IEC TS 62647-3

Edition 1.0 2014-02

TECHNICAL SPECIFICATION

colour inside

Process management for avionics – Aerospace and defence electronic systems containing lead-free solder –
Part 3: Performance testing for systems containing lead-free solder and finishes

IEC TS 62647-3:2014-02(en)

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

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
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 corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
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 It also gives information on projects, replaced and withdrawn publications.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 also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 14 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
More than 55 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

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: csc@iec.ch.

IEC TS 62647-3

Edition 1.0 2014-02

TECHNICAL SPECIFICATION

Process management for avionics – Aerospace and defence electronic systems containing lead-free solder –
Part 3: Performance testing for systems containing lead-free solder and finishes

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE X

ICS 03.100.50; 31.020; 49.060

ISBN 978-2-8322-1456-5

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

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROCESS MANAGEMENT FOR AVIONICS – AEROSPACE AND DEFENCE ELECTRONIC SYSTEMS CONTAINING LEAD-FREE SOLDER –

Part 3: Performance testing for systems containing lead-free solder and finishes

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) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC/TS 62647-3, which is a technical specification, has been prepared by IEC technical committee 107: Process management for avionics.

The text of this technical specification is based on the following documents: IEC/PAS 62647-3 and GEIA-STD-0005-3.

This technical specification cancels and replaces IEC/PAS 62647-3, published in 2011. This edition constitutes a technical revision.

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

a) Terms and definition subclause changed in Clause 3.
b) Coherence with IEC/TS 62647-1, IEC/TS 62647-21 and IEC/TS 62647-22 definitions.
c) Introduction of “g-force” definition.
d) Reference to IEC 62647 documents when already published.
e) Harmonization of preconditioning data at Table B.1 level with regard to 5.3.3.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
107/213/DTS	107/233/RVC

Full information on the voting for the approval of this technical specification 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 the parts in the IEC 62647 series, published under the general title *Process management for avionics – Aerospace and defence electronic systems containing lead-free solder*, 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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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.

INTRODUCTION

The implementation of lead-free (Pb-free) interconnection technology into electronics has resulted in a variety of reactions by designers, manufacturers, and users. While the prime motivation for lead-free (Pb-free) technology was to address the social concern of improving the environment by limiting the amount of toxic and dangerous substances used in products, the ramifications of this initiative have provided a state of uncertainty regarding the performance – in this context, defined as operation and reliability, i.e. the expected life cycle of a product – of aerospace and defence systems. For over fifty years, tin-lead solder was the benchmark for electronics assembly and generations of research baselined its performance under a variety of operating conditions including the harsh settings of aerospace and defence equipment. However, with the integration of lead-free (Pb-free) technology, aerospace and defence companies are faced with questions as to whether these new materials will provide, as a minimum, the same degree of confidence during the life cycle of critical systems and products.

In evaluating performance, two approaches are used: analysis/modelling and test. This document addresses the latter, providing guidance and direction in the development and execution of performance tests for lead-free (Pb-free) electronic interconnections. The user of this document needs to be aware of the following: This document does not give answers as to how to perform a specific test. Products and systems applications vary immensely, so designers need to understand use conditions and the entire life cycle. Once this is understood, then this document can be used to give designers an understanding of how to develop a suitable test, e.g., ascertain the type of platform in which a product will be used, comprehending all the environmental effects on the platform, and learning why material characterization is key to deciding upon test parameters, etc.

Sound engineering knowledge and judgment will be required for the successful use of this document.

The global transition to lead-free (Pb-free) electronics has a significant impact on the electronics industry; it is especially disruptive to aerospace, defence and other industries that produce electronic equipment for high performance applications. These applications, hereinafter described as ADHP (Aerospace, Defence and High Performance), are characterized by severe or harsh operating environments, long service lifetimes, and high consequences of failure. In many cases, ADHP electronics need to be repairable at the soldered assembly level. Typically, ADHP industry production volumes may be low and, due to low market share, may not be able to resist the change to lead-free (Pb-free). Furthermore, the reliability tests conducted by suppliers of solder materials, components, and sub-assemblies cannot be assumed to assure reliability in ADHP applications. This document provides guidance (and in some cases direction) to designers, manufacturers, and maintainers of ADHP electronics in assessing performance of lead-free (Pb-free) interconnections.

Over the past several decades, electronics manufacturers have developed methods to conduct and interpret results from reliability tests for lead-bearing solder alloys. Since these alloys have been used almost universally in all segments of the electronics industry, and since a large body of data, knowledge, and experience has been assembled, the reliability tests for Pb-bearing solder alloys are well-understood and widely accepted.

When it became apparent that the use of Pb-bearing alloys would decline rapidly, programs were implemented to evaluate the reliability of the lead-free (Pb-free) replacement alloys. Those programs have generated a considerable database. To date, however, there is no reliability test method that is widely accepted in the ADHP industries. Reasons for this include:

a) No single lead-free (Pb-free) solder alloy has emerged as a replacement for lead-bearing alloys; instead, a number of alloys are being used in various segments of the electronics industry.

b) The physical, chemical, and metallurgical properties of the various lead-free (Pb-free) replacement alloys vary significantly.

c) Due to the many sources of solder alloys used in electronic component termination materials or finishes, assembly processes, and repair processes, the potential number of combinations of alloy compositions is nearly unlimited. It is an enormous task to collect data for all these combinations.

d) The test methods developed by other segments: the IPC-9701A and IPC/JEDEC-9703 are directed toward shorter service lives and more benign environments. Also, there is still a question of suitable dwell times and acceleration factors. However, the intent of this document is to provide a means of coordinating the information from the IPC-9701A and IPC/JEDEC-9703 into a basic approach for ADHP suppliers.

e) The data from reliability tests that have been conducted are subject to a variety of interpretations.

In view of the above facts, it would be desirable for high-reliability users of lead-free (Pb-free) solder alloys to wait until a larger body of data has been collected, and methods for conducting reliability tests and interpreting the results have gained wide acceptance for high-reliability products. In the long run, this will indeed occur. However, the transition to lead-free (Pb-free) solder is well under way and there is an urgent need for a reliability test method, or set of methods, based on industry consensus. While acknowledging the uncertainties mentioned above, this document provides necessary information for designing and conducting performance tests for aerospace products. In addition, when developing test approaches, the material in question needs to be suitably characterized. Such material properties as ultimate tensile strength, yield strength, Poisson's ratio, creep rate, and stress relaxation have been shown to be key attributes in evaluating fatigue characteristics of lead-free (Pb-free) solders.

Because of the dynamic nature of the transition to lead-free (Pb-free) electronics, this and other similar documents are based on the best information and expertise available; its update will be considered as future knowledge and data are obtained.

PROCESS MANAGEMENT FOR AVIONICS – AEROSPACE AND DEFENCE ELECTRONIC SYSTEMS CONTAINING LEAD-FREE SOLDER –

Part 3: Performance testing for systems containing lead-free solder and finishes

1 Scope

This part of the IEC 62647 series defines for circuit card assemblies (CCA):

– a default method for those companies that require a pre-defined approach, and

– a protocol for those companies that wish to develop their own test methods.

The intent of this document is not to prescribe a certain method, but to aid avionics/defence suppliers in satisfying the reliability and/or performance requirements of IEC/TS 62647-1 as well as support the expectations in IEC/TS 62647-21.

The default method (see Clause 5) is intended for use by electronic equipment manufacturers, repair facilities, or programs that, for a variety of reasons, may be unable to develop methods specific to their own products and applications. It should be used when little or no other information is available to define, conduct, and interpret results from reliability, qualification, or other tests for electronic equipment containing lead-free (Pb-free) solder. The default method is intended to be conservative, i.e., it is biased toward minimizing the risk to users of ADHP electronic equipment.

The protocol (see Clause 6) is intended for use by manufacturers or repair facilities that have the necessary resources to design and conduct reliability, qualification, or process development tests that are specific to their products, their operating conditions, and their applications. Users of the protocol will have the necessary knowledge, experience, and data to customize their own methods for designing, conducting, and interpreting results from the data. Key to developing a protocol is a firm understanding of all material properties for the lead-free (Pb-free) material in question as well as knowledge of package- and board-level attributes as described in 5.3.2. As an example, research has shown that the mechanisms for creep can be different between tin-lead and tin-silver-copper (SAC) solders. Understanding these mechanisms is key to determining critical test parameters such as dwell time for thermal cycling. The protocol portion of this document provides guidance on performing sufficient characterization of new materials in order to accurately define test parameters.

Use of the protocol is encouraged, since it is likely to yield more accurate results, and to be less expensive than the default method. The IEC/TS 62647-22 provides a comprehensive overview of those technical considerations necessary in implementing a test protocol.

This specification addresses the evaluation of failure mechanisms, through performance testing, expected in electronic products containing lead-free (Pb-free) solder. One failure mode, fatigue-failure through the solder-joint, is considered a primary failure mode in ADHP electronics and can be understood in terms of physics of failure and life-projections. Understanding all of the potential failure modes caused by lead-free (Pb-free) solder of ADHP electronics is a critical element in defining early field-failures/reliability issues. Grouping of different failure modes may result in incorrect and/or misleading test conclusions. Failure analysis efforts should be conducted to insure that individual failure modes are identified, thus enabling the correct application of reliability assessments and life-projection efforts.

When properly used, the methods or protocol defined in this specification can be used along with the processes documented in compliance to the IPC-SM-785, to satisfy, at least in part, the reliability requirements of the IPC-SM-785 and JESD22-B110A.

Any portion of this document can be used to develop a lead-free (Pb-free) assembly test program, i.e., this document is tailorable and provides room for flexibility. For those situations in which results are used for reliability, verification, or qualification, stakeholder concurrence needs to be sought and documented so that expectations are understood and addressed.

This specification may be used for products in all stages of the transition to lead-free (Pb-free) solder, including:

- products that have been designed and qualified with traditional tin-lead electronic components, materials, and assembly processes, and are being re-qualified with use of lead-free (Pb-free) components;
- products with tin-lead designs transitioning to lead-free (Pb-free) solder; and
- products newly-designed with lead-free (Pb-free) solder.

For programs that were designed with tin-lead solder, and are currently not using any lead-free (Pb-free) solder, the traditional methods may be used. It is important, however, for those programs to have processes in place to maintain the tin-lead configuration including those outsourced or manufactured by subcontractors.

With respect to products as mentioned above, the methods presented in this document are intended to be applied at the level of assembly at which soldering occurs, i.e., circuit card assembly (CCA) level.

This document may be used by other high-performance and high-reliability industries, at their discretion.

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/TS 62647-22:2013, *Process management for avionics – Aerospace and defence electronic systems containing lead-free solder – Part 22: Technical guidelines*

IPC-9701A:2006, *Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments*

IPC-SM-785, *Guidelines for Accelerated Reliability Testing of Surface Mount Solder Attachments*

JESD22-B110A, *Subassembly Mechanical Shock*

MIL-STD-810G:2008, *Environmental Engineering Considerations and Laboratory Tests*

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
coupon
test sample representing a scaled-down or proportional version of an actual product or higher level test vehicle

3.1.2
CTE
coefficient of thermal expansion
degree of expansion of a material divided by the change in temperature

Note 1 to entry: PCB/PWB CTE (X-Y-axis) is measured in the direction in the plane of the piece part mounting surface and is used to quantify the stresses in the solder joint arising from the differences in CTE between the piece parts and the PCB/PWB during thermal cycling. CTE (Z-axis) is measured in the “thickness” direction and is typically used to quantify plated through hole stress.

[SOURCE: IEC/TS 62647-22:2013, 3.1.8]

3.1.3
g-force
force per unit mass that can be measured with an accelerometer and perceived as weight (with “g” from “gravitational”)

Note 1 to entry: Since such a force is perceived as a weight, any g-force can be described as a "weight per unit mass". g-forces, when multiplied by a mass upon which they act, are associated with a certain type of mechanical force in the correct sense of the term force, and this force produces compressive stress and tensile stress.

3.1.4

lead-free
Pb-free
less than 0,1 % by weight of lead (Pb) in accordance with reduction of hazardous substances(RoHS) guidelines

[SOURCE: IEC/TS 62647-1:2012, 3.8]

3.1.5
PCB
printed circuit board
PWB
printed wiring board
substrate using conductive pathways, tracks or signal traces etched from copper sheets laminated, and allowing to connect electrically un set of electronic components to realize a circuit card.

[SOURCE: IEC/TS 62647-21:2013, 3.1.10]

3.1.6
tin-lead
solder bearing the elements tin and lead, and corresponding to 63% by weight of tin and 37% by weight of lead unless otherwise specified

3.1.7
vehicle
test sample such as a populated circuit card assembly (CCA)

3.2 Abbreviations

ADHP	Aerospace, Defence and High Performance NOTE This refers to a generalized level of equipment used in harsh and stringent operating conditions.

CCA	Circuit card assembly
JCAA	Joint Council of Aging Aircraft (organization within the US Department of Defence that has performed extensive lead-free solder reliability testing)
JG-PP or JGPP	Joint Group on Pollution Prevention (NASA group that began the lead-free solder testing)[1]
PSD	Power spectral density NOTE It describes how the power of a signal or time series is distributed with frequency.
RoHS	Restriction of Hazardous Substances NOTE The RoHS directive is a European directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment

4 Assumption

For the purposes of this document, if the element "lead" is implied, it will be stated either as Pb, as lead (Pb), or as tin-lead.

If a piece part terminal or termination "lead" is referred to, such as in a flat pack or a dual-inline package, the nomenclature lead/terminal or lead-terminal will be used.

5 Default test methods

5.1 General

Use of the default method shall be limited to CCAs. Test coupons may also be used provided the concerns listed in 5.3.2 are considered.

5.2 Test vehicles

5.2.1 Test vehicle type

Test vehicles used in testing of electronic systems containing lead-free solder shall consist of soldered assemblies that are representative of the materials and processes used in the assembly and/or repair procedures used by the ADHP electronics manufacturer or repair facility. Characterization and documentation of the test vehicle attributes (both design and manufacturing) is recommended. Test vehicle attribute documentation shall include, at a minimum, the following data:

- board type, material, size, finish, thickness, copper content
- piece-part material, package size, package type, termination finish
- assembly solder alloy
- assembly processes including fluxes and cleaners
- thermal management materials
- underfill and staking materials
- other mechanically attached structures

[1] JGPP Pb-free solder testing was completed with the support of JCAA.