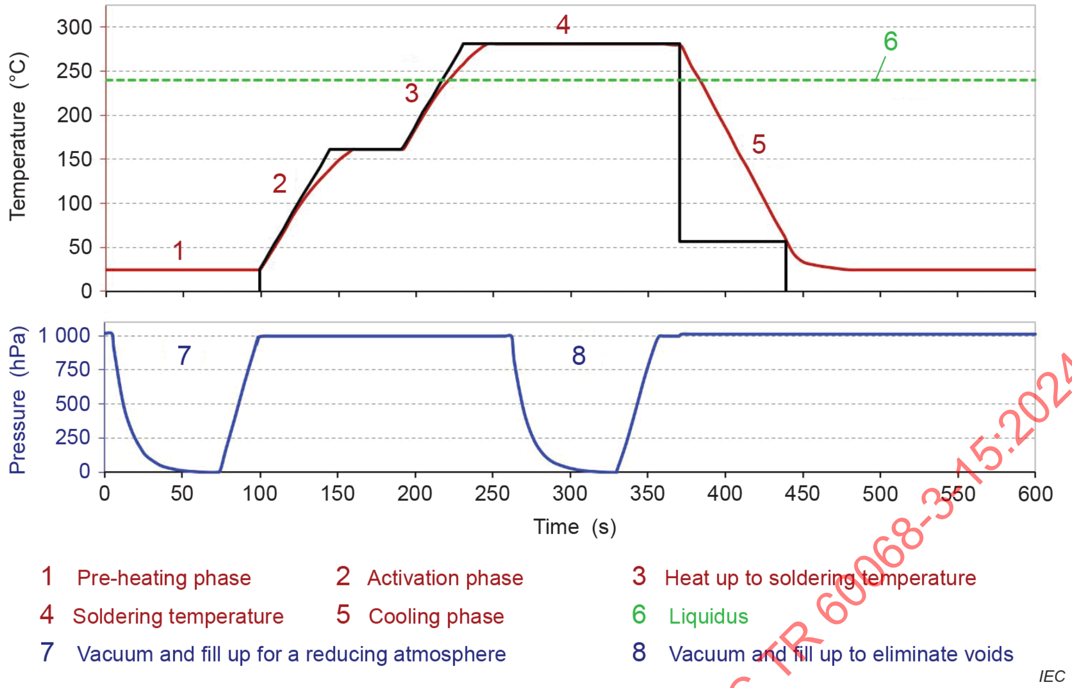


Figure 6 – Typical profile – vacuum-assisted contact soldering

6 Effect of vacuum when reflow soldering

6.1 General

6.1.1 General description

Vacuum is an additional universal parameter in reflow soldering and results in an increase of the mechanical and thermal load for the assembly. This Clause 6 considers essential physical aspects that are relevant as well for the materials (components, circuit board, solder paste) as for the final realized solder joints.

6.1.2 Physical basics

As a general rule, gases which are in the pure gas phase and whose molecules can move freely through the volume available to them (e.g. the vacuum process chamber) are considered as ideal gases. This includes gaseous nitrogen and oxygen, which are the most commonly used gases in reflow soldering. Under these conditions, the ideal gas equation applies:

$$p \cdot V = n \cdot R \cdot T$$

$$p \cdot V = \frac{m}{M} \cdot R \cdot T$$

where

p is the pressure in Pa;

V is the volume in m^3;

n is the substance amount in mol;

m is the mass in kg;

M is the molar mass in kg/Mol;

R is the universal gas constant: 8,314 J/(mol K);

T the temperature in K.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

For V is constant:

$$\frac{p_1}{p_2}=\frac{T_1}{T_2}$$

In reflow soldering systems, it can be assumed that the volume of the process chamber is invariable and thus constant.

There is therefore a direct relationship between the pressure and the temperature of the gas. At room temperature (T = 20 °C corresponds to T = 293 K), there will be approximately 1 000 hPa pressure in the process chamber of a reflow soldering system under normal conditions (no vacuum), i.e. atmospheric pressure. If the temperature is increased by about twice this amount, e.g. to 523 K (250 °C), the pressure in the process chamber also doubles to 2 000 hPa, as long as it is hermetically sealed.

Particularly for hermetically sealed components located on the assembly to be soldered, this relationship is the most relevant. The temperature increase leads to a pressure increase inside the component and an external vacuum additionally increases the pressure difference between the interior and the external environment of the component by a maximum of 1 000 hPa (1 bar).

6.1.3 Vacuum parameters

In technology, a vacuum is understood to be an empty space (e.g., a process chamber) which is largely characterized by the absence of matter (liquids, steam, gases, plasma). In reflow soldering systems, the vacuum is created by a pump that removes the process gas (e.g., air or nitrogen) from the process chamber. This causes the pressure in the process chamber to drop, creating a vacuum lower than ambient pressure.

The physical unit of pressure is Pascal (Pa); 1 hPa (hectopascal, 10^2 Pa) = 1 mbar (millibar).

The atmospheric normal pressure is defined as 1 013,25 hPa.

In the technical world, the quality of the vacuum is differentiated according to the low-pressure level.

Low vacuum	Ambient pressure (atmospheric pressure) down to 1 hPa
Fine vacuum	1 hPa to 10^{-3} hPa
High vacuum	10^{-3} to 10^{-8} hPa

In vacuum reflow soldering, pressures of less than 1 hPa (1 mbar) are very rarely generated, normally low vacuum range is used. The ambient pressure (atmospheric pressure) usually deviates from the normal pressure, as it depends on the topographical location and weather conditions (low- or high-pressure area). Example: The atmospheric pressure (ambient pressure) in the highest city of El Alto-La Paz in Bolivia (4 000 m) is approximately 700 hPa.

6.1.4 Vapour phase vacuum reflow soldering

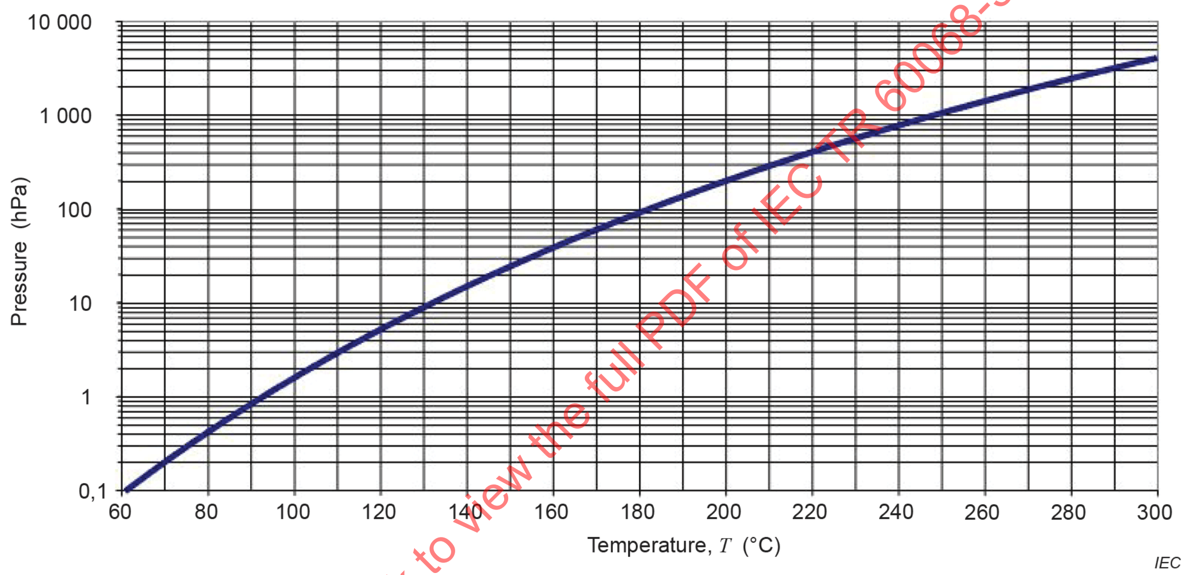
Vapour phase (VP) reflow soldering is generally carried out with a phase change medium. The special feature resulting from this for the vacuum process is that when the vacuum process chamber is evacuated, both VP liquid and VP gas (vapour) are present alongside the medium air or nitrogen (in the gaseous phase).

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

The pressure in the hermetically sealed process chamber p_c therefore depends essentially on the volume of VP liquid introduced. The vapour pressure curve of VP (Figure 7) provides information on the temperature/pressure ratios at which the liquid/solid phase change occurs.

If the process chamber is not filled with 100 % VP gas, then the boiling/condensation point of VP can drop because the partial pressure of VP does not reach normal pressure (1 000 hPa). Two case examples of this:

1) The VP gas only partially displaces the air or nitrogen from the process chamber. Although the process chamber pressure is atmospheric pressure (approximately 1 000 Pa), the partial proportion of VP gas is lower.
2) The VP liquid is introduced into a previously evacuated airless process chamber (e.g. p_c < 10 hPa) and evaporates there. If the liquid volume is not sufficient to fill the process chamber with sufficient VP gas at a given temperature, the resulting pressure in the process chamber cannot reach the atmospheric/normal pressure, p_c < 1 000 hPa.



NOTE Galden is an example of a suitable product commercially available. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of this product.

Figure 7 – Vapour pressure curve of Galden®

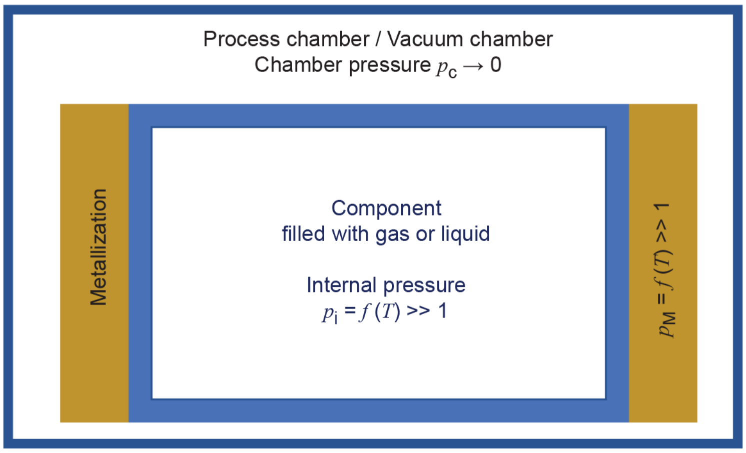
If the vacuum is created following reflow soldering, as is generally the case, the liquid VP on the assembly evaporates as the pressure in the process chamber decreases. The heat required for this is extracted by the medium from the assembly (evaporative cooling). This can be detected in the temperature-time curve of the assembly by a small temperature drop (usually below 5 K).

6.2 Components in the vacuum reflow soldering process

6.2.1 Influence of pressure differences

Figure 8 illustrates the pressures that need to be considered when soldering components with vacuum. For gas-filled hermetically sealed components, at a temperature of 250 °C (reflow soldering temperature) pressures and forces are induced which are of the same order of magnitude as the forces generated by the application of the vacuum. The resulting doubling of forces in case of reflow soldering with vacuum can have an unfavourable effect on the component package and thus on component aging.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024



Key:

p_c Pressure in the hermetical sealed process chamber

p_i Internal pressure in the component package

p_M Pressure, which develops from the gas formation in the metallization

P_A Ambient pressure of the equipment

1 The atmospheric normal pressure is defined as 1013,25 hPa

Figure 8 – Pressures to be considered

In many cases, it cannot be assumed that components are ideally purely gas filled. The internal pressure p_i is then a result of the constituents of the component (e.g., water or electrolyte) which undergo a phase change at reflow soldering temperature. The resulting pressures can be calculated first from the vapour pressure curve, which characterizes the transition from the liquid to the solid phase, then further on with the ideal gas equation. Due to the chemical bonds and concentrations of the substances in the component, it is only possible in practice to estimate how large these pressures (forces) will be with detailed investigations.

The popcorn effect, in which explosively expanding water gas cracks component packages, is generally known. Figure 9 shows the vapour pressure curve of water. At reflow temperature water (humidity) inside the component package can create very high pressure – 20 000 hPa to 50 000 hPa are possible.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

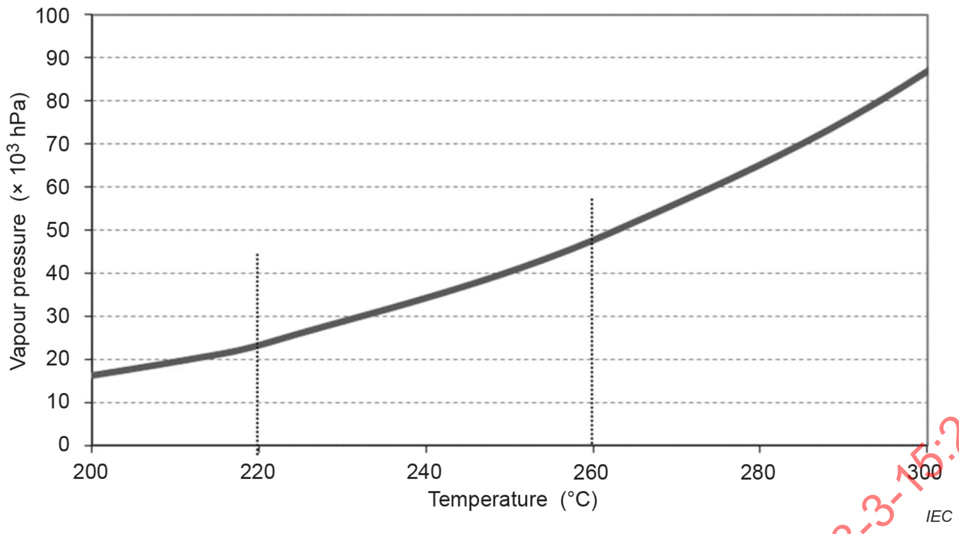


Figure 9 – Vapour pressure curve of water

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

In general, the following applies: The molar mass (mass of 1 mol) of a substance corresponds to the mass of a gas quantity contained in a volume of 22,4 litres at 0°C and approximately 1 000 hPa. For instance, liquid or solid substances in a component can generate large amounts of gas at high temperature. In Table 2 some molar masses are listed comparatively.

In case the molar mass, e.g. of Galden®[2], located in the process chamber is known, it can be used to calculate the maximum pressure p_c that develops. The maximum possible pressure p_i can also be calculated for component packages in this way, provided the substances inside the component that undergo a phase change, e.g. water, are known.

Table 2 – Molar mass

Substance, Element or Molecule	**Molar mass** [g/mol]	**Gas volume created by 100 g of the substance** [litres] [a]
Nitrogen (N_2)	28	159,9
Air	28,96	77,3
Galden®[b] HS240	1 500,00	1,5
Water	18,01	124,4

[a] under standard condition

[b] Galden is an example of a suitable product commercially available. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of this product.

In addition to the material structure of the package, the metallization can also be affected by outgassing, which develops during the phase change of deliberately and incorrectly added organic ingredients. Generally known defects are the so-called blow hole voids (see Figure 10). When the capillary pressure of a void inflates it to such an extent that it reaches the top or interface of the metallization, a blow hole void occurs. The vacuum of the reflow soldering system process chamber increases the differential pressure ($p_M - p_c$) by 1 000 hPa.

2 Galden is an example of a suitable product commercially available. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of this product.

Due to the wide variety of substances that make up a component, which can change from solid to liquid to gaseous over the applied soldering temperature range, it is difficult to derive a prediction for possible vapour pressures. As a general rule, however, it can be said that because of the fairly high difference between temperatures during component manufacture and the soldering temperatures, pressures higher than normal pressure will certainly be built up by the chemicals used. But the height can hardly be estimated mathematically.

6.2.2 Influence of temperature, time, and vacuum

The influence of temperature, time and vacuum needs to be considered when assessing, whether components can be soldered with a specific profile without negative impact to performance and reliability. Besides the mechanical impact of pressure differences, the effect of enhanced time above liquidus can potentially lead to increased thermal ageing of the assembly and components. Thus, this effect should be studied thoroughly especially for new or unknown parts or materials.

The following are key factors and related effects:

a) Sealed components

Time:	Heat input increases
Temperature:	Pressure inside the package increases, depending on the inner material (partial pressure)
Vacuum:	Pressure difference between package and surrounding increases by 1 bar.

b) Moisture sensitive components

Time:	Heat input increases
Temperature:	Moisture (water) becomes gaseous, partial pressure inside the package increases
Vacuum:	Pressure difference between package and surrounding increases by 1 bar, outgassing is accelerated.

In general, components are not qualified according to their ability to be soldered with a vacuum assisted reflow soldering process. Users of components need to check the component specification regarding

– the maximum permissible time-temperature profile and,

– in case of moisture sensitive components, the moisture sensitivity level (MSL) classification profile.

Neither a non-specified MSL nor a specific MSL (e.g. MSL1) is an indicator, whether a component can be soldered with a specific vacuum assisted reflow profile and is not related to the pressure conditions in the process chamber.

Component users can therefore only assess the suitability of components to be soldered with their specific process by performing the required tests.

7 Vacuum equipment restrictions

7.1 General

For the use of vacuum, the system requires a hermetic chamber. For this reason, vacuum-assisted soldering can only be realized as a batch process. Due to this technology, the following limitations arise.

7.2 Chamber size

The size of the chamber is limited and can only be scaled within a specific range. Thus, the size of the assemblies and the size of the chamber need to match.

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

7.3 Time to reach vacuum level

The time to reach the vacuum level and the vacuum level depend on the chamber size and the performance of the pump. While pressures up to 0,1 hPa are possible for contact soldering, pressures in the range >10 hPa have become established for convection and condensation soldering.

7.4 Cycle time

The use of vacuum requires additional time. The process time in the vacuum chamber prolongs the production throughput. For convection reflow soldering the cycle time increase can be in the range of factor 2 as a rule of thumb. This effect might be compensated to some extend by multiple transport systems in the reflow oven.

7.5 Summary

Table 3 shows an overview of the properties of soldering methods in combination with vacuum.

Table 3 – Combination of soldering processes with vacuum

	Contact Soldering with Vacuum	Condensation Soldering with Vacuum	Convection Soldering with Vacuum
Reflow profiling flexibility	Good	Good	Very good
Maximum process equipment temperature	450° C	270° C	300° C
PCB temperature difference (ΔT)	Depends on the PCB	Relatively small	Depends on the number of heat zones
Process environment	Air, nitrogen, microwave plasma, hydrogen, etc.	VP Medium	Air, nitrogen
Productivity	Small lot sizes	Medium lot sizes	Large lot sizes
Impact of temperature & vacuum on components	High*	Middle**	Low***
Environmental aspects	Expensive gases Higher energy consumption	Use of inert fluorine medium PFPE	Use of nitrogen Vacuum increases energy consumption
CO_2 Footprint	Middle	High****	Low

* Due to very low, continuously, or multiple time vacuum application in combination with higher possible temperatures

** Due to multiple time vacuum in combination with higher heat transfer of condensation soldering

*** Due to the application of vacuum only above liquidus temperature for shorter period of time

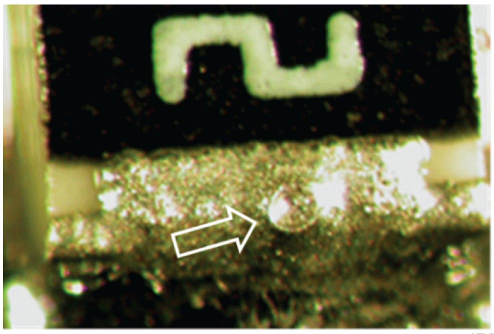
**** Due to the application of PFPE (Higher global warming potential)

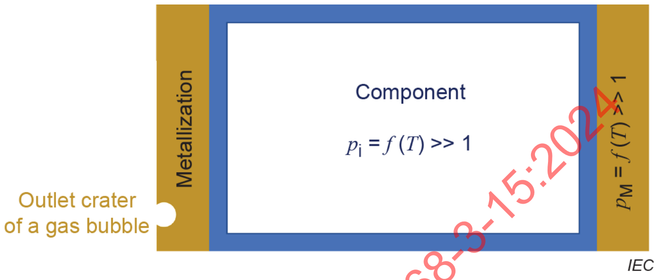
IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024

8 Typical defects after vacuum-assisted reflow soldering

8.1 Typical defect modes occurring at components

Common standards and regulations describe the evaluation of these defect modes.





Reproduced with permission by Technolab GmbH

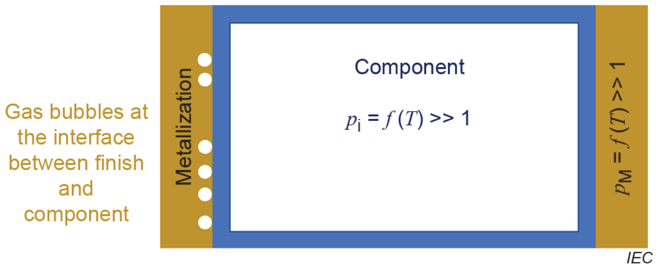
SMD resistor with tin termination

Cause**:** Organic substances or impurities bound in the layer become gaseous at reflow temperature and provoke blowouts. Oxidized layers form gas on flux contact (solder paste). Thermal decomposition products due to temperature, the occurrence of which can be enhanced by vacuum.

p_M is mainly determined by the gas-forming substances.

p_c has an influence when the gas bubbles reach the surface.

Figure 10 – Blow Hole Void in/out of metallization



Reproduced with permission by Technolab GmbH

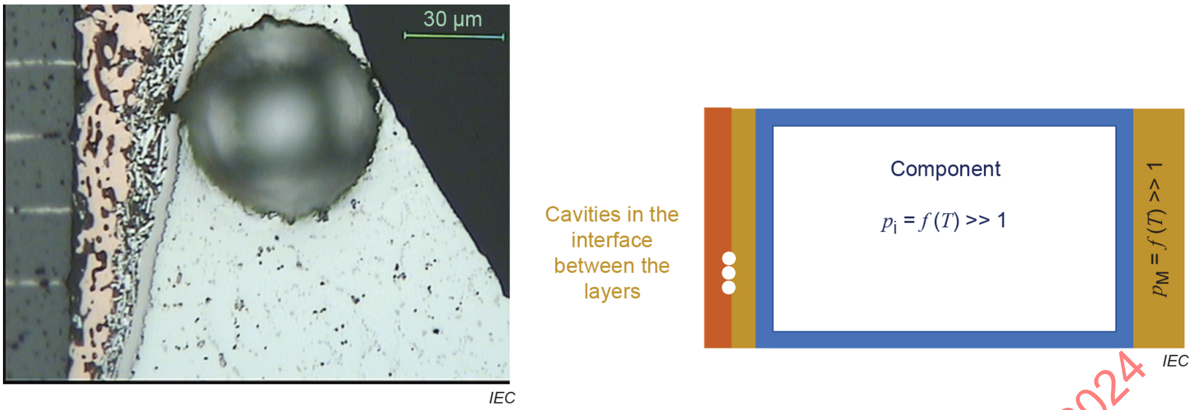
SMD quartz, pin steel + Ni layer + Sn layer with bending cracks, SnPb

Cause: Deposition failure at the interface between metallization (finish) and component produces small gas bubbles in solder. p_M increases with reflow soldering temperature.

In molten state, p_c (vacuum) can influence gas bubble size; individual gas bubbles can coalesce.

Figure 11 – Gas bubbles at metallization interface

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024



Reproduced with permission by Technolab GmbH

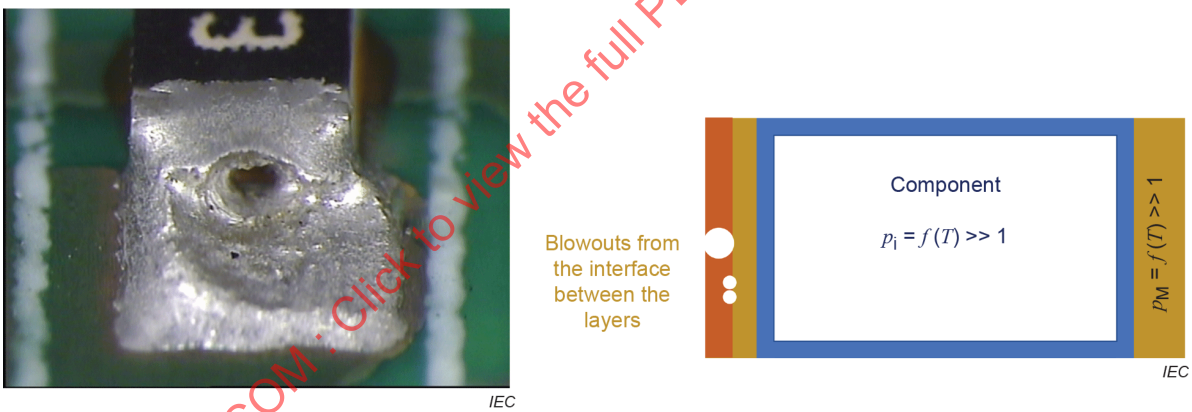
Multilayer SMD Capacitor, soft termination + Ni-barrier layer and Sn plating

Cause: Defective deposition generated at the interface between the finish layers, galvanic metallization with organic interlayer, cavities in which chemical residues (liquid or gaseous) of the metallization chemistry are trapped. Defects without discernible cavern, solder SAC, PCB ENIG.

p_M is essentially determined by the gas-forming substances of the residual chemistry.

p_c has an influence when the gas bubbles reach the surface.

Figure 12 – Gas bubble caused by residues in metallization defect



Reproduced with permission by Technolab GmbH

SMD resistor, blow out voids in solder meniscus

PCB: OSP, SAC, WL

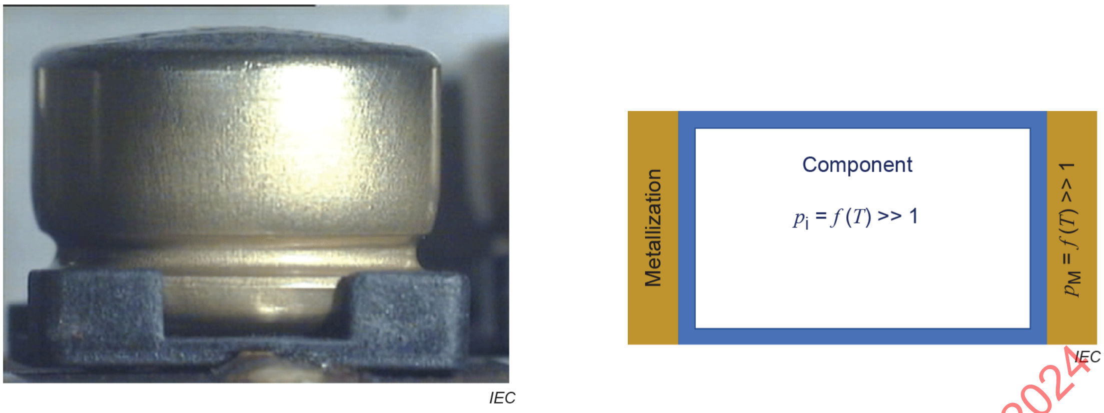
Cause: Blowout due to defective deposition at the interface between the finish layers Cavities in which chemical residues (liquid or gaseous) of the metallization chemistry are trapped

p_M is essentially determined by the gas-forming substances of the residual chemistry.

p_c has an influence when the gas bubbles reach the surface.

Figure 13 – Blow out void in solder meniscus

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024



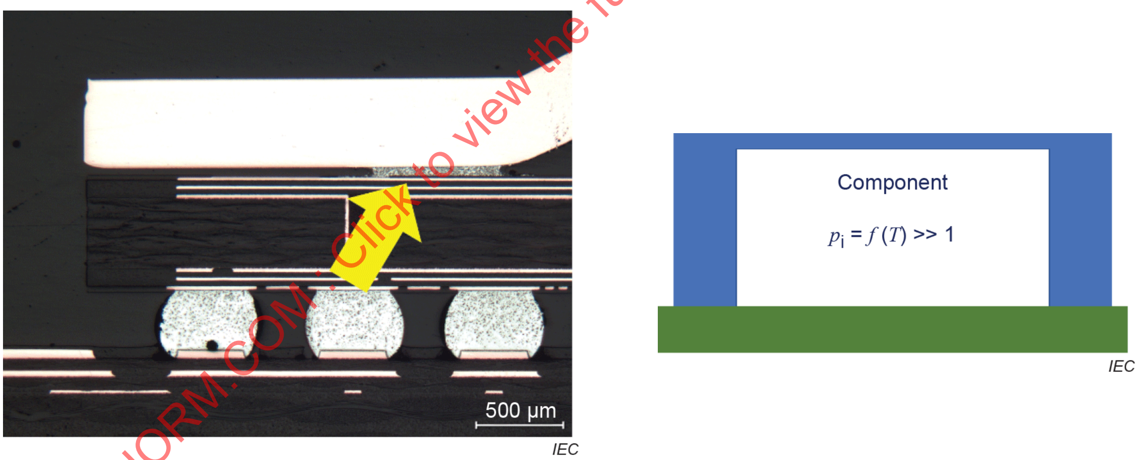
Reproduced with permission by Rehm Thermal Systems GmbH

Aluminium electrolytic capacitors with non-solid electrolyte, boiling temperature of the electrolyte ≤200 °C

Cause: p_i is mainly determined by the electrolyte temperature during reflow soldering. Most electrolytic capacitors are not critical because their sealing system can compensate for minor deformations of the package well in the unaged state. Exception: particularly economical and with high ESR (equivalent serial resistor).

Compared to the internal pressure p_i due to the volume expansion of the contents, the vacuum pressure p_c in the chamber has virtually no influence.

Figure 14 – Aluminium electrolytic capacitors with non-solid electrolyte, bulged



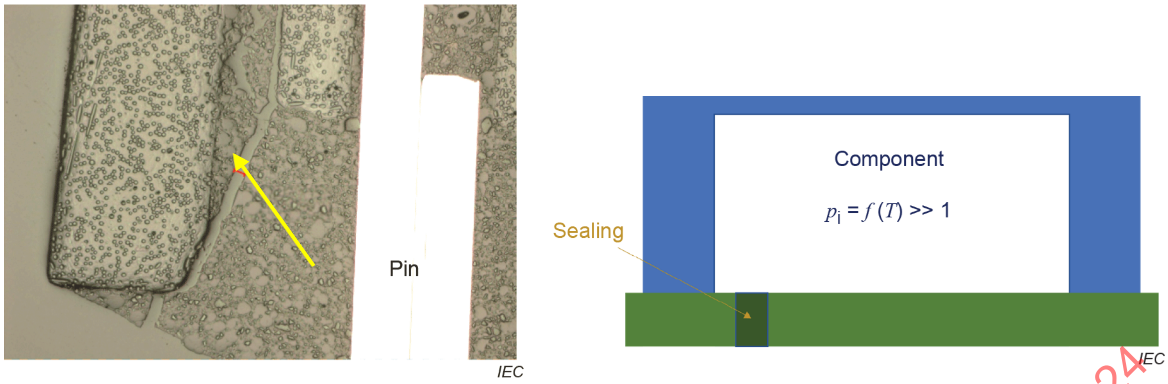
Reproduced with permission by Technolab GmbH

BGA with metal shield, conductive adhesive connection to the interposer PCB (yellow arrow), RL 2, SAC

Cause: p_i is essentially determined by the temperature during reflow soldering; increasing gas pressure lifts the shielding. Compared to the internal pressure p_i due to the volume expansion of the gases under the shielding, the vacuum pressure p_c in the chamber has virtually no influence.

Figure 15 – Composite housing bursts in case of overpressure

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024



Reproduced with permission by Rehm Thermal Systems GmbH

Relay with gap between housing and potting

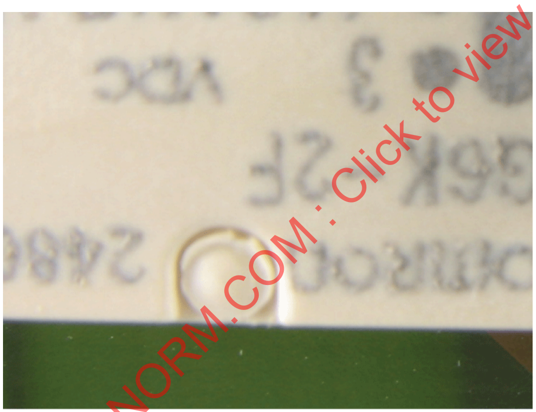
Cause: during reflow soldering, gas pressure rises and cracks the housing or part of the sealing

p_i is mainly determined by the temperature.

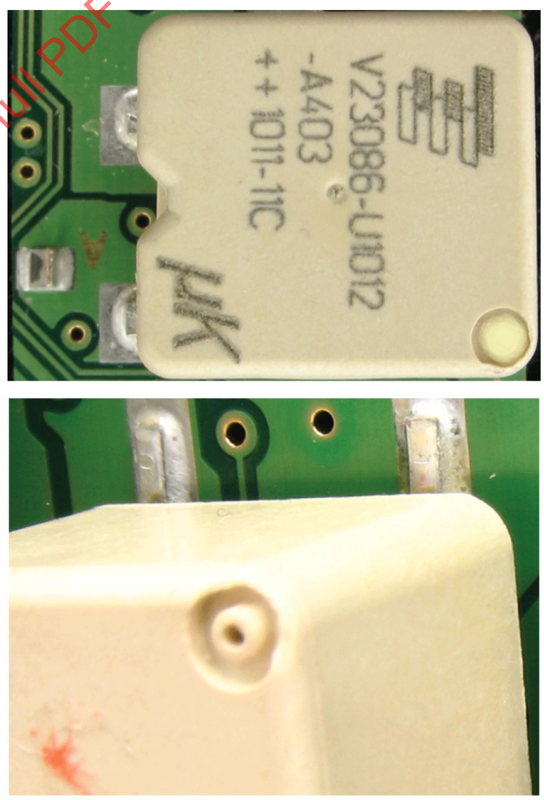
p_c vacuum pressure of the chamber has an influence.

Consequence: loss of device tightness, reliability deficit.

Figure 16 – Housing mainly made of plastic bursts in case of overpressure



Reproduced with permission by Technolab GmbH



Relay SMD Package with opening

Robust version (left): hot caulked, SAC ENIG, before reflow soldering: opening closed. Robust design as heat-sealed/hot-rammed.

Sensitive versions (right) use polymers with poor adhesion properties, varnish or adhesive for sealing. Example: Image top right before and bottom right after vapour phase reflow soldering, lock (polymer dot) is blown off.

Figure 17 – Relay lock (polymer dot) blown off

IECNORM.COM : Click to view the full PDF of IEC TR 60068-3-15:2024