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Process management for avionics – Aerospace and defence electronic systems containing lead-free solder –
Part 22: Technical guidelines

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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- 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 62647-22, 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 document: IEC/PAS 62647-22[1].

This technical specification cancels and replaces IEC/PAS 62647-22, published in 2011. This edition constitutes a technical revision.

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

a) Coherence with IEC/TS 62647-1 and IEC/TS 62647-2 definitions.

b) Reference to IEC 62647 documents when already published.

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

Enquiry draft	Report on voting
107/205/DTS	107/218/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 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- withdrawn,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.

1 IEC/PAS 62647-22, which served as a basis for the present document, has been derived from GEIA-HB-0005-2.

INTRODUCTION

0.1 General

The global transition to lead-free (Pb-free) electronics impacts the aerospace, defence, and high performance (ADHP) industry and other industries having high reliability applications in various ways.

0.2 Transition to Pb-free

In addition to the perceived need to replace the tin-lead solders used as an interconnect medium in electronic and electrical systems, the following variations to established practice will need to be considered:

- components and printed circuit boards (PCBs)/printed wiring boards (PWBs) will need to be able to withstand higher manufacturing process temperatures;
- printed circuit boards (PCBs)/printed wiring boards (PWBs) will need to have robust solderable lead-free (Pb-free) surface finishes;
- manufacturing and inspection techniques are needed that yield repeatable reliability characteristics;
- at least initially, Pb-free alloys used within the equipment should be restricted to those that are compatible with tin-lead soldering systems;
- a maintenance strategy should be developed that will facilitate the support repair of new and existing equipment throughout a long life time which can be higher than 20 years.

This document will establish guidelines for the use of Pb-free solder and mixed tin-lead/lead-free alloy systems while maintaining the high reliability standards required for aerospace electronic and electrical systems. Currently the largest volume of lead (Pb) in many of these electronic systems is in the tin-lead eutectic (Sn-37Pb) and near eutectic alloys (Sn-36Pb-2Ag, Sn-40Pb) used in printed circuit board/printed wiring board assemblies, wiring harnesses and electrical systems. High-lead solder alloys are not specifically addressed in this document; however, many of the methodologies outlined herein are applicable for their evaluation.

A good deal of the information desired for inclusion in this technical guidelines document does not exist. A large number of lead-free (Pb-free) investigative studies for aerospace and high reliability electronic and electrical systems are either in progress or in the initiation stage. The long durations associated with reliability testing necessitates a phased release of information. The information contained herein reflects the best information available at the time of document issuance. It is not the goal of this document to provide technical guidance without an understanding of why that guidance has technical validity or without concurrence of the technical community in cases where sufficient data is lacking or conflicting. The document will be updated as new data becomes available.

Further complicating matters is the fact that no single alloy across the supply base will be replacing the heritage tin-lead eutectic alloy and that it is not likely that qualification of one alloy covers qualification for all other alloys. Given the usual requirement for long, high performance electronic service lives, any lead-free (Pb-free) alloy will need to have predictable performance when mixed with heritage tin-lead alloys. Lead-free (Pb-free) alloys containing elements such as bismuth (Bi) or indium (In) that can form alloys having melting points within the equipment's operating temperature range will need to be considered very carefully before use. Although lead-free (Pb-free) solder alloys are still undergoing some adjustments, it appears that the Sn-Ag-Cu family of alloys will be used for surface mount assembly and either Sn-Ag-Cu, Sn-Cu or Sn-Cu-Ni (Sn-Cu stabilized with nickel) alloys will be dominant in wave solder applications. In addition, some applications are using the Sn-Ag alloy family [1] [2] [3].[2]

The majority of the lead-free (Pb-free) solder alloys being considered have higher melting temperatures than tin-lead eutectic solder. In order to make use of the lead-free (Pb-free) solders, changes to the molding compound, die attach and printed circuit board (PCB)/printed wiring board (PWB) insulation systems are being introduced to accommodate the 30 °C to 40 °C higher (54 °F to 72 °F higher) processing temperature. Thus, not only is the lead-free (Pb-free) transition changing the solder alloy, but a significant portion of the electronic packaging materials are changing as well. The higher melting point, greater creep resistance and higher strength of the lead-free (Pb-free) alloys have driven a significant amount of study into the thermal cycling and mechanical vibration/shock assessments of these new alloys.

The consumer electronics industry has invested considerable resources to ensure that lead-free (Pb-free) solder will perform adequately for their products. Creep resistance of lead-free (Pb-free) alloys can vary considerably from heritage tin-lead solders. The creep/stress relaxation performance of the solder depends on the stress level, temperature and time for a specific solder material and joint composition. Therefore, one needs to establish what the acceleration factor is between a particular test condition and application. The interpretation of the results of a head-to-head testing needs to be assessed in terms of the anticipated service conditions with respect to these acceleration factors. Thermal preconditioning prior to thermal cycling should be considered in the lead-free (Pb-free) solder assessment plan particularly as it relates to changes in solder microstructure. Modeling/analysis is needed to properly compare the tin-lead and lead-free (Pb-free) alloy performance and correct for the stress relaxation differences obtained for the various piece parts and thermal cycling conditions.

While there is much data on near eutectic SAC (e.g., SAC305 and SAC405) Pb-free thermal cycling, there is less information regarding lead-free (Pb-free) vibration and shock performance. Fortunately, the vibration and shock performance data can be obtained relatively quickly. During vibration/shock testing, the near eutectic SAC Pb-free solder behaves more rigidly than the Sn-Pb solder transferring greater loads to the interfaces between the solder alloy and the substrate interfaces. The increased amount of tin in Pb-free alloys increases the intermetallic thickness when copper substrates are used. In addition, when nickel or electroless nickel (nickel – phosphorous) substrates are used, the increased copper in the SAC alloy can result in the formation of intermetallics on the nickel interface, which are less robust than Sn-Cu or Sn-Ni intermetallics that are typical of tin-lead solder joints. Mechanical test results to-date suggest that a robust assessment of lead-free (Pb-free) alloy assembly in vibration and shock environments will need to include thermal aging for interface and microstructural stabilization prior to any dynamic mechanical testing. Alloys other than SAC should be assessed to determine their vibration and shock performance characteristics.

2 Numbers in square brackets refer to the Bibliography.

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Part 22: Technical guidelines

1 Scope

This part of IEC 62647 is intended for use as technical guidance by aerospace, defence, and high performance (ADHP) electronic applications and systems suppliers, e.g., original equipment manufacturers (OEMs) and system maintenance facilities, in developing and implementing designs and processes to ensure the continued performance, quality, reliability, safety, airworthiness, configuration control, affordability, maintainability, and supportability of high performance aerospace systems (subsequently referred to as ADHP) both during and after the transition to Pb-free electronics.

The guidelines may be used by the OEMs and maintenance facilities to implement the methodologies they use to ensure the performance, reliability, airworthiness, safety, and certifiability of their products, in accordance with IEC/TS 62647-1:2012.

This document also contains lessons learned from previous experience with Pb-free aerospace electronic systems. The lessons learned give specific references to solder alloys and other materials, and their expected applicability to various operating environmental conditions. The lessons learned are intended for guidance only; they are not guarantees of success in any given application.

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 62647-1:2012, *Process management for avionics – Aerospace and defence electronic systems containing lead-free solder – Part 1: Preparation for a lead-free control plan*

IEC/TS 62647-2, *Process management for avionics – Aerospace and defence electronic systems containing lead-free solder – Part 2: Mitigation of deleterious effects of tin*

IEC/TS 62647-3:–, *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*[3]

GEIA-HB-0005-4, *Guidelines for Performing Reliability Assessment for Lead Free Assemblies used in Aerospace and High-Performance Electronic Applications*

IPC/JEDEC JP002, *Current Tin Whiskers Theory and Mitigation Practices Guideline*

[3] Under consideration.

IPC-1066, *Marking, Symbols and Labels for Identification of Lead-Free and Other Reportable Materials in Lead-Free Assemblies, Components and Devices*

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